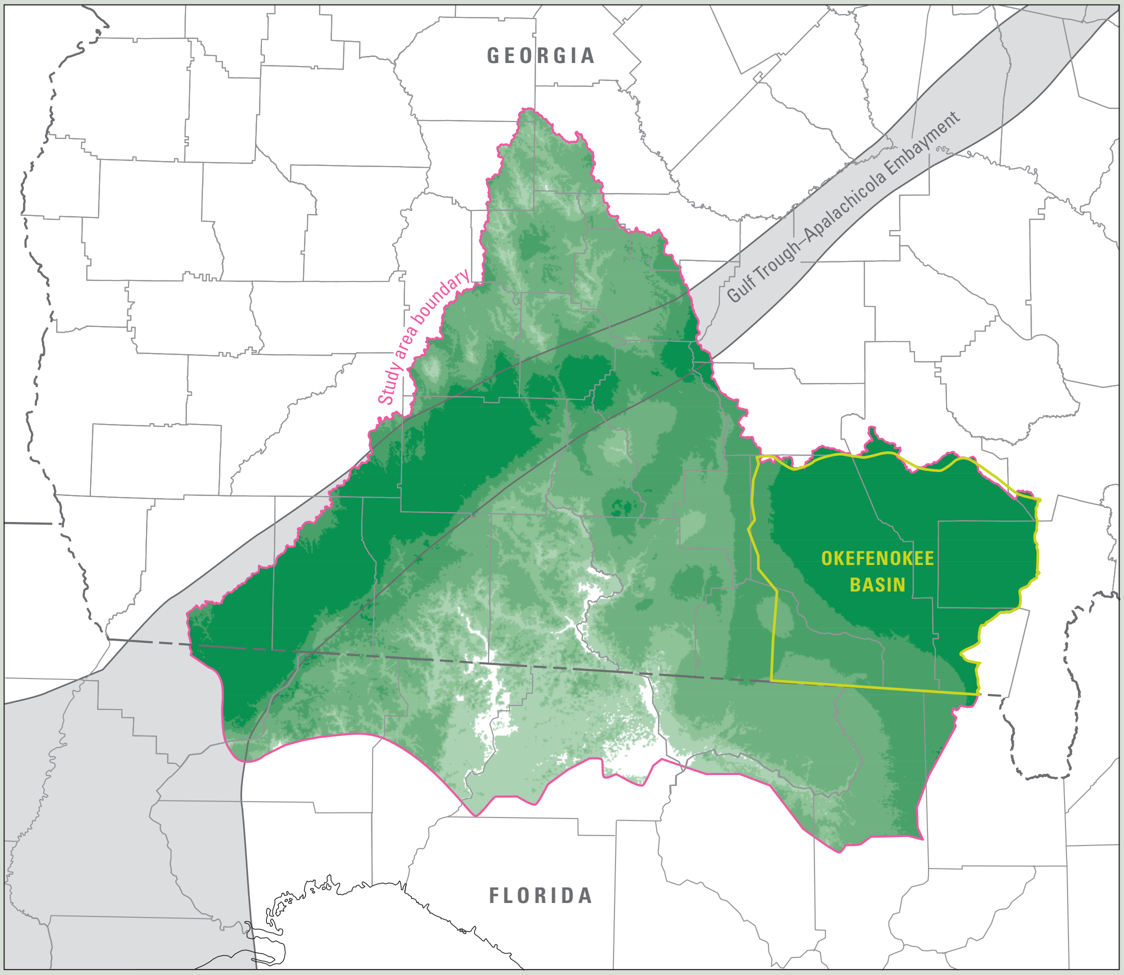
USGS
science for a changing world

Prepared in cooperation with the
Georgia Department of Natural Resources
Environmental Protection Division

Geohydrology of the Aucilla–Suwannee–Ochlockonee River Basin, South-Central Georgia and Adjacent Parts of Florida



Scientific Investigations Report 2010–5072

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

Cover. See figure 15 of this report.

Geohydrology of the Aucilla–Suwannee–Ochlockonee River Basin, South-Central Georgia and Adjacent Parts of Florida

By Lynn J. Torak, Jaime A. Painter, and Michael F. Peck

Prepared in cooperation with the
Georgia Department of Natural Resources
Environmental Protection Division

Scientific Investigations Report 2010–5072

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2010

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment, visit *http://www.usgs.gov* or call 1-888-ASK-USGS

For an overview of USGS information products, including maps, imagery, and publications, visit *http://www.usgs.gov/pubprod*

To order this and other USGS information products, visit *http://store.usgs.gov*

Suggested citation:
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 2010–5072, 78 p.

Contents

Figures

Tables

Conversion Factors and Datums

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Flow rate	
foot per day (ft/d)	0.3048	meter per day (m/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
million gallons per day (Mgal/d)	0.04381	cubic meter per second (m^3/s)
	Mass	
ton, short (2,000 lb)	0.9072	megagram (Mg)
	Specific capacity	
gallon per minute per foot [(gal/min)/ft)]	0.2070	liter per second per meter [(L/s)/m]
	Hydraulic conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
	Hydraulic gradient	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Transmissivity*	
foot squared per day (ft^2/d)	0.09290	meter squared per day (m^2/d)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F = (1.8 \times °C) + 32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

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

*Transmissivity: The standard unit for transmissivity is cubic foot per day per square foot times foot of aquifer thickness [($ft^3/d)/ft^2$]ft. In this report, the mathematically reduced form, foot squared per day (ft^2/d), is used for convenience.

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

Geohydrology of the Aucilla–Suwannee–Ochlockonee River Basin, South-Central Georgia and Adjacent Parts of Florida

By Lynn J. Torak, Jaime A. Painter, and Michael F. Peck

Abstract

Major streams and tributaries located in the Aucilla–Suwannee–Ochlockonee (ASO) River Basin of south-central Georgia and adjacent parts of Florida drain about 8,000 square miles of a layered sequence of clastic and carbonate sediments and carbonate Coastal Plain sediments consisting of the surficial aquifer system, upper semiconfining unit, Upper Floridan aquifer, and lower confining unit. Streams either flow directly on late-middle Eocene to Oligocene karst limestone or carve a dendritic drainage pattern into overlying Miocene to Holocene sand, silt, and clay, facilitating water exchange and hydraulic connection with geohydrologic units.

Geologic structures operating in the ASO River Basin through time control sedimentation and influence geohydrology and water exchange between geohydrologic units and surface water. More than 300 feet (ft) of clastic sediments overlie the Upper Floridan aquifer in the Gulf Trough–Apalachicola Embayment, a broad area extending from the southwest to the northeast through the center of the basin. These clastic sediments limit hydraulic connection and water exchange between the Upper Floridan aquifer, the surficial aquifer system, and surface water. Accumulation of more than 350 ft of low-permeability sediments in the Southeast Georgia Embayment and Suwannee Strait hydraulically isolates the Upper Floridan aquifer from land-surface hydrologic processes in the Okefenokee Basin physiographic district. Burial of limestone beneath thick clastic overburden in these areas virtually eliminates karst processes, resulting in low aquifer hydraulic conductivity and storage coefficient despite an aquifer thickness of more than 900 ft. Conversely, uplift and faulting associated with regional tectonics and the northern extension of the Peninsular Arch caused thinning and erosion of clastic sediments overlying the Upper Floridan aquifer southeast of the Gulf Trough–Apalachicola Embayment near the Florida–Georgia State line. Limestone dissolution in Brooks and Lowndes Counties, Ga., create karst features that enhance water-transmitting and storage properties of the Upper Floridan aquifer, promoting groundwater recharge and water exchange between the aquifer, land surface, and surface water.

Structural control of groundwater flow and hydraulic properties combine with climatic effects and increased hydrologic stress from agricultural pumpage to yield unprecedented groundwater-level decline in the northwestern and central parts of the ASO River Basin. Hydrographs from continuous-record observation wells in these regions document declining groundwater levels, indicating diminished water-resource potential of the Upper Floridan aquifer through time. More than 24 ft of groundwater-level decline occurred along the basin's northwestern boundary with the lower Apalachicola–Chattahoochee–Flint River Basin, lowering hydraulic gradients that provide the potential for groundwater flow into the ASO River Basin and southeastward across the Gulf Trough–Apalachicola Embayment region. Slow-moving groundwater across the trough-embayment region coupled with downward-vertical flow from upper to lower limestone units composing the Upper Floridan aquifer resulted in 40–50 ft of groundwater-level decline since 1969 in southeastern Colquitt County. Multi-year episodes of dry climatic conditions during the 1980s through the early 2000s contributed to seasonal and long-term groundwater-level decline by reducing recharge to the Upper Floridan aquifer and increasing hydrologic stress by agricultural pumpage. Unprecedented and continued groundwater-level decline since 1969 caused 40–50 ft of aquifer dewatering in southeastern Colquitt County that reduced aquifer transmissivity and the ability to supply groundwater to wells, resulting in depletion of the groundwater resource.

Introduction

Episodic-drought conditions and increased pumpage since the mid-1970s have caused unprecedented groundwater-level decline in the Upper Floridan aquifer in much of the roughly 8,000-square-mile (mi^2) Aucilla–Suwannee–Ochlockonee (ASO) River Basin (fig. 1). During 2007, record-low groundwater levels occurred in Charlton, Cook, Tift, Ware, and Worth Counties. The groundwater level in Lowndes County declined nearly 25 feet (ft) during the first 10 months of 2006, after recovering nearly that much and holding stable since 2003. An eastward shift in location of municipal groundwater withdrawal at Cairo, Ga., reversed a 35-ft declining groundwater-level trend that occurred during 1966–1973, although groundwater-level fluctuations of as much as 20 ft occurred in multiyear cycles since that time.

Since the early 1990s, increased center-pivot irrigation along the basin divide with the neighboring Apalachicola–Chattahoochee–Flint (ACF) River Basin (Litts and others, 2001) has intercepted groundwater that, prior to irrigation pumpage, was available to recharge the ASO River Basin as regional (interbasin) groundwater flow. Pumpage increases along the boundary of the ASO and ACF River Basins have accelerated groundwater-level declines in the Upper Floridan aquifer and reduced the hydraulic gradient, thus reducing the amount of regional groundwater flow (interbasin flow) to the south and east into the ASO River Basin (Torak and Painter, 2006). Long-term groundwater-level decline in the Upper Floridan aquifer has the potential to reduce springflow, decrease groundwater discharge to streams (baseflow), and diminish interbasin flow from the north and west, threatening the ability of the basin's water resources to meet current and future demand.

As a result of these concerns, the U.S. Geological Survey (USGS), in cooperation with the State of Georgia, Department of Natural Resources, Environmental Protection Division (GA-EPD), began a study in September 2006 to acquire, compile, and interpret geohydrologic information in the ASO River Basin. Study results would enable development of science-based, cause-and-effect relations between groundwater withdrawal for agricultural, municipal, industrial, and drinking-water purposes and groundwater-level and streamflow trends. Hydrologic relations developed from this study would enable evaluation of emerging resource issues related to groundwater-level and streamflow declines, such as aquatic-habitat degradation and potential local or regional groundwater shortages resulting from excessive groundwater withdrawal and dry climatic conditions.

Purpose and Scope

This report describes the geohydrologic investigation of the ASO River Basin performed primarily in Georgia; however, adjacent areas of the panhandle of northwestern Florida have been included as needed (fig. 1). Investigative results described herein provide a framework for evaluation of groundwater level and streamflow decline in the ASO basin, as jointly developed by the GA-EPD and USGS. Objectives of this investigation and report accomplish the following tasks,

1. Describe the lithology and hydraulic properties of the Upper Floridan aquifer and hydraulically connected geologic units that would enable assessment of water exchange between the Upper Floridan aquifer and other geohydrologic units and surface water.
2. Develop a hydrogeologic framework and conceptual model for evaluating agricultural pumpage and groundwater and surface-water exchange between the Upper Floridan aquifer and other geohydrologic units connected to surface water.
3. Present an overview of 2006 groundwater-level and streamflow conditions.
4. Explain hydrologic concepts of the groundwater and surface-water exchange mechanisms that control causal relations between groundwater pumpage in the Upper Floridan aquifer, climatic variations, groundwater-level decline, reductions in streamflow and springflow, and changes in interbasin flow.

Previous Studies

Early investigations provided general descriptions of the geology and groundwater in the area (McCallie, 1898, 1908; Stephenson and Veatch, 1915; Cooke, 1943; and Herrick and Vorhis, 1963). Cooke (1943) mapped the geology of the coastal plain of Georgia, and MacNeil (1947) mapped Tertiary and Quaternary formations in the study area. Wait (1960) published water-chemistry analyses of selected wells in the basin. Herrick (1961) compiled detailed lithologic and paleontological logs of wells throughout the Georgia Coastal Plain.

Previous hydrologic investigations in Georgia have neither included the entire area of the ASO River Basin nor evaluated causal relations between groundwater pumpage and declining groundwater level, streamflow, and springflow. Studies performed for the National Water-Quality Assessment (NAWQA) Program, Georgia–Florida Coastal Plain Drainages study unit (U.S. Geological Survey, 2006), included evaluation of nutrient loads of several major rivers, including the main rivers of the ASO River Basin in Georgia and Florida; however, none of these studies compiled geologic and hydrologic data into a comprehensive geohydrologic framework in the study area. A NAWQA Program study by Pittman and Berndt (2003) focused on water-quality issues related to herbicide degradation in the surficial aquifer and streams located in the upper part of the basin.

Priest (2004) evaluated the groundwater contribution to streamflow in the coastal area of Georgia and adjacent Florida and South Carolina; however, the study area encompassed only part of the Suwannee River Basin and excluded the Aucilla and Ochlockonee Rivers to the west. Falls and others (2005) investigated the hydrogeology of the Lower Floridan aquifer in 24 coastal counties in Georgia and adjacent Florida and South Carolina, which included only the extreme eastern part of the ASO River Basin. Payne and others (2005) compiled additional geologic information for a larger study area than that of Falls and others (2005) still excluding the western parts of the ASO River Basin. Studies by Torak and Painter (2006) and Jones and Torak (2006), investigated stream-aquifer relations in the neighboring ACF River Basin to the north and west, and only marginally investigated the geohydrology of the Ochlockonee River and upper Suwannee River Basins inasmuch as it affected groundwater flow in the western basin of interest.

McConnell and Hacke (1993) and Plummer and others (1998a, b) performed hydrologic studies of the water chemistry of the karst area in the Upper Floridan aquifer at Valdosta, Ga. Katz and others (1995a,b, 1997), Katz (1998), and Crandall and others (1999) investigated hydrochemistry of stream-lake-aquifer interaction in karst areas of northern Florida. Studies describing the geochemistry and groundwater quality of the Upper Floridan aquifer include Sever (1965), Sprinkle (1989), and Katz (1992).

A geohydrologic investigation by Torak and Painter (2006) and simulation of groundwater and surface-water exchange by Jones and Torak (2006) indicate that irrigation pumpage in outcrop and recharge areas of the Upper Floridan aquifer in the lower ACF River Basin intercepts groundwater that once was available to recharge the ASO River Basin as regional (interbasin) groundwater flow. The geohydrologic investigation by Torak and Painter (2006) indicates that reduced interbasin flow from irrigation pumpage in the ACF River Basin limits groundwater availability and development potential in the ASO River Basin and can reduce baseflow of streams located along the basin's northwestern boundary and interior. Lithologic descriptions given in the study by Torak and Painter (2006) indicate that large variations in hydraulic conductivity of the Upper Floridan aquifer exist at regional and local scales that could alter the amount of groundwater and surface-water exchange between the aquifer and surface water within short distances.

Previous investigations provided water-use information in the ASO River Basin and documented increases in rates of groundwater withdrawal for irrigation, industry, and public supply. Thomson and others (1956) noted increases in statewide irrigation following the 1954 drought. Carter and Johnson (1974) compiled statewide estimates of irrigated acres based on a 1969 U.S. Census Bureau national summary of agriculture and compiled water-use estimates according to Area Planning and Development Commission regions. Pierce and others (1984) documented large increases in agricultural irrigation in southwestern Georgia during the 1970s, differentiated groundwater- and surface-water-irrigation withdrawal, and identified locations of center-pivot irrigation systems in a "High Irrigation Water Use Zone" during 1980 that included the ACF and ASO River Basins. Harrison and Tyson (1999) and Harrison (2001) reported results of the Georgia Irrigation Survey that identified steadily increasing trends in agricultural water-use statewide and increased use of center-pivot irrigation. Turlington and others (1987), Fanning and others (1992), and Fanning (1997, 2003) compiled water-use data by county and type of use, and provided summaries of water use, by county, for 1985, 1990, 1995, and 2000, respectively. Litts and others (2001) reported significant increases in center-pivot-irrigation systems during the 1990s within and along the boundary between the ASO and lower ACF River Basins (table 1). Unfortunately, the investigation by Litts and others (2001) only reported irrigated acreage and acreage change associated with the lower ACF River Basin, although seven Georgia counties are located partially in both basins.

Geologic nomenclature used herein is consistent with previous geologic and hydrologic investigations performed in the study area and adjacent regions to the north and west, and described in reports by Sever (1964, 1965), Sever and Herrick (1967), Miller (1986), Torak and McDowell (1996), Torak and others (1996, 2006), Albertson and Torak (2002), Mosner (2002), and Jones and Torak (2004, 2006). Consistent nomenclature with that used in the neighboring ACF River Basin and recent investigations, referenced above, promotes increased understanding of the role of geologic units during assessment of water resources in the ASO River Basin and emphasizes regional importance of these units northward and westward to the outcrop areas. Alternate naming conventions of geologic units are presented and cited for reference where appropriate.

Table 1. Center-pivot irrigation in the lower Apalachicola–Chattahoochee–Flint River Basin during 1993 and 1999 in Georgia counties co-located along the basin divide with the Aucilla–Suwannee–Ochlockonee River Basin (see fig. 1 for county locations; modified from Litts and others, 2001).

[—, not applicable]

County	Center-pivot irrigation[a] (acres)		1993 to 1999 increase (acres)	Percent increase
	1993	1999		
Crisp	3,895	11,951	8,056	207
Decatur	47,870	59,579	11,709	24
Dooly	6,984	12,487	5,503	79
Grady	2,828	3,254	426	15
Mitchell	47,610	58,425	10,815	23
Turner	211	1,384	1,173	556
Worth	9,552	15,675	6,123	64
Total	**118,950**	**162,755**	**43,805**	—

[a]Acreage located in Apalachicola–Chattahoochee–Flint River Basin only.

Well and Climatological-Station Identification and Surface-Water-Station-Numbering System

A system based on USGS topographic maps identifies wells in Georgia. Each 7½-minute topographic quadrangle map in Georgia has been given a number and letter designation beginning at the southwestern corner of the State. Numbers increase eastward through 39, letters advance northward through "Z," then double-letter designations "AA" through "PP" are used. The letters "I," and "O" are not used. Wells inventoried in each quadrangle are numbered sequentially beginning with "1." Thus, the 49th well inventoried in the Tifton East quadrangle (designated 18K) is designated 18K049 (fig. 1). Wells in Florida are numbered with a four-digit numerical code that is assigned by the Northwest Florida Water Management District (Christopher J. Richards, Northwest Florida Water Management District, Havana, Fla., written commun., April 2000).

Climatological stations are given a name that corresponds to the nearest city, town, or locality; figures and letters following the name indicate the distance in miles and compass direction from the post office or town community center, such as Albany 3 SE (National Oceanic and Atmospheric Administration, 2002), located 3 miles (mi) southeast of the town center. Additionally, climatological stations are "identified by a six-digit number that constitutes the National Weather Service (NWS) Cooperative Station Network. The first two digits designate a state or territory code. The last four digits are assigned to stations within a state in general accordance with the alphabetical order of the station name. A station in this network, as designated by a single Cooperative Station Identifier, can be one site or a series of sites whose locations fall within 2 mi horizontal or 100 ft vertical distance. There are exceptions to this rule, with 'climatic compatibility,' as determined by the NWS field manager, being the overriding factor" (National Oceanic and Atmospheric Administration, 2008). For example, station number 092266 corresponds to the station "CORDELE," located in Cordele, Ga. (fig. 1). The leading "0" of the state or territory code has been omitted in this report.

Partial- and continuous-record surface-water stations are given an identification number, which is assigned in "downstream order" (Stokes and others, 1990). No distinction is made between partial-record stations and other stations; therefore, the number for a partial-record station indicates downstream-order position in a list made up of both types of stations. The complete number for each station, such as 02314500, includes a 2-digit part number "02" plus a six-digit downstream-order number, "314500."

Study Area

The study area is located in the Coastal Plain Physiographic Province of south-central Georgia and adjacent Florida, and consists mainly of the land area and geologic units contributing to the headwaters of the Aucilla, Suwannee, and Ochlockonee Rivers, and similar headwater drainage to the St. Marks River (fig. 1). Drainage basins of the Alapaha, Little, and Withlacoochee Rivers, and tributaries to the Suwannee River, are contained wholly within the study area. The Alapaha, Little, and Withlacoochee Rivers and their tributaries either flow directly over the limestone aquifer on a gentle, seaward-sloping karst plain, or incise sandy to clayey sediments overlying the limestone, carving a dendritic drainage pattern in the landscape.

Climate and Precipitation Variability

Long summers and mild winters characterize the climate of the ASO River Basin, which ranges from temperate in the northwestern part to humid subtropical in the southern and southeastern parts. Proximity of the basin to the Gulf of Mexico and Atlantic Ocean influences the seasonal variation of temperature and precipitation. Mean-annual temperatures for the climatic period 1971–2000 vary about 3 degrees Fahrenheit (°F), from about 69 °F in the southern and southeastern parts of the basin near the Gulf of Mexico and Atlantic Ocean (Tallahassee and Lake City, Florida, respectively; fig. 1) to about 66 °F inland in the northwestern and eastern parts of the basin (Cordele and Waycross, Ga., respectively) (Southeast Regional Climate Center, 2008a, b, c, d). Winter-low temperatures during December and January vary from the mid- to upper-30s °F in the northwestern and eastern parts of the basin, to the low- to mid-40s °F to the south and southeast. Summer-high temperatures occur during June, July, and August and vary from the low-90s °F in the northwestern and eastern parts of the basin, to the mid- to upper-90s °F to the south and southeast. Occasional freezing temperatures occur throughout the study area during fall through spring. Temperatures approaching 100 °F and above generally occur during late-spring through early-fall within much of the study area except to the south, where summertime cloudiness and thunderstorms limit high temperatures to the low-90s °F.

Precipitation varies geographically and temporally in the ASO River Basin according to the seasonal influence of weather patterns that bring humid subtropical and maritime air northward from the Gulf of Mexico and Atlantic Ocean and that move continental air masses into the basin from the north and west. Long-term records indicate nearly an 18-inch variation in total annual precipitation, from about 62.5 inches in Tallahassee, Fla., to the south, to about 44.9 inches in Cordele, Ga., to the northwest (table 2) (Southeast Regional Climate Center, 2008a, c). Summertime southwesterly winds bring tropical moisture inland from the Gulf of Mexico causing higher precipitation in the southern part of the study area (near Tallahassee, Fla.) than to the northwest (near Cordele, Ga.). Coastal storms from the Atlantic Ocean increase precipitation along the eastern part of the study area (near Waycross, Ga.). The southeastern part of the study area receives precipitation from the remains of coastal and gulf storms that move inland

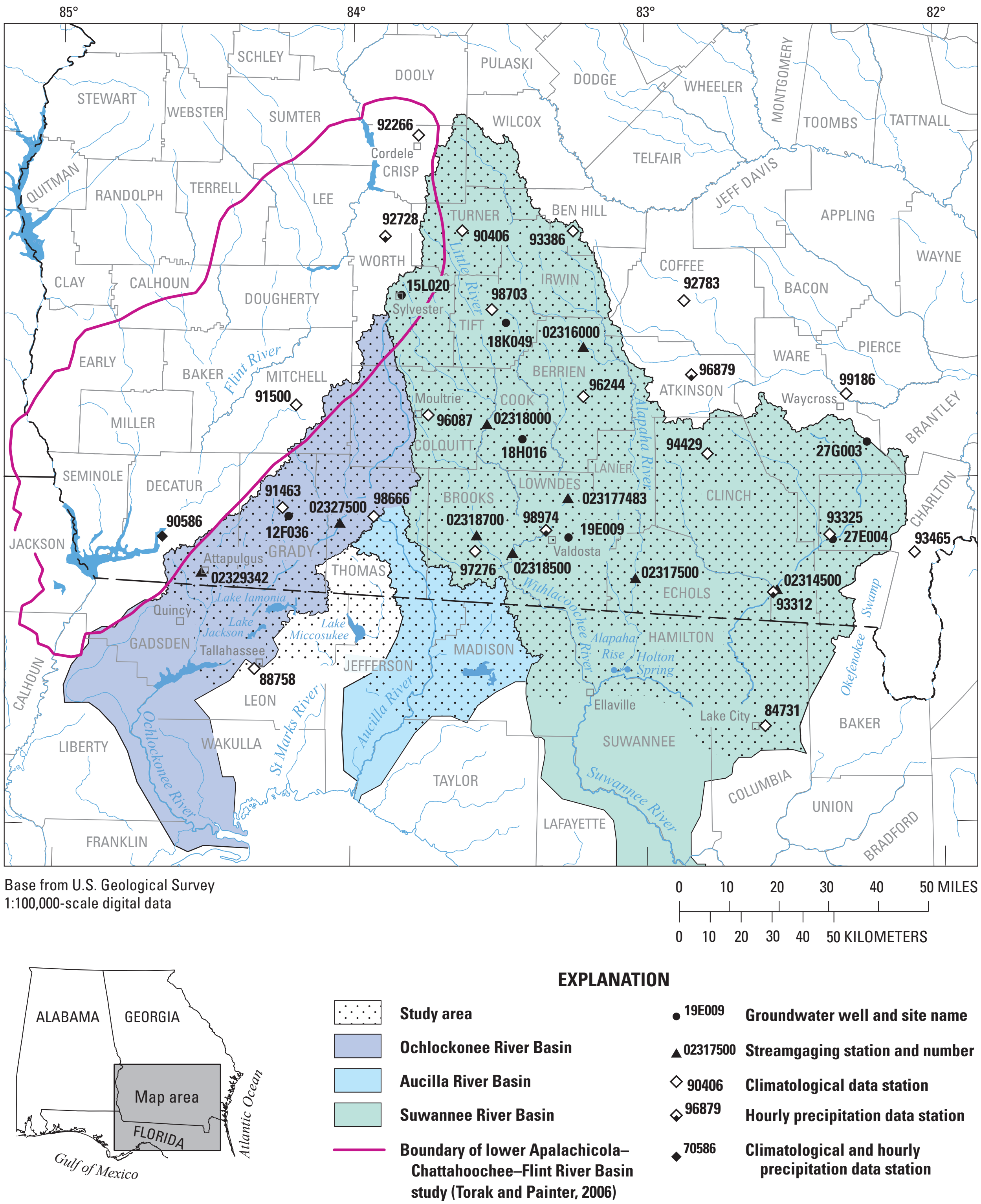


Figure 1. Location of study area in the Aucilla–Suwannee–Ochlockonee River Basin and lower Apalachicola–Chattahoochee–Flint River Basin, and of continuous-recorder observation wells and climatological and streamgaging stations in south-central Georgia and northwestern Florida.

Table 2. Period-of-record monthly average precipitation at Lake City and Tallahassee, Florida, and at Cordele and Waycross, Georgia (Southeast Regional Climate Center 2008a, b,c, d; see fig. 1 for location).

Month	Period-of-record average precipitation, in inches			
	Cordele, Georgia (92266) 1948–2006	Waycross 4 NE, Georgia (99186) 1930–2005	Lake City 2 E, Florida (84731) 1931–2006	Tallahassee, WSO AP, Florida (88758) 1948–2005
January	4.10	3.89	3.67	4.42
February	4.20	3.57	3.73	4.81
March	4.98	4.49	4.50	5.98
April	3.37	3.21	3.15	3.72
May	3.14	3.40	3.50	4.35
June	4.21	5.63	6.58	7.14
July	5.00	6.56	7.27	8.50
August	3.89	5.95	7.12	7.21
September	3.83	4.68	5.48	5.69
October	1.97	2.84	2.95	3.16
November	2.74	2.32	2.24	3.36
December	3.54	3.10	3.01	4.11
Annual	**44.86**	**49.63**	**53.19**	**62.46**

to the northern-peninsular and eastern-panhandle region near Lake City, Fla. Continental storms associated with frontal passages bring precipitation to the central and northwestern parts of the basin during late fall through early spring. Annual precipitation is fairly uniformly distributed throughout the year; however, slightly less precipitation occurs during April and May and during October through December than during the remaining months of the year.

Variations in monthly mean, minimum, and maximum precipitation measured at National Oceanic and Atmospheric Administration climatological stations that encompass the ASO River Basin (Cordele and Waycross, Ga., and Lake City and Tallahassee, Fla.) give an indication of the susceptibility of the basin to extremely dry or wet conditions (fig. 2). Monthly precipitation records at Cordele and Waycross, Ga., and at Lake City and Tallahassee, Florida, indicate dry conditions from September through May. Each of these stations recorded no precipitation for at least 1 month during the fall, and Cordele, Ga., listed no precipitation during October, November, and December during the period of record 1948–2006. June, July, and August have the highest minimum precipitation amounts of the year, most likely the result of summer thunderstorms and tropical storms, such as hurricanes.

The highest maximum precipitation recorded at Cordele and Waycross, Ga., and at Lake City and Tallahassee, Florida, occurred during September, which also can be one of the driest months (fig. 2). All four weather stations listed a maximum precipitation during September of at least 18 inches, perhaps the result of tropical storms. One such storm deposited nearly 8 inches of rain at Lake City, Florida, and nearly 5 inches of rain at Waycross, Ga., on September 7, 2004, which contributed to the September period-of-record maximum precipitation at each station (Southeast Regional Climate Center, 2008b, d). Most other months recorded maximum precipitation in the 10–15-inch range, with the exception of Cordele, Ga., where the maximum precipitation of 7–8 inches occurred during February, April, October, and November. The southern and southeastern parts of the basin (Tallahassee and Lake City, Florida) historically have recorded monthly maximum precipitation in excess of 10 inches year-round, with two minor exceptions occurring at Lake City, Florida, during February (about 9.9 inches) and November (about 9 inches) during the period of record 1931–2006.

Physiography and Drainage

Three distinct regions of the Coastal Plain Physiographic Province define unique landforms and surface drainage in the study area: a region of dissected hills and sand-hill ridges; an area of low relief that decreases to the southeast and contains numerous swamps; and a relatively flat, coastal-sediment region with karst limestone at or near land surface. The hilly region—termed the Tifton Upland District in Georgia and the Tallahassee Hills District (Puri and Vernon, 1964) and Northern Highlands (Cooke, 1939) in Florida—contains headwater drainage to the Alapaha, Aucilla, Ochlockonee, and Withlacoochee Rivers (fig. 3). The Tifton Upland is bounded to the west by the Solution Escarpment (MacNeil, 1947) and to the east by the eastern drainage divide of the Alapaha River. The swampy area of low relief to the east of the Tifton Upland and Tallahassee Hills is termed the Okefenokee Basin District (Clark and Zisa, 1976) and is drained by the Suwannee River.

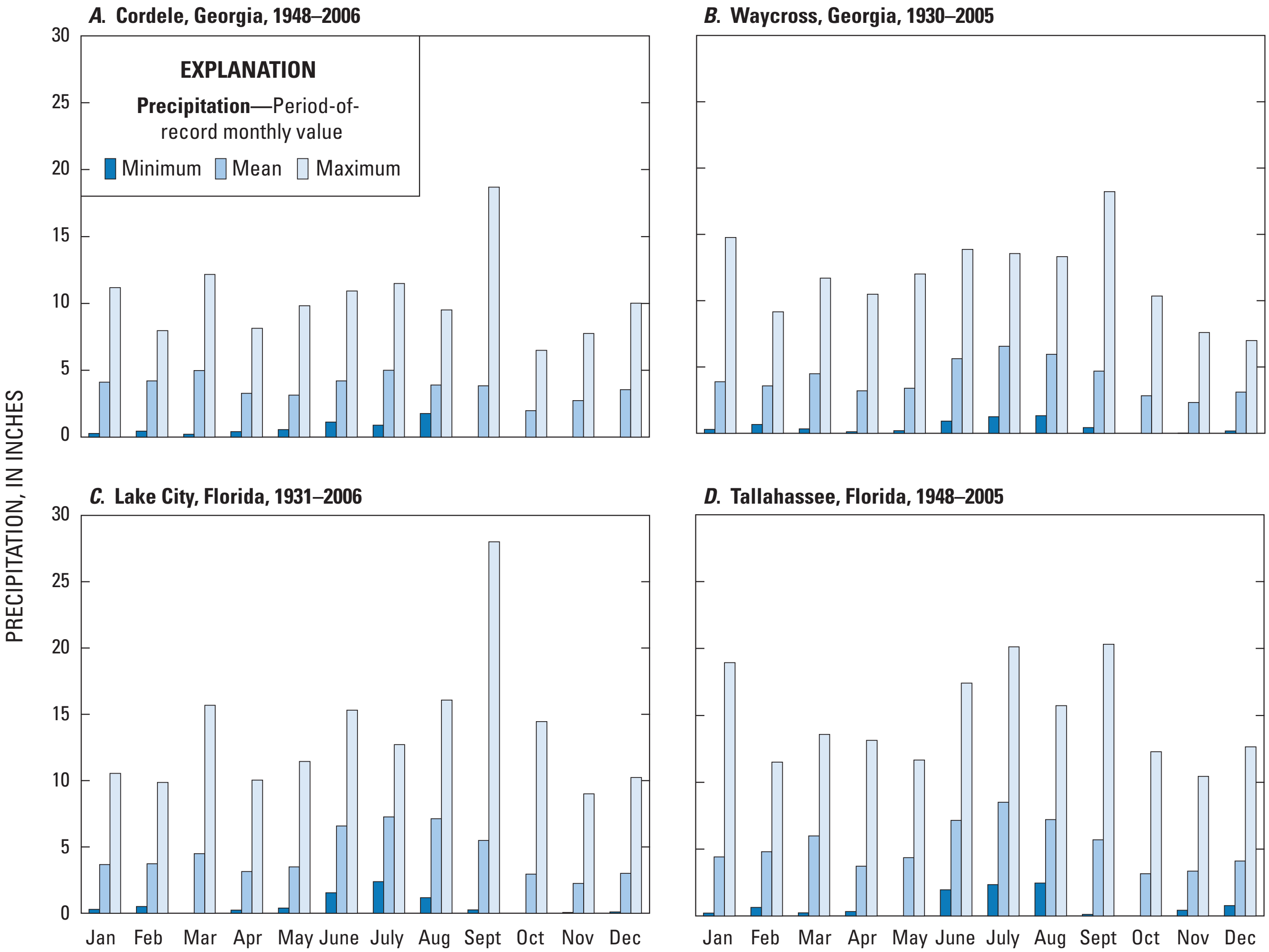


Figure 2. Period-of-record monthly mean, minimum, and maximum precipitation at climatological stations (*A*) 92266, Cordele, Georgia, 1948–2005; (*B*) 99186, Waycross, Georgia, 1930–2005; (*C*) 84731, Lake City, Florida, 1931–2006; and (*D*) 88758, Tallahassee, Florida, 1948–2005 (Southeast Regional Climate Center, 2008a, b, c, d).

The Cody Scarp, called the "most persistent topographic break in the state" by Puri and Vernon (1964), denotes a transition between the Tallahassee Hills and Northern Highlands and the relatively flat coastal region of the Gulf Coastal Lowlands, which frames the southern study area boundary. Above the escarpment, the thin, clastic cover is commonly breached by erosion, both from above by streams and from below by subsidence sinkholes. This erosional dissection has broadened the escarpment into a transition zone. Where the cover is breached, virtually all surface drainage flowing off the highlands disappears underground; numerous springs occur a short distance below the escarpment. Several of these, such as the Alapaha Rise, constitute discrete resurgences apparently connected to the sinking point by continuous conduits, although this has not been absolutely documented. The outflow is frequently turbid, reddish-brown, river-type water; however, there is also a substantial groundwater component to this flow (Ceryak, 1977).

The Tifton Upland, Tallahassee Hills, and Northern Highlands are parts of a nearly continuous series of topographically high uplands containing gently rolling hills with broad rounded summits situated between the low-lying Dougherty Plain to the northwest, Gulf Coastal Lowlands to the south, and Okefenokee Basin to the east (fig. 3). The upland regions appear to be disconnected remnants of a once-continuous residual highland (Yon, 1966). Stream valleys divide the Northern Highlands into a series of local geomorphic subzones. The Tallahassee Hills was the name proposed by Cooke (1939) for the region bounded by the Georgia State line to the north, coastal terraces to the south, the Withlacoochee River to the east, and the Apalachicola River to the west (Rupert, 1990). The hilly regions contain resistant clayey sands, silts, and clays (Arthur and Rupert, 1989), which slope gently to the southeast.

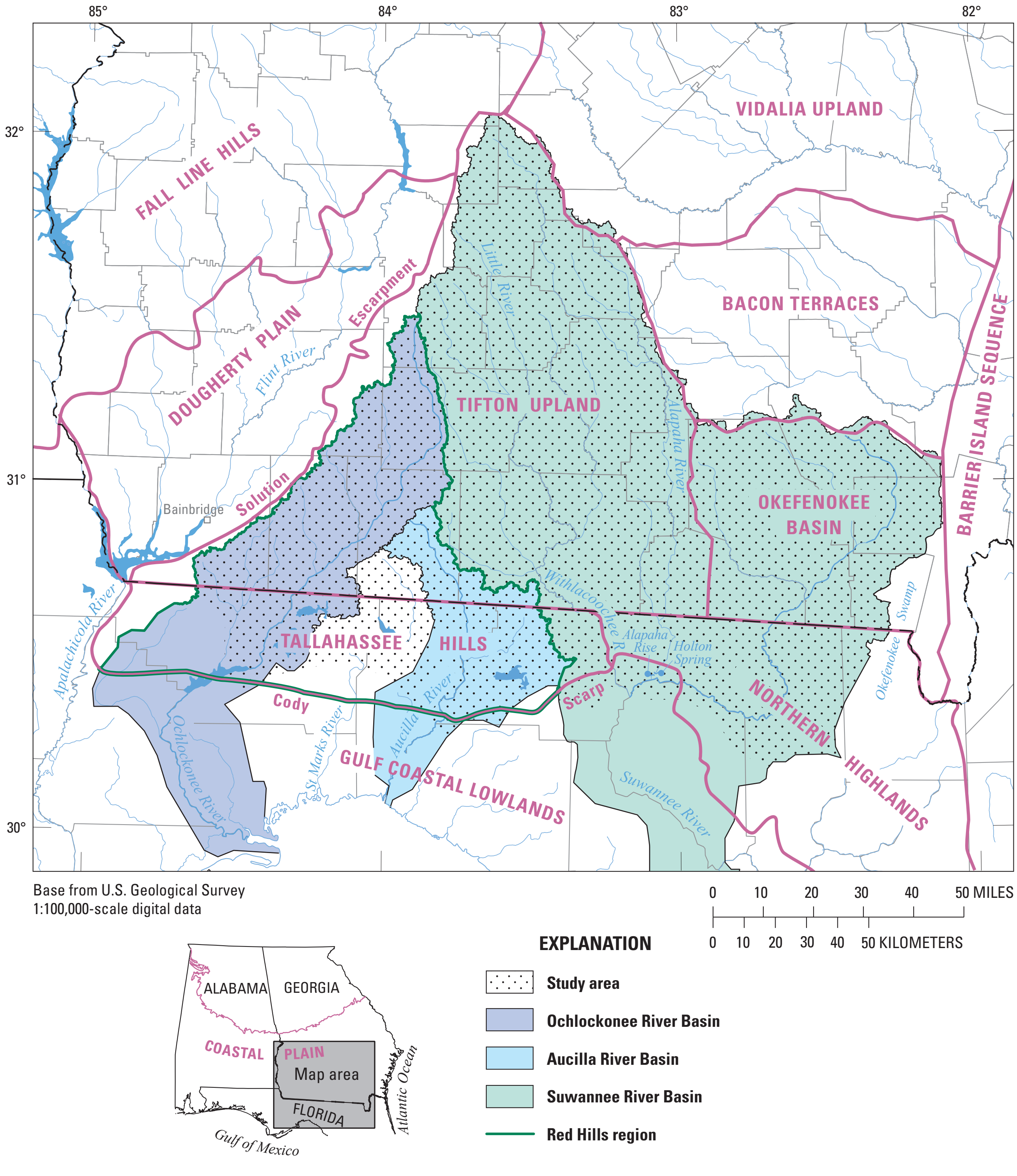


Figure 3. Physiographic divisions in the Aucilla–Suwannee–Ochlockonee River Basin (modified from Cooke, 1939; and Clark and Zisa, 1976).

The Tifton Upland is a distinct cuesta that begins just west of the study area with a prominent escarpment (the Solution Escarpment) nearly 150 ft high overlooking the Flint River (Fenneman, 1938) (fig. 3). Land-surface altitude in the Tifton Upland ranges from about 480 ft in the north to about 150 ft to the southeast, which is indicative of the regional dip of underlying sediments (Clark and Zisa, 1976). Land-surface altitude in the Florida counterpart to the Tifton Upland, the Tallahassee Hills, ranges from about 330 ft near the Florida–Georgia State line to about 100 ft in the southern part of the region. The high- altitude areas of the Tifton Upland contain solution features, some of which are abundant in a broad east-west strip along the Florida–Georgia State line (Fenneman, 1938). Dendritic drainage of many surface streams dissects the hills and forms deeply incised valleys and ravines (Rupert, 1990) in the otherwise broad, flat plain.

The Tifton Upland and Tallahassee Hills contain the 927-mi^2 Red Hills region, which encompasses the Aucilla and Ochlokonee River Basins in Florida and Georgia and is bounded on the south by the Cody Scarp (Cox and others, 2001) (fig. 3). The Red Hills region comprises part of a belt of Eocene hilly terrain that extends across Alabama and Mississippi and contains ravines and clay-capped ridges (Schwaner and Mount, 1970; Davis, 1996b) that, in Florida and Georgia, drain to the Aucilla and Ochlockonee Rivers. Sandy loam soil supports sandhill vegetation that covers ridge tops composed of uneroded clay (Schwaner and Mount, 1970). Ravines form, however, from selective clay erosion. Surface runoff and dissolution subsidence control topography, and small karst depressions hold temporary ponds (Davis, 1996a).

The Red Hills region of the Aucilla and Ochlockonee River Basins provides habitat to rare flora and fauna. This region may contain the only known localities in Florida and Georgia for the salamander *Phaeognathus hubrichti*, which has been located in equivalent hilly regions in Alabama (Schwaner and Mount, 1970). One of the largest remaining populations of federally endangered red-cockaded woodpeckers (*Picoides borealis*) is present in the Red Hills region, as well as some of the best examples of old-growth longleaf pine (*Pinus palustris*) remaining in the southeastern United States (Cox and others, 2001).

The Aucilla River is a distinctive blackwater stream that rises in central Thomas County, Ga., and drains marshes and lakes before flowing over karst limestone east of Tallahassee, Fla., where it disappears in sinkholes located along the Cody Scarp, only to reappear downstream as springflow (1,000 Friends of Florida, 2006). Blackwater streams have a naturally dark appearance or are tea-colored due to dissolved organic matter carried by the stream (Wakulla County Tourist Development Council, 2007).

The Ochlockonee River rises just south of Sylvester, Ga., and flows southward about 300 mi over clayey sediments of the Tifton Upland and Tallahassee Hills to an estuary before emptying to the Gulf of Mexico (fig. 1). Transported sediment and organic matter give the Ochlockonee River a distinct yellow color. The organic matter nourishes numerous species of fish and shellfish, which sustain recreational and commercial fishing in the estuary and Gulf of Mexico. The Ochlockonee River is State-designated as Outstanding Florida Water and is a well-known canoe trail (Wakulla County Tourist Development Council, 2007).

The Okefenokee Basin District (fig. 3) contains numerous swamps and low relief that decreases to the southeast (Clark and Zisa, 1976). Land-surface altitude ranges from about 240 ft in the northwest on Pliocene-Pleistocene deposits to about 75 ft to the southeast on Pleistocene deposits; relief varies from about 50 ft to about 5 ft. The swamps range in size from a few hundred square feet to the 660-mi^2 Okefenokee Swamp. The Suwannee River rises in the Okefenokee Basin District of southeastern Georgia, where a series of southeasterly flowing tributaries joins the main channel and drains the Okefenokee Swamp as the river flows southwest into north-central Florida (fig. 1).

The Suwannee River receives major tributary flow from the Alapaha and Withlacoochee Rivers, which rise on the Tifton Upland and join the Suwannee River in the northern panhandle of Florida near Ellaville (fig. 1). The Alapaha River flows through a mature karst terrain of numerous sinkholes, stream sinks, and springs on the Tifton Upland and Northern Highlands before disappearing into several large sinkholes (Raulston and others, 1998). The subterranean river flows through solution channels in the limestone for about 19 mi before emerging at two springs—Alapaha Rise and Holton Spring—and before joining the Suwannee River. The Suwannee River contains the second largest streamflow in Florida, after the Apalachicola River in northwestern Florida (Raulston and others, 1998). In Florida, a few northwesterly flowing tributaries drain the Northern Highlands before the Suwannee River crosses the Cody Scarp and flows onto the Gulf Coastal Lowlands.

The Gulf Coastal Lowlands (fig. 3) is a sandy, flat, seaward-sloping feature shaped mostly by wave and current activity from Pleistocene high sea-level stands (Arthur and Rupert, 1989). Land surface in the lowlands contains relic Pleistocene marine bars, terraces, spits, and sandbar dunes (Leitman and others, 1984) with limestone at or near the surface. Streams entering the Gulf Coastal Lowlands from the Northern Highlands disappear into the limestone aquifer at the Cody Scarp, only to reappear downstream as springflow.

Geohydrology

Geologic and hydrologic settings within the ASO River Basin define distinct lithologic and fluid-flow characteristics that control groundwater movement and interaction with surface water. The Upper Floridan aquifer and overlying and underlying semiconfining units contain geologic formations, the hydraulic properties of which combine with human-induced stress to influence water-resource availability, groundwater and surface-water exchange, and development potential.

The following sections describe geologic and hydrologic characteristics of the Upper Floridan aquifer, and overlying and underlying semiconfining units, that improve current understanding of the lithology and hydraulic properties of the aquifer and hydraulically connected geologic units. Such an understanding enables conceptualization of water exchange among the Upper Floridan aquifer, hydraulically connected geologic units, and surface water in the ASO River Basin and promotes development of causal relations between groundwater pumpage in the Upper Floridan aquifer and groundwater-level decline and reductions in streamflow and springflow.

Geologic Setting

A thick Jurassic to Holocene sequence of sedimentary rocks and unconsolidated to semiconsolidated sediments underlies the Coastal Plain Physiographic Province in the ASO River Basin and forms a tilted wedge of permeable and semipermeable layers that thickens seaward from a feather-edge in outcrop areas to the northwest to more than 20,000 ft in southern Alabama and Florida (Miller, 1986). Miller (1986) identified the section of mostly Paleocene to early Miocene carbonate and clastic geologic units, variously hydraulically connected, as the Floridan aquifer system of the southeastern United States. The Eocene to Holocene sequence of geologic units defines the Upper Floridan aquifer and hydraulically connected sediments that contribute to groundwater and surface-water exchange in the study area (fig. 4). Middle Miocene to Holocene clastic sediments overlie the Floridan aquifer system nearly everywhere except where erosion has removed poorly consolidated sediments and exposed carbonates at land surface. Dissolution by infiltrating precipitation forms local to regional karst features where carbonates presently lie at or near land surface, or where now-buried carbonates previously were exposed at land surface on the paleo landscape.

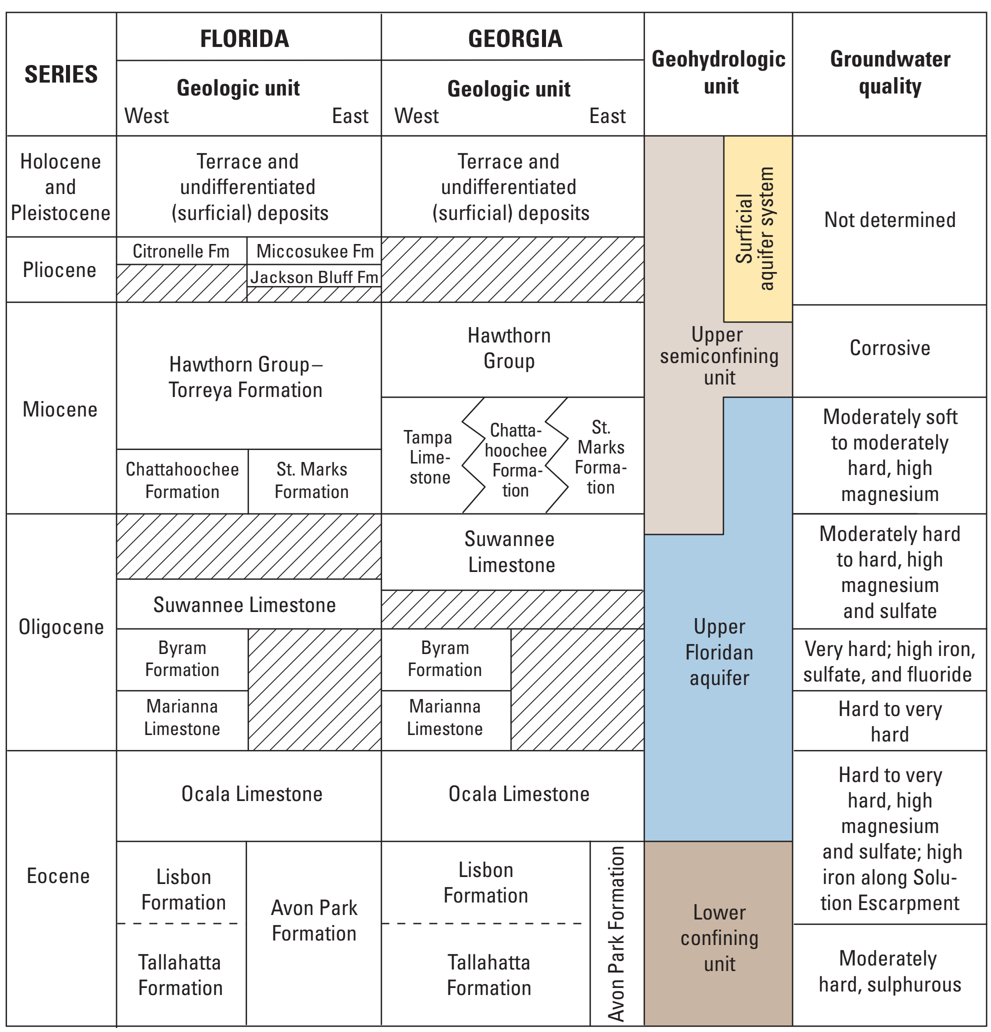


Figure 4. Geologic and geohydrologic units and groundwater quality of the Upper Floridan aquifer and hydraulically connected sediments in the Aucilla–Suwannee–Ochlockonee River Basin (modified from Miller, 1986; Rupert, 1990; and Torak and Painter, 2006).

Structural Features

Local tectonics in the ASO River Basin associated with altered crystalline basement rocks, differential compaction, and solution and collapse of limestone affected the accumulation and lithology of Coastal Plain sediments that constitute the aquifers and confining units of the Floridan aquifer system. Upwarping during early Mesozoic to late Cretaceous produced by compressional tectonics associated with the seaward extension of the Appalachian and (or) Ouachita structural belts (Chen, 1965) formed the Peninsular Arch in north-central Florida, which dominated sedimentation in the southeastern part of the study area (Miller, 1986) (fig. 5). Clastic and carbonate sediments accumulated on the flanks of the Peninsular Arch to the northeast, north, northwest, and west since at least the Early Cretaceous in depositional features termed, respectively, the Southeast Georgia (or Savannah) Embayment, Suwannee Strait, Gulf Trough (fig. 6), and Apalachicola (or Southwest Georgia) Embayment, (Miller, 1986). The Southeast Georgia Embayment represents a shallow east-to-northeast-plunging syncline that subsided at a moderate rate allowing an accumulation of clastic and carbonate sediments (Miller, 1986) (fig. 7). In contrast, a nearly continuous sequence of late Jurassic clastic sediments fill the southwest-plunging syncline of the Apalachicola Embayment and Gulf Trough (Miller, 1986), followed by thickening of Oligocene to Miocene sediments (figs. 8 and 9).

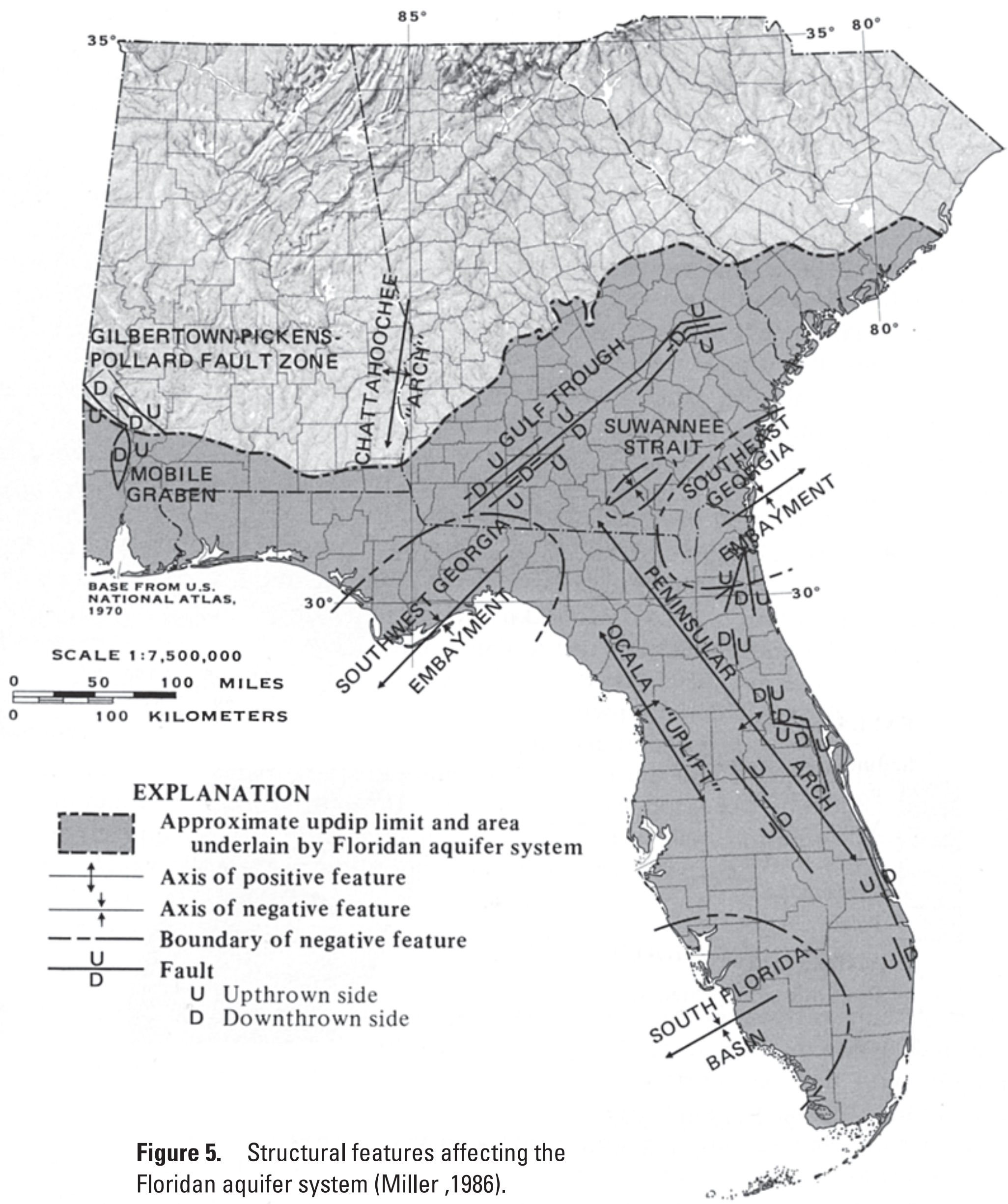


Figure 5. Structural features affecting the Floridan aquifer system (Miller ,1986).

Kellam and Gorday (1990) describe the Gulf Trough–Apalachicola Embayment as part of a subsurface paleomarine channel system in the Georgia Coastal Plain, with the former (Gulf Trough) a northeastward extension of the latter. Declining sea level restricted circulation within this channel, allowing deposition of a thick accumulation of fine-grained material (Davis, 1996a). Miller (1986) describes the Gulf Trough as a series of boundary faults to grabens that position low water-bearing clastic sediments opposite limestone of the Floridan aquifer system. The low water-transmitting ability of these features allows them to be discussed in this report as a single geohydrologic entity termed the Gulf Trough–Apalachicola Embayment (fig. 6).

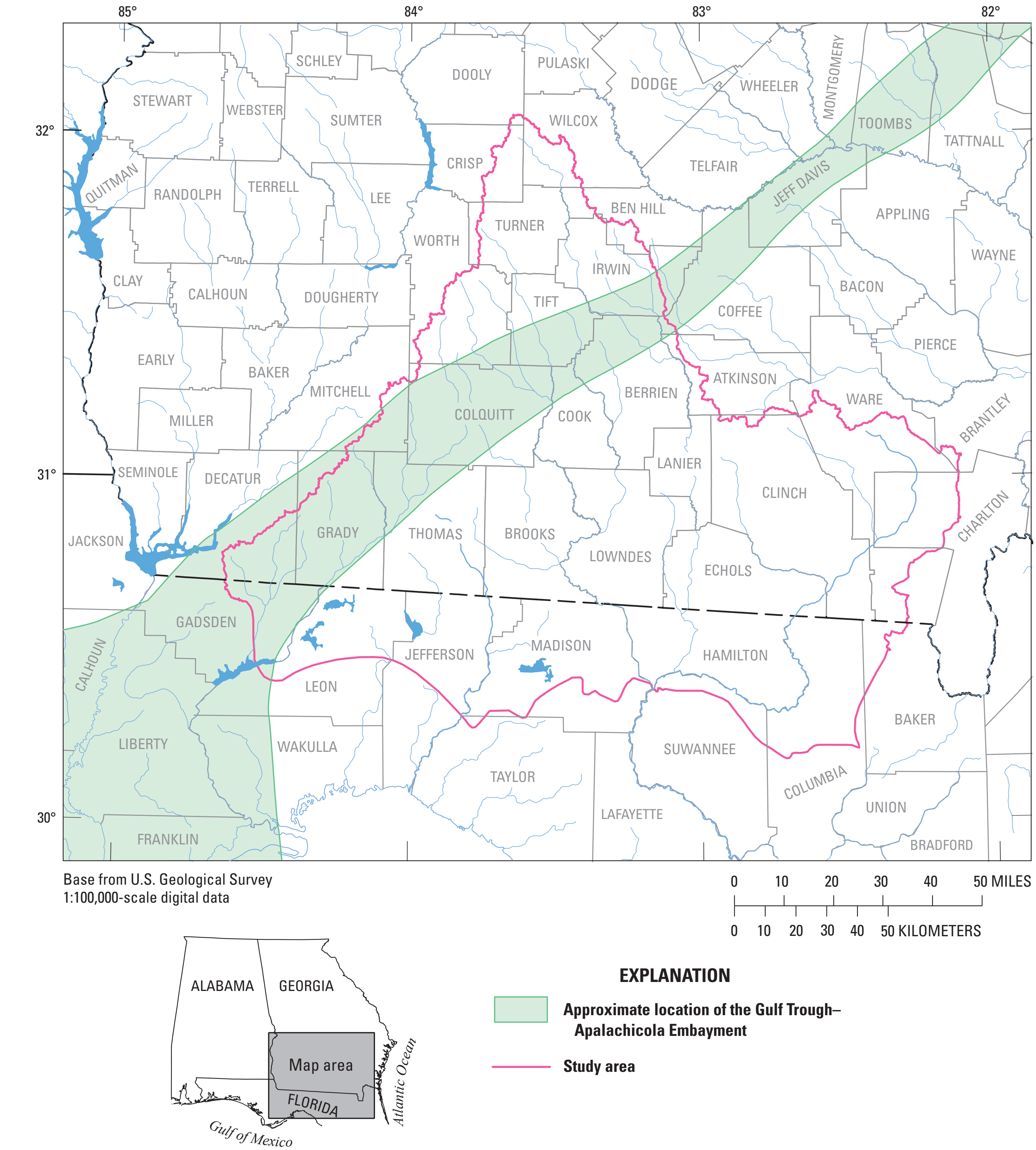


Figure 6. Approximate location of the Gulf Trough–Apalachicola Embayment in the Aucilla–Suwannee–Ochlockonee River Basin in southern Georgia and adjacent parts of Florida (modified from Kellam and Gorday, 1990; Davis, 1996a).

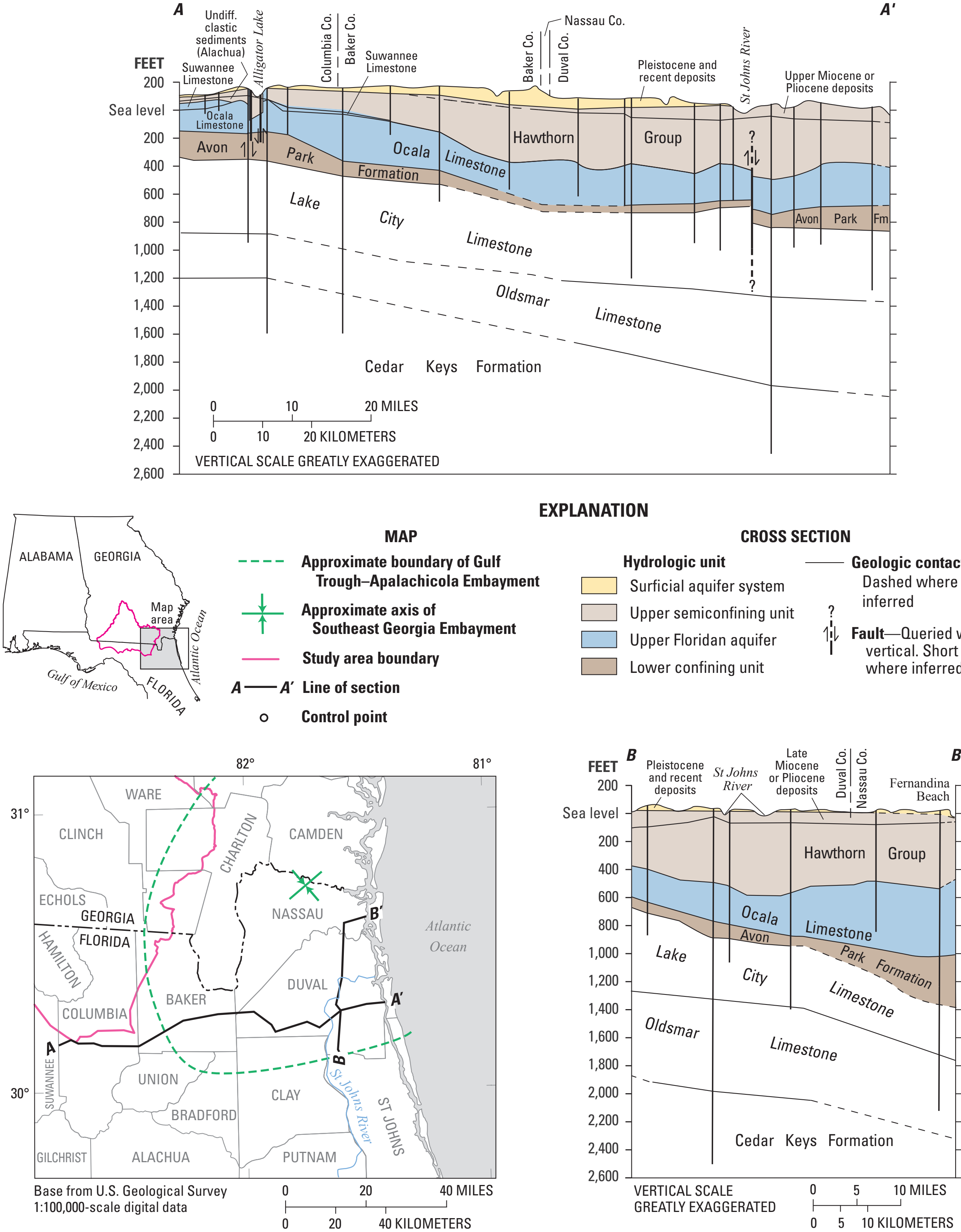


Figure 7. Geologic sections across northeastern Florida showing relations between geologic units and the Floridan aquifer system along *A–A′*, from west of Lake City, Florida, to the Atlantic Ocean; and *B–B′*, from Duval County, Florida, to Fernandina Beach, Florida (modified from Leve, 1968).

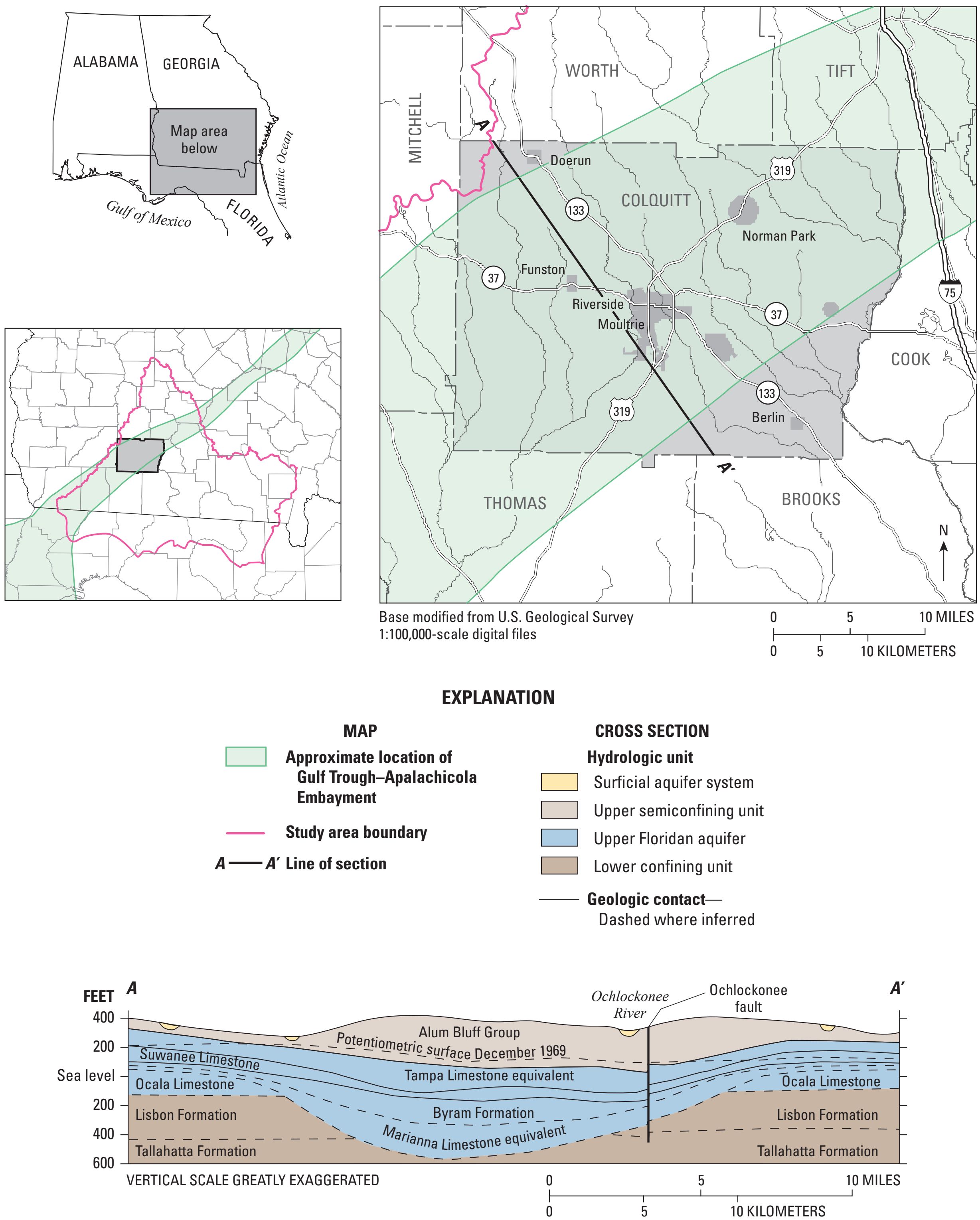


Figure 8. Geologic section across Colquitt County, Georgia, showing sediment thickening in the area of the Gulf Trough–Apalachicola Embayment (modified from Zimmerman, 1977).

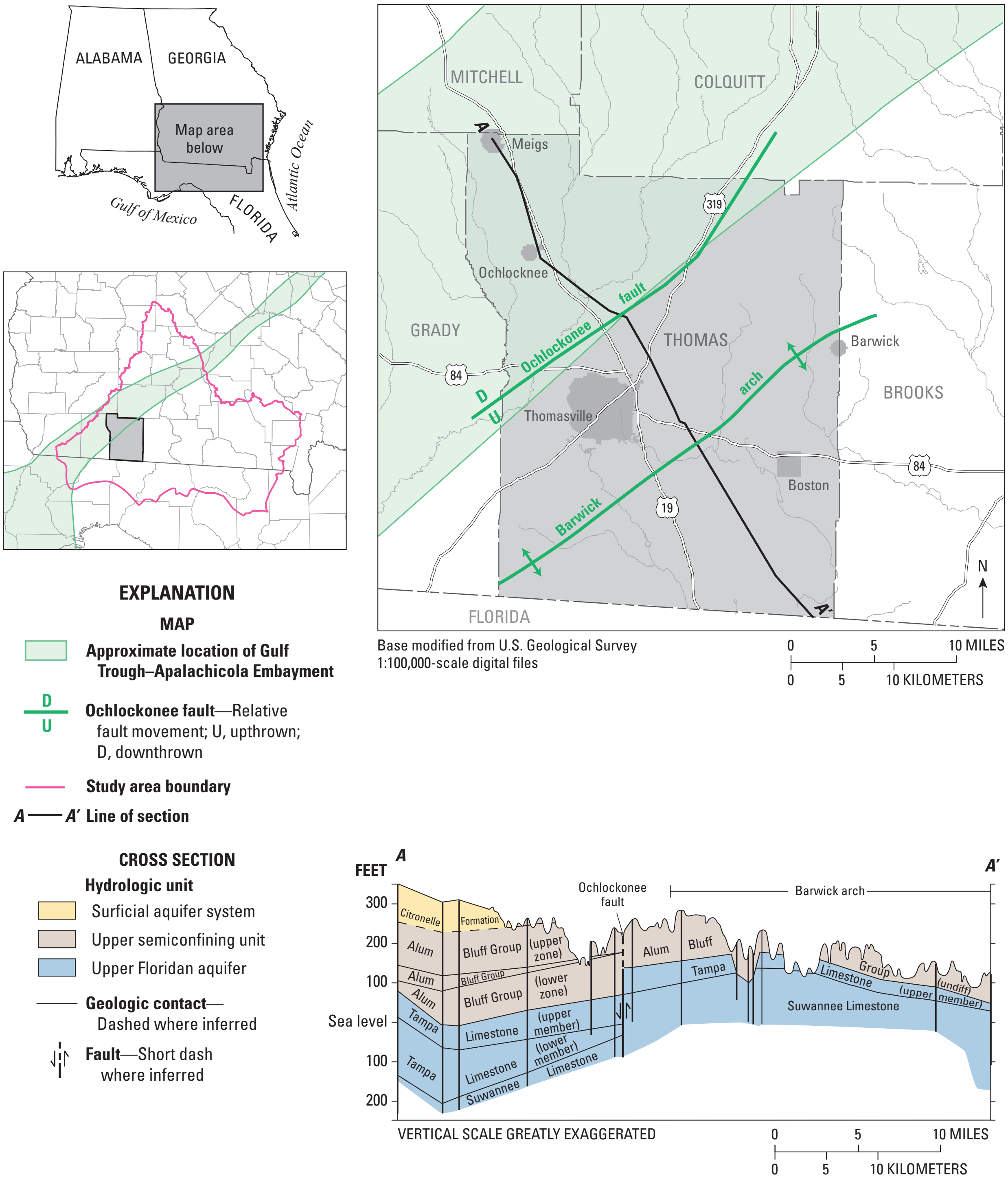


Figure 9. Geologic section across Thomas County, Georgia, showing sediment thickening in the area of the Gulf Trough–Apalachicola Embayment (modified from Sever, 1966).

The Ocala “Uplift,” a comparatively younger structure than the Peninsular Arch (fig. 5), first began to develop southwest of the arch during post-Oligocene or lower Miocene, based on the configuration of Miocene sediment that directly overlies upper Eocene carbonates (fig. 10) and the lack of thinning of Eocene sediments along the crest of the uplift (Chen, 1965). Winston (1976) attributed the uplift to an anomalous buildup of middle Eocene carbonates. Miller (1986) suggested that differential compaction of these sediments shortly after deposition had given rise to the Ocala “Uplift.” Often confused and used synonymously with the Peninsular Arch, the Ocala “Uplift” represents a gentle and local flexure parallel to the Peninsular Arch in central Florida where middle to upper Eocene sediments outcrop on the west coast of the peninsula (Chen, 1965).

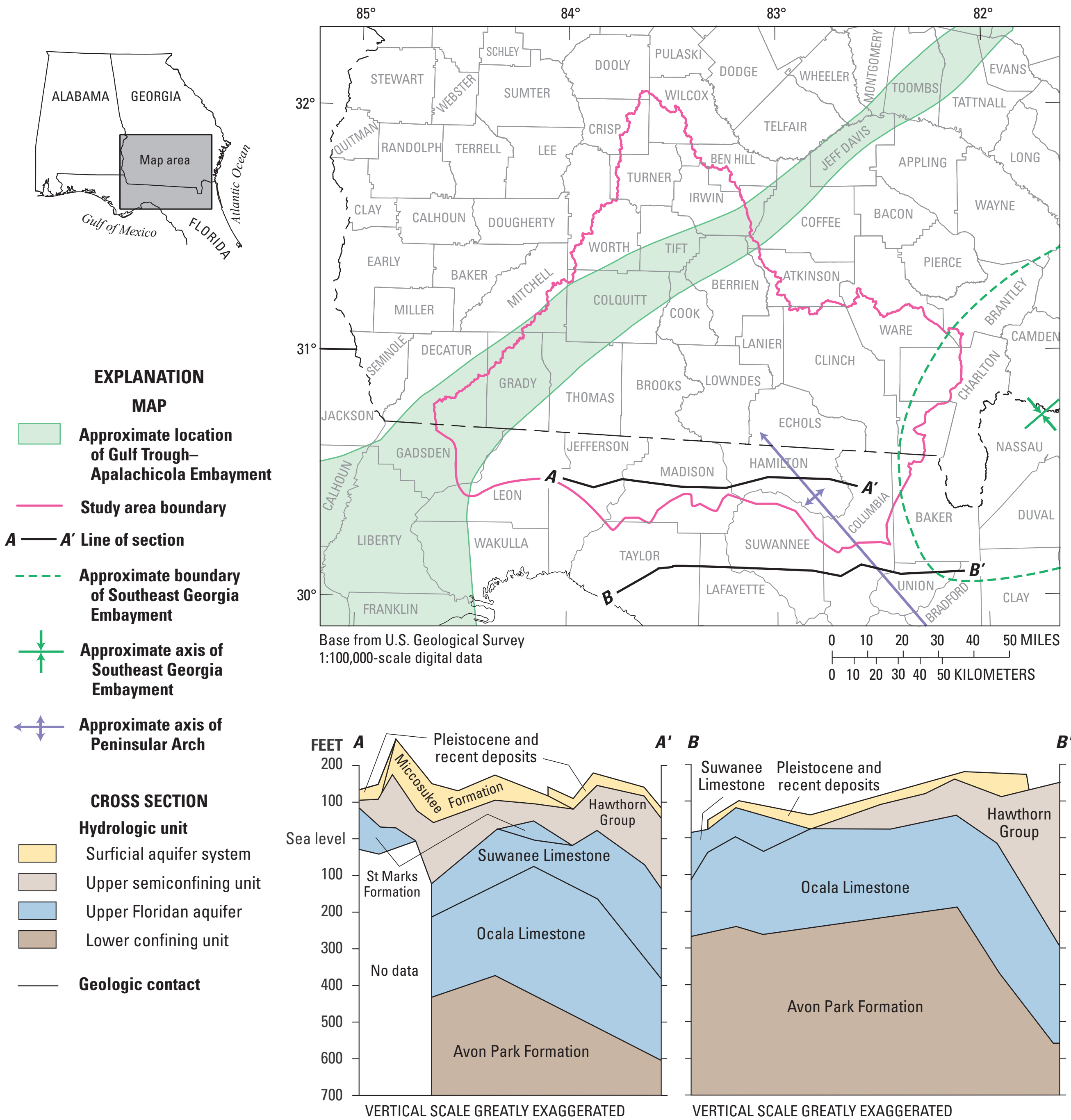


Figure 10. Geologic sections across northeastern Florida showing accumulation of Eocene sediment over the Peninsular Arch along *A–A′*, from western Jefferson County, Florida, to Columbia County, Florida; and *B–B′*, from Taylor County, Florida, near Gulf of Mexico, to Bradford County, Florida (modified from Kellam and Gorday, 1990; Davis, 1996a; Raulston and others, 1998).

The Suwannee Strait (Dall and Harris, 1892) represents a negative feature, such as a closed basin or trough, within which several stratigraphic units are anomalously thin (Miller, 1986). Paleocene to Eocene environmental stress and sea-level rise possibly suppressed carbonate-sediment production, prohibiting accumulation rates from keeping pace with tectonic subsidence (Hine and others, 2001). Dall and Harris (1892) described the Suwannee Strait as a northeast-trending trough extending from the Suwannee River in Florida through the Okefenokee Swamp. Well data indicate a closed depression on the top of the Paleocene, compatible with an extension of the Southeast Georgia Embayment but separated from the embayment by a sill-like ridge (Miller, 1986). Miller (1986) suggested that during early Eocene, the Suwannee Strait ceased to be an actively subsiding basin and accordingly, had little effect on the Floridan aquifer system except that the aquifer thickens slightly within the strait. Deltaic sedimentation by rivers draining off the Appalachian Mountains during late Oligocene probably caused infilling of the seaway. This deltaic sedimentation extended southward and onlapped carbonates of northern Florida (Hine and others, 2001).

Applin and Applin (1944) suggested the existence of “a channel or trough extending southwestward across Georgia through the Tallahassee area to the Gulf of Mexico.” “This channel cut nearly at right angles to the trend of the Peninsular Arch and lay between the carbonate-evaporite facies to the southeast and the terrigenous clastic facies to the north and northwest” (Chen, 1965). Jordan (1954) termed this channel the Suwannee Strait, in apparent conflict with the previous usage of the term by Dall and Harris (1892).

The Suwannee Strait possibly formed beneath the Suwannee Seaway and combined with the Gulf Trough to form consecutive seaways linking the Gulf of Mexico with the Atlantic Ocean (Hine and others, 2001). Chen (1965) attributes the continuous existence of the Suwannee Strait (or “Channel”) during Paleocene and lower Eocene to current action that “considerably reduced the rate of accumulation of fine sediments … and would have prevented the spread of fine terrigenous sediments over the peninsula area to the southeast.” Applin (1951) recognized distinct clastic and non-clastic sedimentary facies in the area of the Suwannee Strait; these facies have shifted northward and northwestward through geologic time (Chen, 1965).

A number of investigators have expressed various explanations about the nomenclature associated with the structural feature known as the Gulf Trough as well as its origin. Herrick and Vorhis (1963) associated the name Gulf Trough of Georgia (or Gulf Trough, figs. 5 and 6) with the same structural feature described previously as the Suwannee Strait by Dall and Harris (1892) and Jordan (1954) (fig. 8). Sever (1966) defined the Meigs Basin as a local synclinal sedimentary structure of the larger Suwannee Strait, or Gulf Trough, in northwestern Thomas County, Ga. (fig. 9). The principal hypotheses for the origin of the Gulf Trough have been summarized by Patterson and Herrick (1971) and listed by Zimmerman (1977). These hypotheses are that the Gulf Trough defines (1) a buried submarine valley or strait analogous to the Straits of Florida; (2) a graben; (3) a syncline; or (4) a buried solution valley analogous to the Flint River valley (fig. 11).

In the Flint River valley, solution and weathering of carbonate rocks transformed the Oligocene Suwannee Limestone into a residuum (Flint River residuum) of greatly reduced thickness (fig. 11). Weathering completely leached the Suwannee Limestone and replaced it with silica that formed chert boulders in the residuum (Vorhis, 1972). By analogy, the Marianna Limestone and Byram Formation supplanted the Lisbon Formation and Ocala Limestone in the Gulf Trough region by sedimentation, rather than through solutioning and weathering as in the Flint River valley. The resulting formation consisted of a thick, low-water-transmitting zone in the aquifer containing poor water quality.

Herrick and Vorhis (1963), Gelbaum (1978), and Gelbaum and Howell (1982) identified a series of northeasterly trending boundary faults in the Gulf Trough region. Miller (1986) described a process where low-permeability clastic sediments fill grabens in the fault zone and are juxtaposed with high-permeability limestone units in the Floridan aquifer system. Zimmerman (1977) described the pinch-out of high-permeability Upper Eocene fossiliferous limestone along the trend of the Gulf Trough and deposition of low-permeability Oligocene dolomitic limestone and marl in its place (fig. 8). The juxtaposition of low-permeability sediments of the Gulf Trough with high-permeability limestone presents a barrier to groundwater flowing southeastward in the Upper Floridan aquifer from outcrop/recharge areas located to the northwest of the study area (figs. 9 and 12).

Geologic Units

Structural control of sedimentation in the ASO River Basin resulted in a vertically layered sequence of clastic and carbonate sediments that also grades laterally within these layers to define geologic units. The sequence of middle Eocene and younger geologic units provide the setting for groundwater and surface-water exchange within the Upper Floridan aquifer, lower and upper semiconfining units, and surficial aquifer (fig. 4).

A lithostratigraphic-transition zone in south-central Gadsden County, Fla., divides late Eocene calcareous and clastic facies and separates low-permeability middle Eocene carbonates of the Avon Park Formation of northern and peninsular Florida from the age-equivalent, glauconitic, sandy, and clayey limestone and sand of the Lisbon (Rupert, 1990) and Tallahatta Formations to the west (Miller, 1986) (fig. 4). The

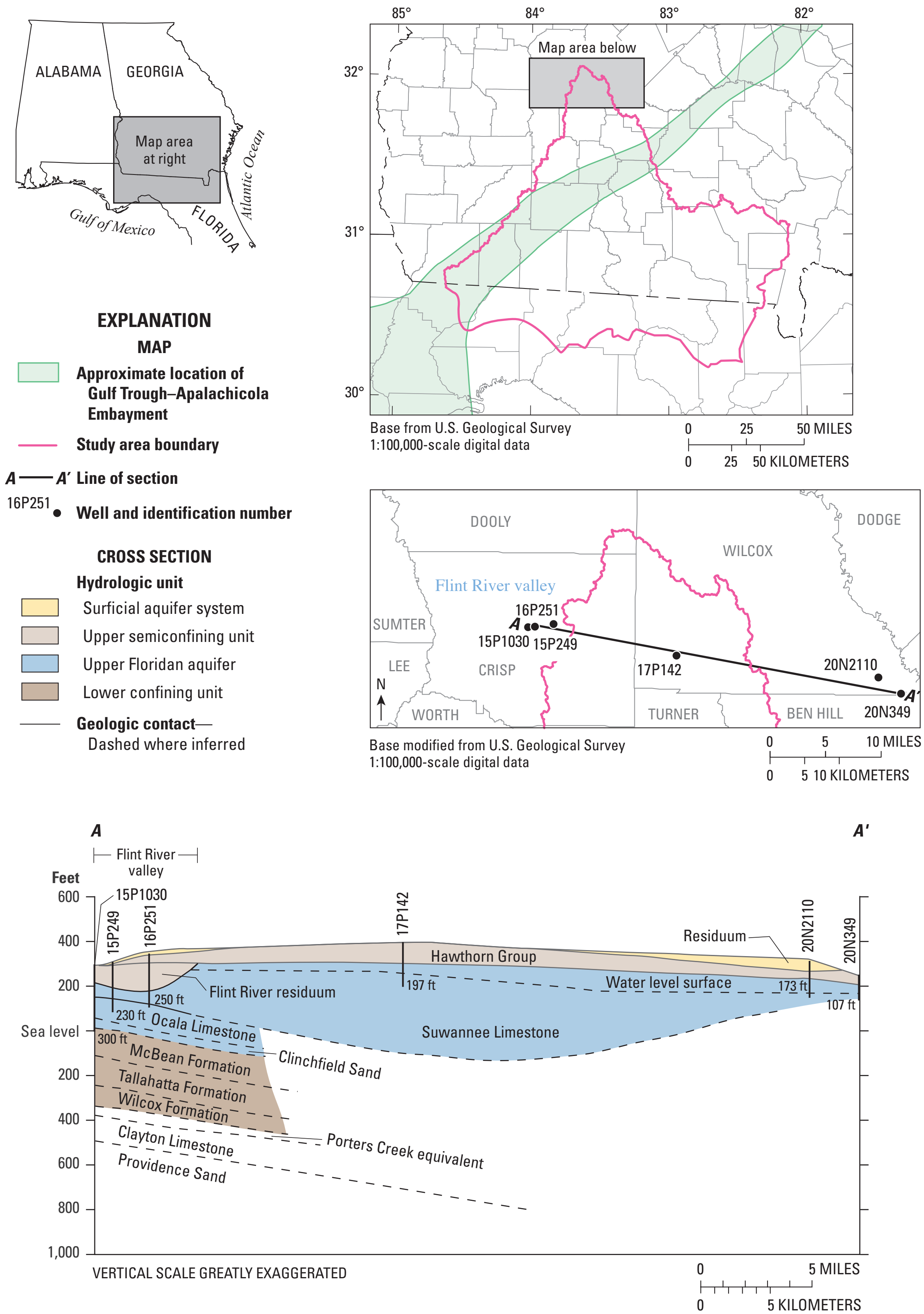


Figure 11. Geologic section across Crisp and Wilcox Counties, Georgia, showing reduction of Suwannee Limestone thickness to Flint River residuum (modified from Vorhis, 1972).

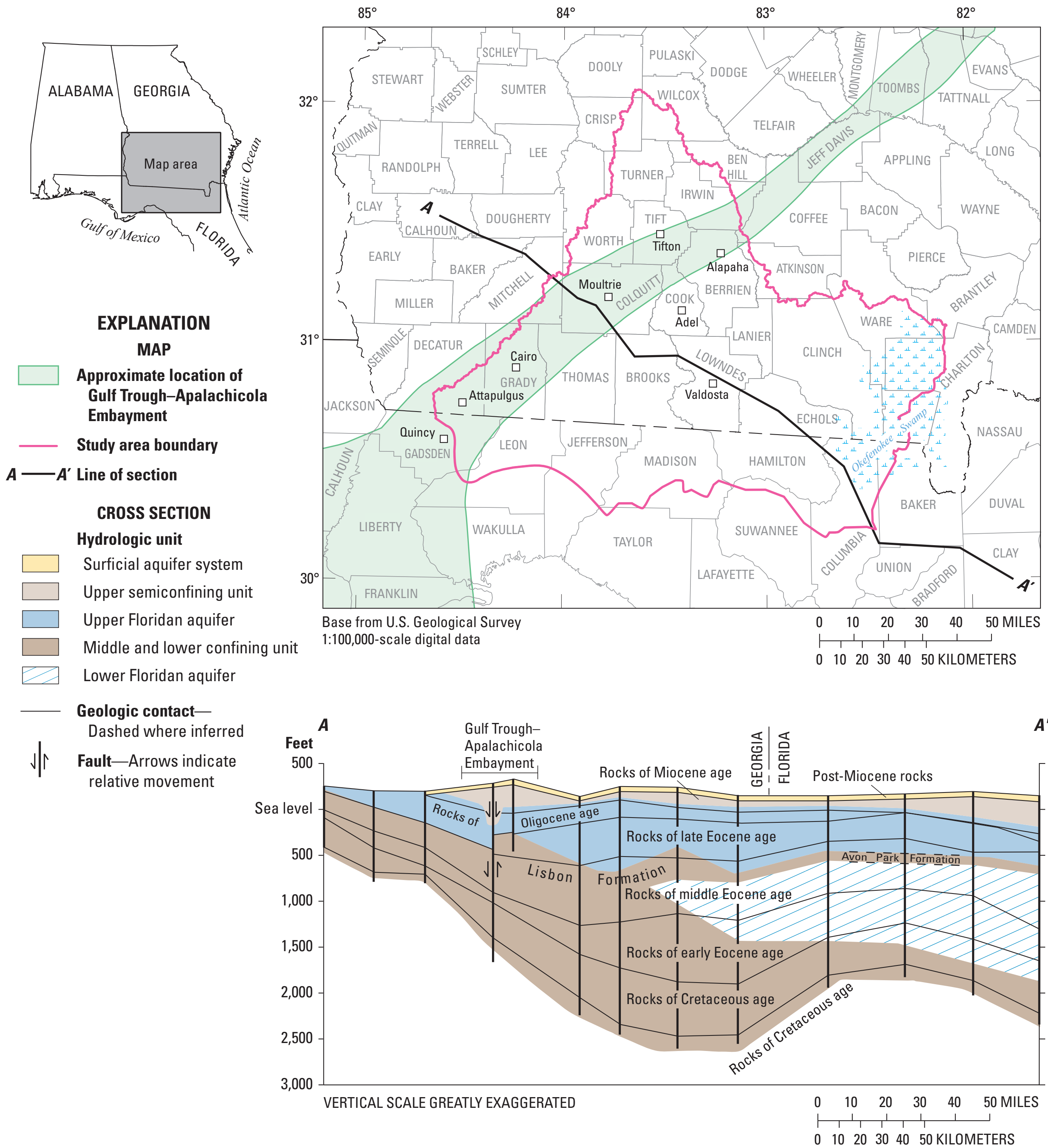


Figure 12. Geologic section of Floridan aquifer system from Calhoun County, Georgia, southeast to Clay County, Florida, showing hydrostratigraphic relations and structure of sediments in the Aucilla–Suwannee–Ochlockonee River Basin (modified from Miller, 1986).

middle third of the Avon Park Formation in the eastern half of the Florida peninsula and in much of southeastern Georgia is micritic, finely pelletal limestone; the lower half of the Avon Park Formation in west-central peninsular Florida consists of gypsiferous limestone and dolomite. In the Florida peninsula and southeastern Georgia, the variable lithology of the Avon Park Formation constitutes a subregional confining unit within the Floridan aquifer system (Miller, 1986). The Lisbon Formation defines the lower confining unit of the Upper Floridan aquifer (Miller, 1986) in the northern, western, and north-central parts of the study area; the Avon Park Formation defines the lower confining unit of the Upper Floridan aquifer to the south and east.

The middle Eocene Lisbon and Avon Park Formations hydraulically separate water-bearing carbonates of the Floridan aquifer system into two major permeable zones termed the Upper and Lower Floridan aquifers (Miller, 1986) (fig. 12). The area of separation of these permeable units occurs in a region bounded by Moultrie, Ga., to the north, the Okefenokee Swamp and Baker County, Fla., to the east, and Attapulgus, Ga., and Quincy, Fla., to the west. Miller (1986) indicates the occurrence of a Lower Floridan aquifer near Valdosta, Ga. Here, the Lisbon and Avon Park Formations form a middle confining unit to the Upper and Lower Floridan aquifers; however, gypsiferous rocks of the intervening confining unit grade downward into low-permeability clastic sediments of the aquifer system's lower confining unit, where total confining-unit thickness exceeds 200 ft. Well data limit the definition and areal extent of these confining units because neither unit crops out in the study area. This separation sufficiently impedes groundwater and surface-water exchange with Paleocene-to-middle-Eocene rocks of the Lower Floridan aquifer in the ASO River Basin; thus, these units are not discussed in this report. Further, the middle confining unit of Miller (1986) functions as and is termed the lower confining unit of the Upper Floridan aquifer. Accordingly, only late-middle Eocene-to-Holocene geologic units (fig. 4) define the hydrologic setting for groundwater and surface-water exchange in the basin.

The mostly carbonate middle-to-late Eocene Ocala Limestone and late Oligocene Suwannee Limestone (fig. 4) form a single, vertically continuous, permeable layer in the Upper Floridan aquifer in updip parts of the ASO River Basin toward the northwestern boundary. The Ocala Limestone consists of an upper part containing white, soft, friable porous coquina, large forams, bryozoan fragments, and echinoid remains in a micritic limestone matrix. A lower part contains cream-to-white, fine, soft to semi-indurated micritic limestone with miliolid remains and scattered forams, and glauconite locally. To the east of the Flint River in Dooly and Crisp Counties, the Suwannee Limestone weathered into the Flint River residuum (fig. 11) or Flint River Formation, "making a porous permeable unit that favors recharge" (Vorhis, 1972).

In the southwestern part of the basin near Cairo, Grady County, Ga., nearly 400 ft of middle Oligocene sediments separate the Suwannee and Ocala Limestones. These sediments consist of the stratigraphically equivalent Marianna Limestone and Byram Formation, which were known previously to exist only in Florida. Formerly considered part of the late Eocene Ocala Limestone (Sever and Herrick, 1967), sediments of the Marianna Limestone and Byram Formation have been included in the Suwannee Limestone (Davis, 1996a). The Byram Formation consists predominantly of yellowish-brown, dense, clayey, finely crystalline dolomite and is similar to the Byram Formation described by Puri and Vernon (1964) at an outcrop in Jackson County, Fla. (Sever and Herrick, 1967). The Marianna Limestone consists of interbedded pale orange to cream, soft, granular, fossiliferous limestone, cream fossiliferous marl, and thin beds of pale-grown dolomite and dolomitic limestone. Foraminiferal evidence correlates part of the nearly 500 ft of middle Oligocene sediments penetrated in a test well at Cairo, Ga., with the Marianna Limestone of Florida, as well as with part of a 635-ft section of sediments from a well in Coffee County, Ga. (Sever and Herrick, 1967). The northeastward trend of these sediments from Grady to Coffee Counties coincides with the location of the Gulf Trough–Apalachicola Embayment (fig. 6), inferring continuous separation of the Suwannee and Ocala Limestones by geologic units of similar lithology as the Byram Formation and Marianna Limestone in a southwest-to-northeast corridor.

The Suwannee Limestone consists of hard to soft, yellowish-gray, calcitized, crystalline fossiliferous limestone in the western part of the study area near Cairo, Grady County, Ga. (Sever and Herrick, 1967). In southwestern Georgia, along the Solution Escarpment, and in the eastern panhandle of Florida, the Suwannee Limestone consists of cream to tan, crystalline, vuggy limestone with gastropod and pelecypod casts and molds. Another facies contains white to cream, finely pelletal limestone with small foraminifers, pellets of micrite bound by a micritic to finely crystalline limestone matrix. Fine sand in cast and mold facies is present locally. The micritic pelletal facies contains trace amounts of fine to medium, light to dark-brown phosphate (Miller, 1986). South and west of the Solution Escarpment, and in Florida, dolomitic, silty, and sandy limestone layers of early-to-middle Miocene Tampa Limestone and Chattahoochee and St. Marks Formations (fig. 4) represent permeable zones that contribute locally to aquifer thickness; although clastic sediments mostly compose Miocene and younger units (Miller, 1986). A transition zone near south-central Gadsden County, Fla., separates the calcareous downdip (southeastward) facies of the Tampa Limestone, termed the St. Marks Formation (Puri, 1953; Rupert, 1990), from the clastic updip (northwestward) facies, termed the Chattahoochee Formation (Puri and Vernon, 1964; Rupert, 1990; Scott, 1986, 1992). Stratigraphically, the Chattahoochee Formation grades upward into the siliciclastic and clayey middle-to-late Miocene Hawthorn Group–Torreya Formation in Florida (Rupert, 1990) and the basal part of the Hawthorn Group in Georgia (Huddlestun, 1988).

Middle-to-late Miocene deposits termed the Torreya Formation (Banks and Hunter, 1973) in the eastern panhandle of Florida, and the Hawthorn Group (Huddlestun, 1988) in Georgia and in the remaining parts of the study area in Florida (fig. 4), contain very fine-to-medium, clayey sand, silty clay, limestone, dolomite, and phosphate grains. Beyond the study area, to the west of the Apalachicola River in Florida, Hawthorn Group sediments transition to a thinly bedded, fine-to-coarse clastic, shelly sequence termed the Alum Bluff Group (Miller, 1986). In Georgia, the Alum Bluff Group was identified by previous investigators in Colquitt County (Zimmerman, 1977) (fig. 8) and Thomas County (Sever, 1966) (fig. 9); however, Sever (1965) described equivalent geologic units of the Alum Bluff Group as the “Hawthorne Formation.” Hawthorn Group sediments range in thickness from a feather-edge in northwestern Colquitt County to about 300 ft in or near the Gulf Trough–Apalachicola Embayment (Zimmerman, 1977). The “Hawthorne Formation” thickens to 500 ft in Ware County, where very sticky, cohesive, greenish-blue clay in the upper part of the formation confines sandy and phosphatic dolomite and limestone of the middle and lower parts, in addition to confining the underlying Upper Floridan aquifer (Matthews and Krause, 1984).

Carbonate sediments of the Hawthorn Group-Torreya Formation (fig. 4) consist of clayey limestone or dolomitic limestone, which grade downward to a predominantly limestone base in the western part of the study area in Gadsden County, Fla. Fossiliferous and phosphatic sand and fuller’s earth (palygorskite) clay, montmorillonite, and kaolin clay interfinger with limestone and dolomite (Rupert, 1990). Dense, crystalline, dolomitic limestone, and limonitic and phosphatic clay interbedded with limestone characterize the Hawthorn Group in south-central Georgia near Adel, Ga. (Herrick, 1961). Sever (1966) divided the Hawthorn-equivalent Alum Bluff Group into three mappable zones: a sandy marl lower zone, a sandy limestone middle zone, and a fuller’s earth clay upper zone that is mined commercially in the Gulf Trough–Apalachicola Embayment region. Clastic sediments in the “Hawthorne Formation” may contain minor surficial and intermediate aquifers; however, the clastic sediments primarily function as confining units, restricting local recharge to the Upper Floridan aquifer (Pratt and others, 1996).

The Pliocene Jackson Bluff Formation (fig. 4) crops out to the west of the study area in Gadsden County, Fla., and consists of three clayey, sandy shell beds (Schmidt, 1984; Puri and Vernon, 1964). The Jackson Bluff Formation overlies either the Tampa Limestone or the Hawthorn Group–Torreya Formation, depending on the presence of each unit, and functions as a semiconfining unit, impeding vertical movement of water into and out of deeper water-bearing units (Torak and McDowell, 1996).

The Citronelle Formation exists only in the southwestern part of the ASO River Basin and consists of late Pliocene, orange to red, clayey, medium to coarse, quartz sand containing clay lenses and beds of friable quartz pebbles. About 90 ft of Pliocene gravel and coarse sand termed the Citronelle Formation overlies Hawthorn-equivalent sediments of the Alum Bluff Group in northwestern Thomas County (fig. 9). In the absence of Holocene and Pleistocene deposits, sediments of the Citronelle Formation exist at land surface, capping many of the hills in Gadsden County, Fla. In Decatur, Grady, and Seminole Counties, Ga., Sever (1965) described a Citronelle-equivalent, unnamed red clayey sand and gravel containing hematite concretions, and in Thomas County, Sever (1966) described the Citronelle Formation as cross-bedded, yellow to red gravel, sand, and clay. Thickness varies from about 20 to 100 ft; although the original thickness is uncertain because of removal by erosion throughout much of its areal extent. Zimmerman (1977) noted small isolated patches of the Citronelle Formation in Colquitt County, Ga. To the east, the reddish siliciclastic sediments are lithologically similar to the late Pliocene Miccosukee Formation (Rupert, 1990) (fig. 4). Clay lenses in the Citronelle Formation impede groundwater recharge from precipitation and limit vertical leakage to the underlying Hawthorn Group and Upper Floridan aquifer.

The Miccosukee Formation contains interbedded clay, silt, sand, and gravel, similar in overall lithology to the Citronelle Formation, except that the Miccosukee contains less gravel and more fine-to-medium clayey sand than the Citronelle (Rupert, 1990). Sediments of the Miccosukee Formation extend eastward from Gadsden County, Fla., and northeastward into Georgia, pinching out in the south-central part of the study area in eastern Madison County, Fla. (Rupert, 1990). The Miccosukee Formation caps topographically high areas on the Tifton Upland and lies unconformably on the Miocene Hawthorn Group–Torreya Formation. The Red Hills region of the Ochlockonee and Aucilla River Basins most likely owes its name to the distinct reddish color of siliciclastic sediments of the Miccosukee and Citronelle Formations, which contribute to the sediment load of those streams giving them a distinct yellow color. The predominantly clayey quartz sand and sandy clay identified in exposures and core of the Miccosukee Formation can impede groundwater recharge to the underlying Hawthorn Group and Upper Floridan aquifer; although locally sandy zones can yield groundwater to domestic wells.

Pleistocene and Holocene undifferentiated sand and clay mantle most of the surface of the study area forming the uppermost water-bearing zones of the surficial aquifer system (fig. 4). Marine-terrace deposits consisting of Pleistocene undifferentiated quartz sand and clay lie unconformably on the Citronelle, Miccosukee, Torreya, or Chattahoochee Formations in the western part of the study area in Florida. Holocene alluvial deposits thinly blanket stream valleys and commonly are indistinguishable from Pleistocene sediments (Rupert, 1990).

Hydrologic Setting

Groundwater flow and exchange with surface water in the ASO River Basin occur within a hydraulically connected sequence of middle Eocene to Holocene sediments grouped according to similarities in hydraulic properties to form geohydrologic units termed the surficial aquifer system, upper semiconfining unit, Upper Floridan aquifer, and lower confining unit (fig. 4). Differences in hydraulic characteristics within and among geologic units form geohydrologic-unit boundaries that transcend time-stratigraphic and paleontological divisions. Geohydrologic units define the hydrogeologic framework for conceptualizing groundwater and surface-water exchange in the basin (fig. 13).

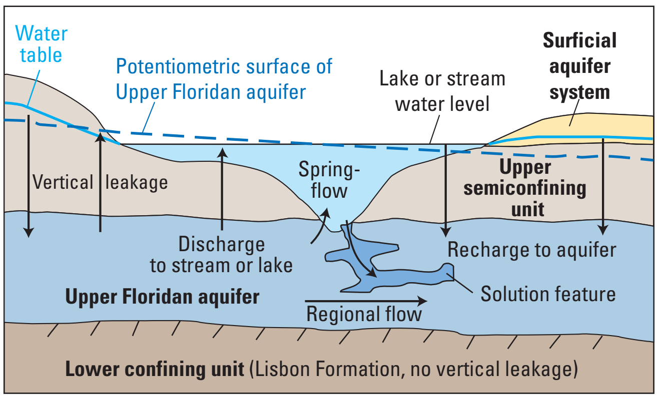


Figure 13. Conceptual diagram of groundwater and surface-water flow in the interconnected stream-lake-aquifer flow system of the Aucilla–Suwannee–Ochlockonee River Basin (modified from Torak and Painter (2006).

The uppermost water-bearing zone to provide groundwater and surface-water exchange in the ASO River Basin consists of late Miocene-to-Holocene sediments termed the surficial aquifer system by the Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition (Florida Geological Survey, 1986) and by Miller (1990) (fig. 13). The surficial aquifer system covers the study area except where erosion exposes geologic units of the upper semiconfining unit or Upper Floridan aquifer (fig. 14). Sediments of the surficial aquifer system represent “the permeable hydrogeologic unit contiguous with land surface that is comprised principally of unconsolidated to poorly indurated clastic deposits” (Florida Geological Survey, 1986), although the surficial aquifer system contains gravel, sandy limestone, limestone, clay, and silt in places (Miller, 1986). Complex interbedding of fine- and coarse-textured sediments characterizes the system (Miller, 1990).

Groundwater and surface-water exchange in the surficial aquifer system occurs where aquifer material directly contacts surface-water features, such as in stream valleys or flood plains or in the bottom of sinkhole ponds or lakes (fig. 13). The relative positions of the water table in the surficial aquifer system and the surface-water level determine the potential for recharge to the surficial aquifer system from surface-water or for groundwater discharge to surface water from the surficial aquifer system.

The surficial aquifer system interacts hydraulically with the Upper Floridan aquifer through direct contact, in the absence of the upper semiconfining unit, or indirectly by vertical leakage through a thin upper semiconfining unit (fig. 13). Miller (1986) noted the occurrence of a “surface veneer” of post-Miocene sediments, generally 10–50-ft thick, overlying the Upper Floridan aquifer within most of the ASO River Basin. Erosion of Oligocene-to-middle-Miocene sediment associated with the Ocala Uplift near Lake City, Fla. (fig. 14), caused the surficial aquifer to contact the Upper Floridan aquifer, providing a mechanism for direct recharge of the Upper Floridan aquifer by infiltrating precipitation and vertical leakage. Erosion of Pliocene-to-Miocene geologic units and deposition of Holocene-to-Pleistocene undifferentiated sediments places the surficial aquifer system in contact with the Upper Floridan aquifer in southeastern Thomas County, Ga. (Sever, 1966). In extreme northwestern Colquitt County, Ga., erosion to a featheredge of outcropping Hawthorn Group-equivalent sediments of the Alum Bluff Group provides nearly direct contact of isolated remnants of the Pliocene Citronelle Formation with the Upper Floridan aquifer. These permeable clastic sediments function hydrologically the same as the upper part of the Alum Bluff in northwestern Colquitt County, Ga. (Zimmerman, 1977).

Indirect interaction of the surficial aquifer with the Upper Floridan aquifer occurs in Brooks, western Echols, and Lowndes Counties, Ga., where vertical leakage from overlying clastic sediment of the surficial aquifer to the underlying Upper Floridan aquifer occurs through clay confining layers (Krause, 1979). Interior drainage through deep sands of the surficial aquifer system in Columbia and Suwannee Counties, Fla., enhances recharge to the overlying Upper Floridan aquifer (Raulston and others, 1998). Less than 50 ft of post-Oligocene sediment composing the surficial aquifer system and upper semiconfining unit occur in contact with the Upper Floridan aquifer along the lower half of the Withlacoochee River in Brooks and Lowndes Counties, Ga. (fig. 14). The condition of a relatively thin surficial aquifer system in direct contact with the Upper Floridan aquifer extends into Florida along the flood plains of the Alapaha, Aucilla, Suwannee, and Withlacoochee Rivers, enhancing recharge-discharge relations.

Potentially high recharge to the Upper Floridan aquifer by vertical leakage from the surficial aquifer system exists where a relatively thin (less than 50 ft) upper semiconfining unit separates the two aquifers (fig. 15), and where the water table in the surficial aquifer system lies above the potentiometric surface of the Upper Floridan aquifer. Subtracting estimates for the altitude of the top of the Upper Floridan aquifer (fig. 16) from the USGS National Elevation Dataset digital-elevation model of land surface (U.S. Geological Survey, 2008) yielded a distribution of the combined thickness of the surficial aquifer system and upper semiconfining unit,

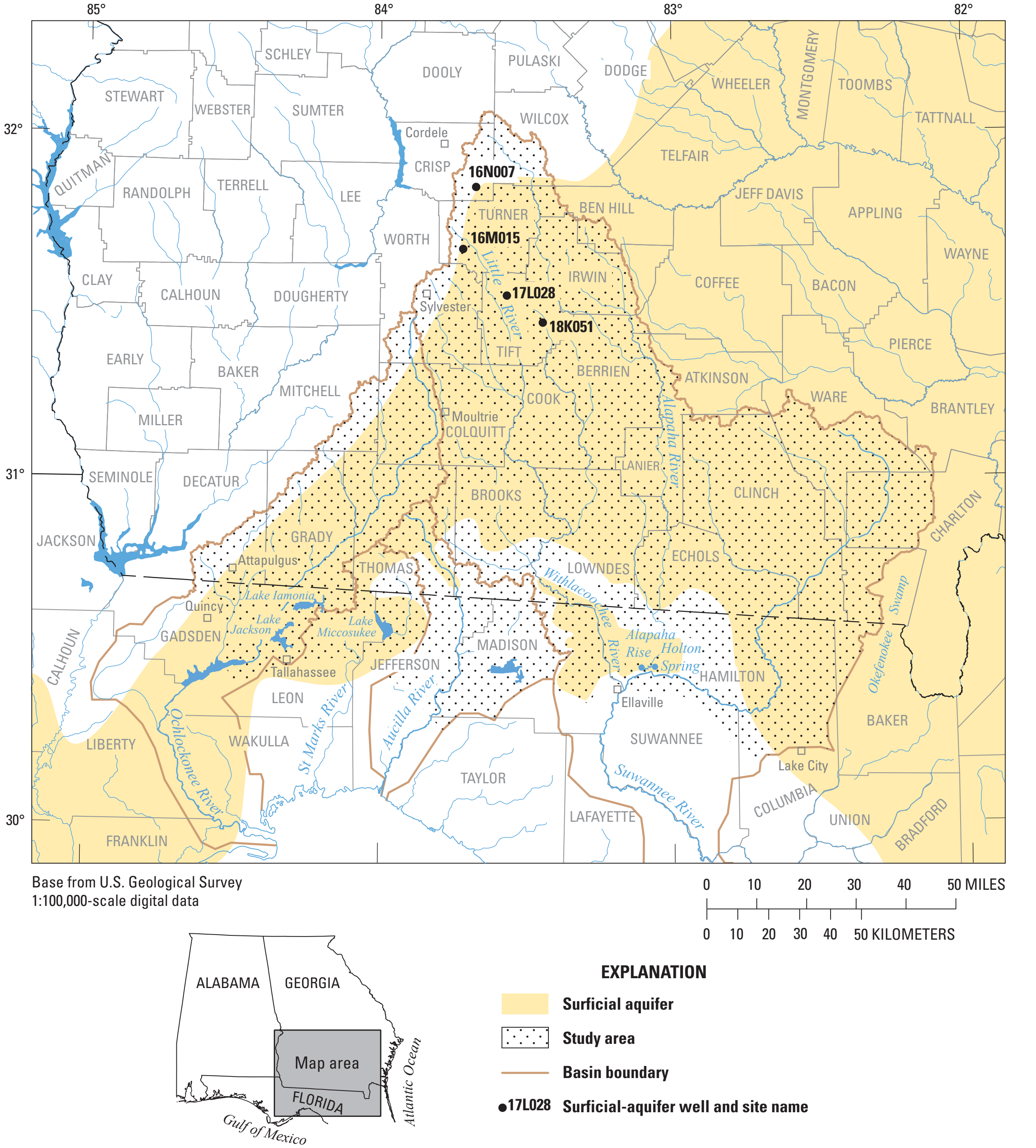
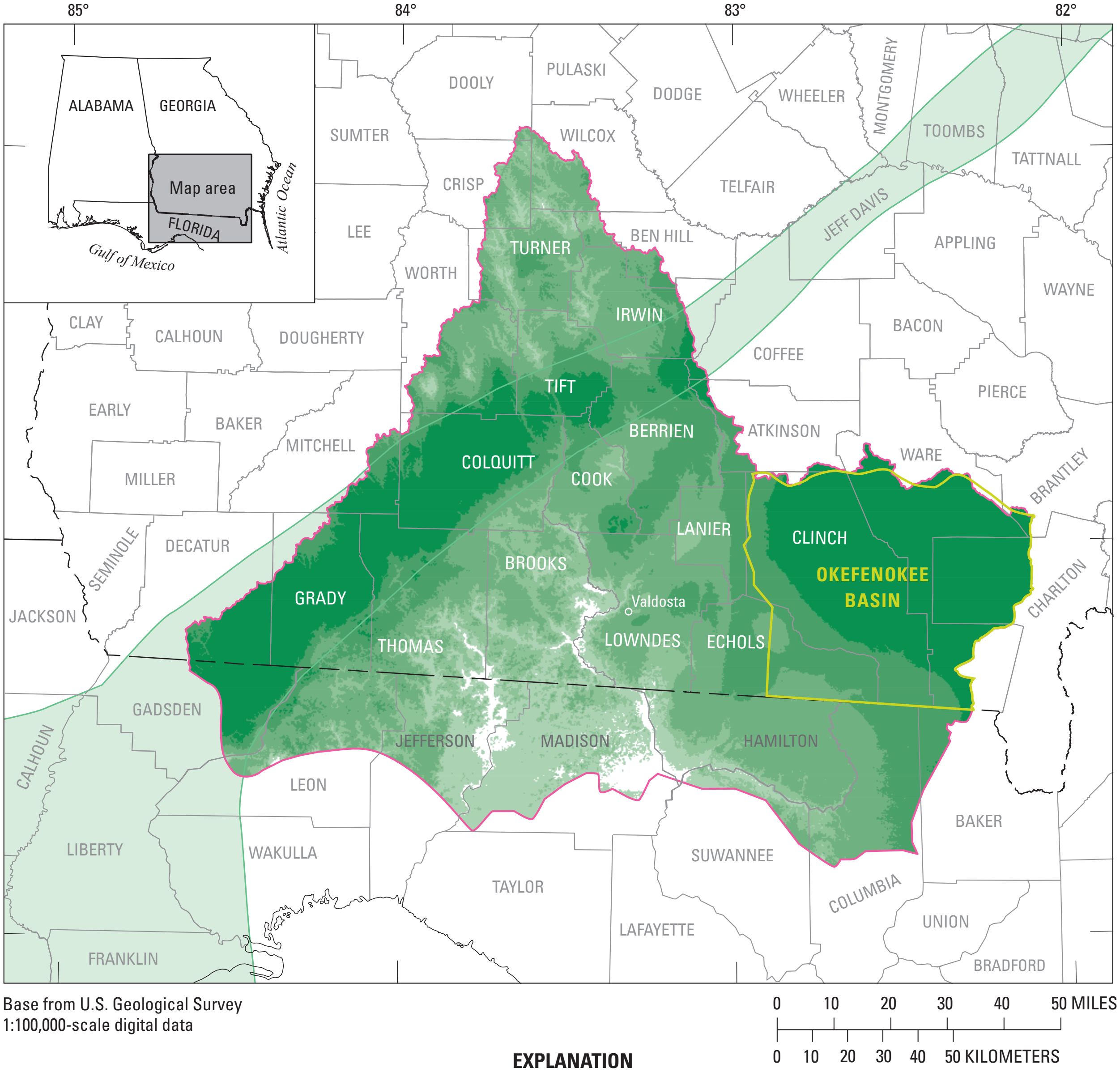


Figure 14. Areal extent of surficial aquifer system in the Aucilla–Suwannee–Ochlockonee River Basin (modified from Sever, 1966; Krause, 1979; Miller, 1990; and Raulston and others, 1998).



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

EXPLANATION

Overburden thickness, in feet*	Potential	
	Vertical leakage	Water exchange
Absent	N/A	High
Less than 50	High	High
50 to 100	Moderate	Moderate
100 to 200	Low	Low
200 to 300	Extremely low	Extremely low
Greater than 300	None	None

*Contains up to 50 feet of surficial aquifer system overlying upper semiconfining unit

N/A—Not applicable; direct recharge to Upper Floridan aquifer

None—No vertical leakage or water exchange

Approximate location of Gulf Trough–Apalachicola Embayment

Study area boundary

Figure 15. Overburden thickness and leakage potential of the upper semiconfining unit in the Aucilla–Suwannee–Ochlockonee River Basin.

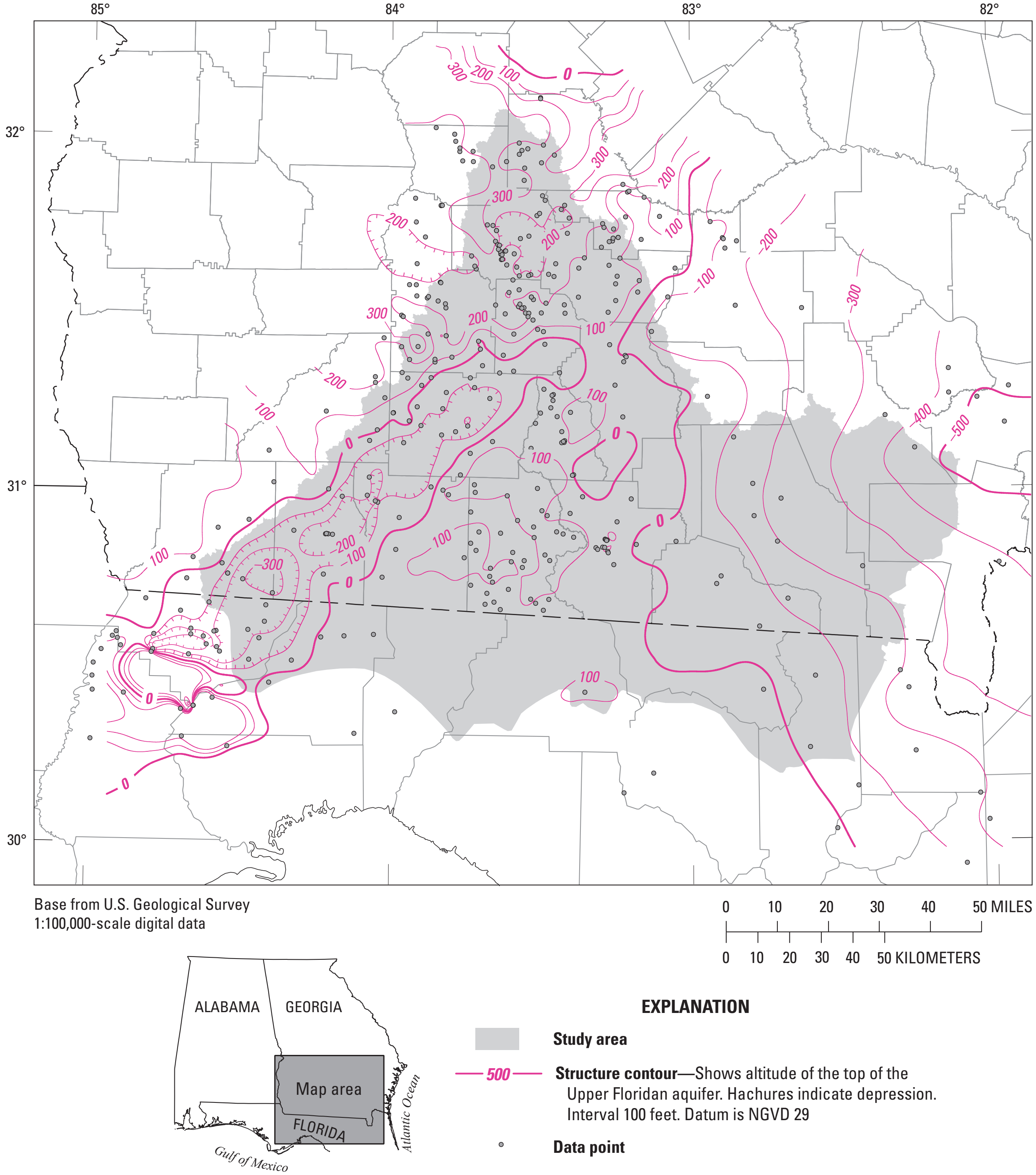


Figure 16. Altitude of the top of the Upper Floridian aquifer in the Aucilla–Suwannee–Ochlockonee River Basin.

termed "overburden." Differentiation of constituent thickness of the surficial aquifer system and upper-semiconfining-unit within the overburden was not possible from the geohydrologic data (Appendix); therefore, overburden thickness of less than 50 ft can consist entirely of sediments constituting either the surficial aquifer system or upper semiconfining unit, as noted by Miller (1990). Overburden thickness of 50–100 ft can contain up to 50 ft of surficial aquifer system sediments; these areas warranted classification as a moderate potential for recharge by vertical leakage. Areas of low leakage and recharge potential exist where overburden thickness of 100–200 ft occurs; extremely low leakage and recharge potential exists where overburden thickness of 200–300 ft occurs. No potential for leakage or recharge exists where more than 300 ft of overburden thickness occurs.

The potential exists for the surficial aquifer system to receive upward vertical leakage of groundwater from the Upper Floridan aquifer in areas where the potentiometric surface of the aquifer lies above the water table in the surficial aquifer system. In some areas, however, extensive thickness of the upper semiconfining unit and low-permeability clay and other clastic sediments limit vertical leakage between the surficial aquifer system and Upper Floridan aquifer (fig. 15).

The surficial aquifer system generally does not yield much water (Miller, 1990), although groundwater occurs under mostly unconfined conditions. The thin and discontinuous distribution of the surficial aquifer system yields sufficient amounts of water for domestic and small-farm supply from dug, jetted, or shallow drilled wells (Krause, 1979). Surficial aquifer system sediments of the Alum Bluff Group in Colquitt County, Ga., are considered unreliable because these sediments only receive recharge from precipitation (Zimmerman, 1977).

The upper semiconfining unit consists of a thick sequence of low-permeability clastic and carbonate rocks that hydraulically separate the overlying surficial aquifer system from the underlying Upper Floridan aquifer (fig. 13). Depending on hydraulic characteristics and occurrence, terrace and undifferentiated (surficial) deposits and the Citronelle, Miccosukee, and Jackson Bluff Formations constitute part of the upper semiconfining unit. Thin permeable zones in the Miccosukee Formation supply water for domestic needs in northeastern Lowndes County, Ga. (McConnell and Hacke, 1993); however, the predominantly clayey lithology and potential thickness of 100–200 ft for the Miccosukee and other Pliocene formations impede recharge of groundwater by precipitation and vertical leakage (fig. 15). The dense, clayey, dolomitic, and phosphatic lithology of the Hawthorn Group–Torreya Formation and thickness of more than 100 ft combine with low-permeability layers in overlying geologic units to provide an effective barrier preventing recharge of groundwater to the Upper Floridan aquifer by vertical leakage from the surficial aquifer system or by infiltration of precipitation directly onto and through the upper semiconfining unit. Erosion and carbonate dissolution, however, removes this upper semiconfining unit and exposes the Upper Floridan aquifer to karstification near Valdosta, Ga., and along the Florida–Georgia State line, promoting recharge through karst features situated at or near land surface.

Hydrologic conditions of the Upper Floridan aquifer vary from semiconfined to unconfined and hydraulic connection with surface water equally varies depending on location in the ASO River Basin. The aquifer transitions from unconfined conditions in the southern part of the study area to semiconfined conditions to the north in karst areas along the Florida–Georgia State line in Brooks and Lowndes Counties. Unconfined conditions also occur in southern Colquitt and northeastern Thomas Counties, where uplift along the flanks of the Peninsular Arch (fig. 5) and smaller structural features provided sufficient relief for late Eocene rocks and younger to be stripped away by erosion (Miller, 1986), subjecting the Suwannee and Ocala Limestones to dissolution. The Cody Scarp, located along the southern boundary of the study area (fig. 3), denotes an area of active limestone dissolution where erosion also removed overlying geologic units, exposing the Upper Floridan aquifer at or near land surface. In these karst areas, limestone dissolution increases aquifer transmissivity through the formation of solution cavities and conduit-flow conditions (fig. 13) and also increases the hydraulic connection of the aquifer with surface water.

Exposure of the Upper Floridan aquifer at land surface causes the most dynamic interaction of groundwater and surface-water exchange in the ASO River Basin. Mature karst features such as springs, steep-sided sinkholes, disappearing streams, lakes that periodically drain downward, and resurgences of disappearing streams characterize the Upper Floridan aquifer along the Cody Scarp (Raulston and others, 1998). Major rivers, such as the Withlacoochee, Alapaha, and Suwannee Rivers, flow over limestone that crops out in streambeds and freely exchange surface water and groundwater depending on the relative water levels of the aquifer and streams.

North of the Cody Scarp and karst areas in southern Georgia, thick clastic sediments of the upper semiconfining unit overlie and separate the Upper Floridan aquifer (fig. 13) from karst processes, groundwater and surface-water exchange, and recharge by infiltration of precipitation. Limited karstification in this area causes a precipitous decrease in aquifer transmissivity (Miller, 1986) and groundwater exchange with surface water. To the north of karst areas in Brooks and Lowndes Counties, upper semiconfining unit thickness in excess of 100 ft decreases aquifer recharge by infiltration of precipitation and by vertical leakage from recharge received by direct infiltration of precipitation and surface-water leakage from streams (fig. 15).

In the northern part of the ASO River Basin, along the boundary with the ACF River Basin, recharge to the Upper Floridan aquifer occurs where the Suwannee Limestone weathered into the Flint River residuum (fig. 11). This residuum, termed the Flint River Formation by Vorhis (1972), facilitates recharge to the Upper Floridan aquifer in a limited area in Dooly and Crisp Counties along the boundary of both basins east of the Flint River (fig. 1).

Lithostratigraphic separation of the Upper and Lower Floridan aquifers by geologic units constituting the lower confining unit, that is, the Avon Park, Lisbon, and Tallahatta Formations (figs. 4; 12), creates an effective hydraulic barrier to groundwater flow that isolates permeable zones underlying the lower confining unit from above-lying units and restricts groundwater flow (Leve, 1968). In the northern, western, and north-central parts of the study area, the Avon Park Formation contains micritic, low permeability limestone that grades into a clayey, micritic, glauconitic limestone. This lithology, in turn, grades into calcareous, glauconitic, commonly shelly sand and clay beds of the Lisbon and Tallahatta Formations (Miller, 1986). The micritic limestone and gypsiferous carbonate beds constitute important subregional confining beds within the Floridan aquifer system (Miller, 1986), and represent an impermeable base to the Upper Floridan aquifer. Near Valdosta, Ga., low-permeability rocks of the lower confining unit coalesce with deeper clastic sediments to form a confining unit of more than 200 ft in thickness. The lower confining unit yields only small amounts of water to wells and contains high sulfide concentrations—attesting to the confining and hydraulic isolation of this unit from deep formations containing mineralized water—therefore, it functions as the lower boundary to groundwater flow and surface-water exchange in the ASO River Basin (fig. 13).

Hydrochemistry

Limestone, dolomite, and gypsum composing the Upper Floridan aquifer supply groundwater with ions derived from dissolution of calcium carbonate, magnesium carbonate, and calcium sulfate, respectively (Torak and others, 2006). Glauconite and pyrite contained in the residuum and Upper Floridan aquifer contribute potassium, iron, silica, and sulfate ions to the chemical composition of groundwater through dissolution (Sever, 1965). Clastic Miocene and younger sediments weathered from crystalline host rocks of the Piedmont contain uranium and radioactive minerals such as monazite, a cerium-lanthanum thorium-neodymium-yttrium phosphate (Kellam and Gorday, 1990; Mineral Gallery, 2008). Groundwater derived from Miocene sediments contains the highest natural radioactivity in the Gulf Trough–Apalachicola Embayment area, specifically in Tift and Berrien Counties, Ga. (Kellam and Gorday, 1990).

The general chemical composition of groundwater in the Upper Floridan aquifer is a calcium-magnesium-bicarbonate type; however, local recharge mechanisms and lithologic variations in the geohydrologic units alter the water chemistry. Hard, calcium-magnesium-bicarbonate-type water exists near the western boundary of the ASO River Basin. In the Tifton Upland, very hard water containing sulfate occurs in some places. High iron concentration exists in a 100-mi^2 region that trends roughly parallel with the Solution Escarpment and Flint River, southeast of Bainbridge, Ga. (fig. 3) (Sever, 1965, fig. 2). Inferior-quality water once thought to occur in the Ocala Limestone in Grady County, Ga., actually occurs in the overlying Byram Formation and consists of extremely hard water having high concentrations of sulfate, iron, fluoride, and dissolved solids (Sever and Herrick, 1967). Water in geologic units underlying the Upper Floridan aquifer in the western part of the study area emits a moderate hydrogen-sulfide odor because of pyrite and gypsum contained in these rocks, and probably contains high sodium and chloride concentrations as well as high concentrations of iron and sulfur (Sever, 1965).

Unstable decay of several radioactive isotopes, or daughter products, of uranium-238 cause elevated gamma-ray activity in the ASO River Basin that can help identify subsurface zones of high radiation emission. High-radioactive zones are represented as peaks, kicks, or points on natural-gamma geophysical logs (Wait, 1960). Laboratory results indicate that radium-226 is the dominant alpha emitter in the Gulf Trough–Apalachicola Embayment area, and that radium-228 activity is negligible (Kellam and Gorday, 1990). Radon-222 exists naturally in virtually all soil and rock as a decay product of radium-226, the fifth daughter in the decay of uranium-238 (Torak and others, 2006). As radon-222 forms, some atoms leave the soil or rock and enter the surrounding air or water (Samet and Nero, 1989).

Highly phosphatic sediment in the Hawthorn Group and phosphatic sandy Oligocene limestone and dolomite from coastal areas of Georgia are proportionately more radioactive than other local geologic units, indicating that they are a source of radon to groundwater (Torak and others, 2006). Not all wells in the Gulf Trough–Apalachicola Embayment area contain high levels of radioactivity, or gross alpha activity. Highest levels of radioactivity occur near Tifton, Tift County, and near Alapaha, Berrien County, Ga. (fig. 12). Here, municipal wells tapping Oligocene carbonates of the Upper Floridan aquifer produced higher-than-normal amounts of radioactivity. One well, City of Tifton municipal well 5, was removed from production because of high radioactivity levels. Wells containing high gross alpha activity in Tift and Berrien Counties seem to be associated with the low altitude of the top of the Upper Floridan aquifer, which contains high relief in this area (Kellam and Gorday, 1990). The structural lows in the top of the aquifer at these locations probably result from erosion or dissolution, which created a favorable environment for deposition of post-Oligocene, radioactive, phosphatic clastic sediments.

Organic material mixed with surface water enters the Upper Floridan aquifer by direct recharge in karst areas of the ASO River Basin, altering the natural water chemistry of groundwater. In the Valdosta, Ga., area, large quantities of organic material from the Withlacoochee River enter the aquifer through a sinkhole area that has been formed in the streambed, providing a source of soluble organic carbon to groundwater. About 2.6 tons of total organic carbon (TOC) was estimated to enter the Upper Floridan aquifer daily through sinkholes in the streambed from 1972 to 1989 (McConnell and Hacke, 1993). Increased concentrations of TOC, chloride, total sulfide, and methane in wells located downgradient from the sinkhole area in the Withlacoochee River, compared with lower concentrations in upgradient wells, indicate that mixing of organic-rich river water catalyzes the growth of microbiota in the aquifer, which in turn produces methane and hydrogen sulfide. Humic substances associated with organic material in the water can form trihalomethane during chlorination of groundwater for drinking-water supplies.

Water samples collected from the Little and Withlacoochee Rivers (fig. 1) and from wells completed in the surficial aquifer adjacent to agricultural fields in the ASO River Basin contained herbicide-degradation compounds derived from land application of the herbicides metolachlor and alachlor, indicating an active flow system consisting of groundwater and surface-water exchange (Pittman and Berndt, 2003). While streams contained mostly degradation compounds of metolachlor and alachlor, some groundwater samples contained the parent compound metolachlor; however, no groundwater samples contained alachlor. Concentrations of metolachlor in groundwater did not exceed 0.13 microgram per liter (µg/L), although its degradation products, metolachlor ethane sulfonic acid and metolachlor oxanilic acid, attained maximum concentrations of 19 µg/L and 0.13 µg/L, respectively.

The lower confining unit yields small amounts of water containing a high sulfate concentration, which results from dissolution of gypsum (Sprinkle, 1989). Underlying units to the lower confining unit contain slow-moving, poor-quality water (Miller, 1986).

Hydrologic Characteristics

Variations in physical properties of geologic units composing the surficial aquifer system, upper semiconfining unit, Upper Floridan aquifer, and lower confining unit determine the degree of hydraulic connection among these units and control groundwater and surface-water exchange in the ASO River Basin. Areal and vertical distribution of physical properties within geohydrologic units define heterogeneities in hydrologic characteristics that improve current understanding of the relative contribution of each unit to groundwater and surface-water exchange and that refine the hydrogeologic framework and conceptual model of groundwater flow and water exchange in the basin.

Surficial Aquifer System

Hydraulic properties and groundwater level control the exchange of groundwater in the surficial aquifer system with surface water and determine the potential for vertical leakage to and from the Upper Floridan aquifer (fig. 13). Variations in thickness and areal extent determine the resource potential of the surficial aquifer system (figs. 14 and 15)

Hydraulic Properties

The surficial aquifer system blankets most of the ASO River Basin with a thin veneer of late Miocene-to-Holocene sediments typically less than 50-ft thick (Miller, 1990) (fig. 15). Thickness of the surficial aquifer system in the southwestern part of the study area in Florida generally ranges from 30 to 50 ft (Moore, 1955; Scott, 1992). In southeastern Georgia, thickness of about 60 ft has been mapped (Miller, 1990).

Transmissivity of the surficial aquifer system in the study area ranges from 1,000 to 10,000 feet squared per day (ft^2/d) (Miller, 1990). Miller (1990) attributed large transmissivity values to beds of shell and limestone that constitute the surficial aquifer system in eastern and southern peninsular Florida beyond the study area.

Wells completed in the surficial aquifer system generally yield less than 50 gallons per minute (gal/min) in the study area (Miller, 1990). The surficial aquifer system in the Florida part of the study area yields only small amounts of water when pumped and generally is not used (Davis, 1996a). The surficial aquifer system in Colquitt County, Ga., generally extends less than 50 ft below land surface and supplies small amounts of water for domestic and stock use (Zimmerman, 1977). In Thomas County, Ga., one well drilled in a Miocene phosphatic sandy limestone constituting the surficial aquifer system yielded a maximum of 6 gal/min of moderately hard, good-quality water. Dug wells in Miocene sand beds produced corrosive water containing excessive dissolved iron (Sever, 1966). Holocene flood plain deposits up to 40-ft thick contain water-sorted sand and gravel that could supply domestic or light industrial needs; however, swampy conditions and the potential for flooding render these deposits untested as a water resource (Zimmerman, 1977).

Hawthorn-equivalent sediment constituting the surficial aquifer system in Cook County contains as much as 85 ft of medium to very coarse phosphatic sand. Wells installed in this sediment produce moderate amounts of corrosive water that contain excessive dissolved iron suitable for domestic, irrigation, and industrial uses (Sever, 1972). Dug and bored wells completed in Pleistocene-to-Holocene alluvial deposits provide moderate amounts of water from quartz sand and gravel up to 30-ft thick.

Groundwater Levels and Fluctuations

Groundwater levels measured synchronously with stream-stage altitudes during September 2006 agree favorably and depict a potentiometric surface having a strong surface-water influence as well as topographic control (fig. 17). The similarities in groundwater levels and stream stages indicate hydraulic connection and water exchange between the surficial aquifer system and surface water. The water table in the surficial aquifer system parallels topography in a subdued manner and generally lies within 10 ft of land surface (Planert, 2007). Steep gradients occur between streams and ridges or hills; gentle gradients exist in broad, flat interstream areas and under broad topographic highs. Groundwater that enters the system as precipitation moves quickly along short flowpaths perpendicular to potentiometric contours and discharges to streams as baseflow (Miller, 1990). Hydraulic gradients and groundwater-flow directions change within short distances in the surficial aquifer system.

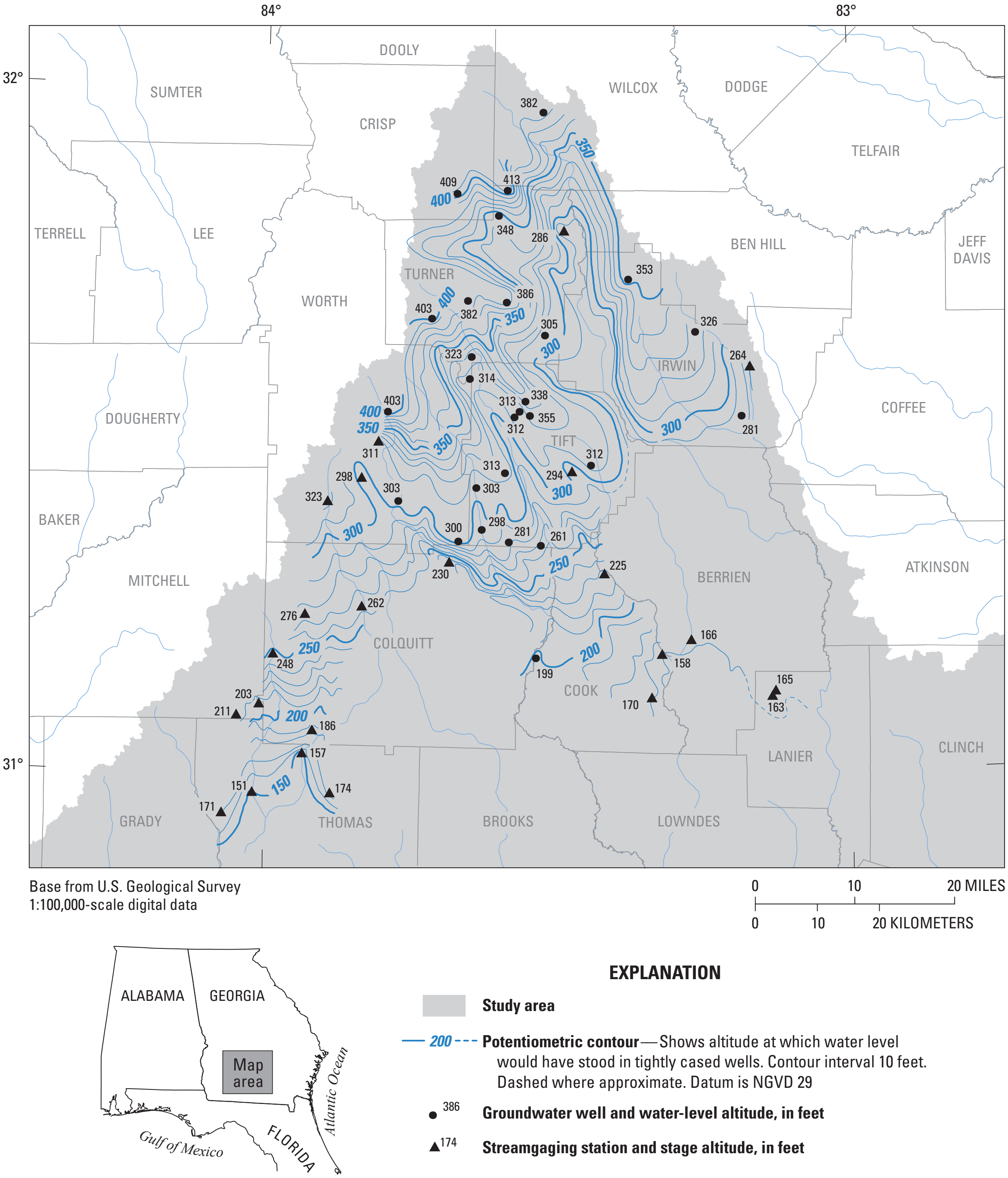


Figure 17. Potentiometric surface of the surficial aquifer system in the Aucilla–Suwannee–Ochlockonee River Basin, September 2006.

Periodic groundwater-level measurements in four wells indicate that the water table in the surficial aquifer system responds seasonally to precipitation and changes in evapotranspiration rates (fig. 18). High groundwater levels occur during late fall through early spring, when frequent precipitation from long-duration, low-intensity storms associated with frontal passages promotes infiltration. Sparse vegetation from minimal crop activity and leaf fall gives rise to low evapotranspiration rates during this time, allowing groundwater levels to recover (recharge) from the spring and summer growing season. During mid-spring through mid-fall, high evapotranspiration rates from crop vegetation and trees combine with high runoff and low infiltration of precipitation to cause seasonal groundwater-level decline. The limited number of water-level measurements at the four wells demonstrated the severity of dry climatic conditions during 2006 and 2007 by recording unprecedented low groundwater levels in the surficial aquifer system.

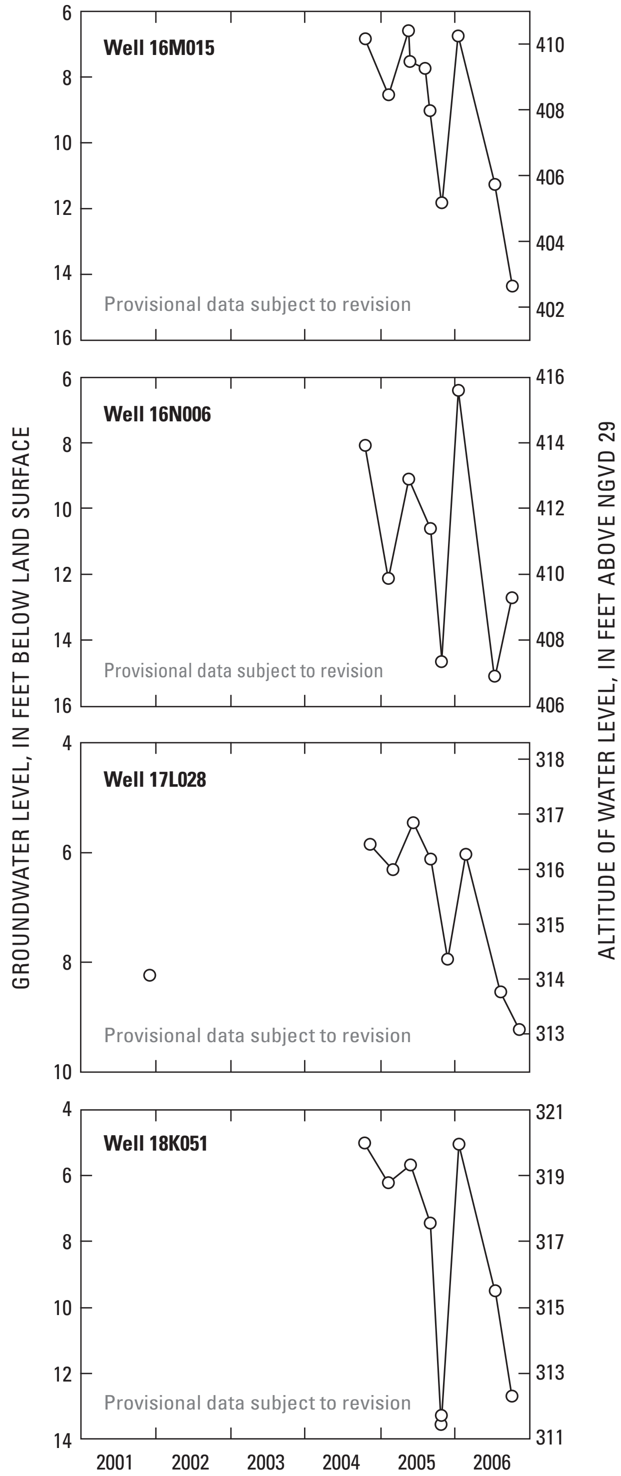


Figure 18. Groundwater hydrographs of wells 16M015, 16N006, 17L028, and 18K051, completed in the surficial aquifer system, for the period 2001–2007.

Upper Semiconfining Unit

The thickness of low-permeability clay and clastic sediments constituting the upper semiconfining unit creates a hydraulic barrier to groundwater that limits recharge to the Upper Floridan aquifer by downward vertical leakage from the surficial aquifer system (fig. 15). A low vertical-leakage potential exists where thick sequences (100–200 ft) of sediment in the upper semiconfining unit overlie the Upper Floridan aquifer.

Thickness

Thickness of the upper semiconfining unit ranges from absent in karst areas along the Florida–Georgia State line to more than 300 ft in the Gulf Trough–Apalachicola Embayment region to the northwest and in the Okefenokee Basin to the east (fig. 15).

Davis (1996a) indicated that several hundred feet of fine-grained, low-permeability material of the upper semiconfining unit exists in the Apalachicola Embayment–Gulf Trough region of the ASO River Basin (fig. 6). Thickness of the Hawthorn Group–Torreya Formation of the upper semiconfining unit ranges from about 100 to 230 ft in the northern and western parts of the study area (Sever, 1966; Zimmerman, 1977; and Rupert, 1990). Additional thickness of up to 100 ft of low-permeability sediment from the Citronelle, Miccosukee, and Jackson Bluff Formations creates a substantial barrier to groundwater recharge from infiltration or vertical leakage from the surficial aquifer system. Erosion and carbonate dissolution, however, remove this upper semiconfining unit and expose the Upper Floridan aquifer at some locations in the study area, such as in southeastern Colquitt and Thomas Counties, Ga. (figs. 8 and 9, respectively), along the Withlacoochee River near Valdosta, Ga., and in karst areas along the Florida–Georgia State line.

Vertical-Leakage Potential

Thickness variations cause the upper semiconfining unit to range in hydrologic function from an impermeable boundary to allowing vertical leakage between the Upper Floridan aquifer and the surficial aquifer system or surface water (fig. 15). The upper semiconfining unit contains a high vertical-leakage potential where it is relatively thin and generally less than 50-ft thick, allowing recharge to the Upper Floridan aquifer by infiltrating precipitation or by groundwater flow from the surficial aquifer system. Areas of relatively thin upper semiconfining unit promote groundwater exchange between the Upper Floridan aquifer and surface water, such as in some upland stream valleys of the ASO River Basin north of Tifton, Ga., and northwest of the Gulf Trough–Apalachicola Embayment.

High to moderate leakage potential exists between the Gulf Trough–Apalachicola Embayment region and the State line in areas where the combined thickness of surficial aquifer and upper semiconfining unit total 50 to 100 ft (fig. 15). These areas can contain up to 50 ft of surficial aquifer, increasing the potential for vertical leakage from moderate to high in the absence of the upper semiconfining unit.

Moderate to low vertical-leakage potential exists in areas located between the Gulf Trough–Apalachicola Embayment and karst areas along the Florida–Georgia State line (fig. 15). In these areas, thick (more than 50 ft) upper-semiconfining-unit sediments overlie the Upper Floridan aquifer, limiting or preventing groundwater exchange with surface water or recharge from the surficial aquifer system.

Moderate, to low, to extremely low potential for vertical leakage and groundwater and surface-water exchange exists in a broad region of the ASO River Basin trending northeast to southwest, beginning along the western and northwestern basin boundary and extending northeast to Atkinson, Coffee, and Irwin Counties, Ga. (fig. 15). A band of increased thickness of low-permeability clastic sediments identifies the Gulf Trough–Apalachicola Embayment in this area. Little or no potential for vertical leakage and groundwater and surface-water exchange exists in the center of this area where thickness of the upper semiconfining unit reaches 250 ft or more.

Extremely low to no potential for vertical leakage and groundwater and surface-water exchange exists in the eastern part of the study area defined by the Okefenokee Basin (fig. 3). More than 300 ft of low-permeability clastic sediments overlie the Upper Floridan aquifer in parts of Charlton, Clinch, and Ware Counties, Ga. (fig. 15) and effectively isolate the aquifer from groundwater and surface-water exchange and infiltration of precipitation.

Upper Floridan Aquifer

The Upper Floridan aquifer contains Eocene-to-Miocene carbonate sediments consisting of the Tampa, Suwannee, Marianna, and Ocala Limestones and the Chattahoochee, St. Marks, and Byram Formations (figs. 4, 7–12). Natural and human-induced factors affect the hydrologic characteristics of the Upper Floridan aquifer. Aquifer thickness, hydraulic properties, limestone dissolution, connection with surface water, climatic effects, and groundwater withdrawal simultaneously affect the water resources of the Upper Floridan aquifer and influence groundwater flow and exchange with surface water.

Thickness Variations

Thickness variations for the Upper Floridan aquifer (fig. 19) correspond with geologic structural control of sediment accumulation in the basin. Subtraction of the areal distribution of the base of the Upper Floridan aquifer (fig. 20) from the altitude of the aquifer top (fig. 16) yielded the thickness distribution of the Upper Floridan aquifer in the study area. The aquifer thins at the updip limits in the northwestern part of the basin, just east of the Solution Escarpment (fig. 3), and thickens substantially into the Gulf Trough–Apalachicola Embayment region (fig. 6) and seaward to the Gulf of Mexico and Atlantic Ocean, corresponding with the regional dip of geologic units. Thickness of the Upper Floridan aquifer ranges from about 150 ft in Worth County, Ga., to more than 900 ft in parts of Atkinson, Clinch, Grady, and Lanier Counties, Ga., and Gadsden, Hamilton, and Leon Counties, Fla. Clastic and carbonate sediments accumulated in the Gulf Trough–Apalachicola Embayment in Grady and Leon Counties, setting the altitude of the base of the Upper Floridan aquifer at nearly –1,000 ft (fig. 20). Similar sedimentation in the Suwannee Strait (fig. 5) in Clinch County, set the altitude of the base of the Upper Floridan aquifer slightly deeper than –1,100 ft. Accumulation of sediment in the Apalachicola Embayment extends southward through Jefferson and Leon Counties, Fla., and beyond the study area in Wakulla County, Fla., where thickness of the undifferentiated Floridan aquifer system reaches about 2,800 ft (Pratt and others, 1996). Thickness of the Upper Floridan aquifer varies by about 300 ft locally in Leon County, Fla., owing to limestone dissolution and channel erosion of the Suwannee Limestone and St. Marks Formation (Hendry and Sproul, 1966). Regional seaward thickening of Coastal Plain sediments (Miller, 1986) increases the thickness of the Upper Floridan aquifer from near zero in the northwest to more than 750 ft in the southeast in Hamilton and Columbia Counties, Fla.

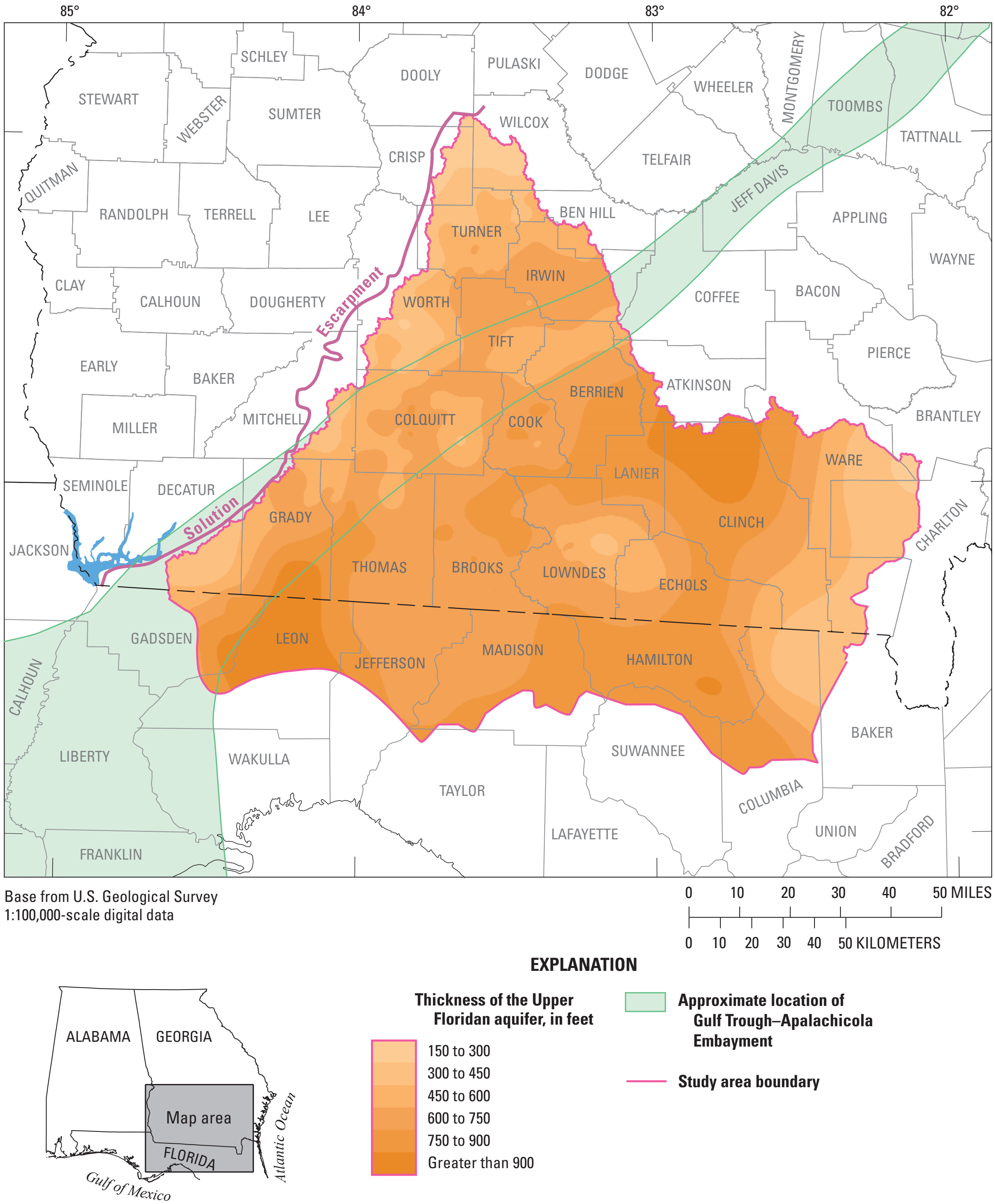


Figure 19. Thickness of the Upper Floridan aquifer in the Aucilla–Suwannee–Ochlockonee River Basin.

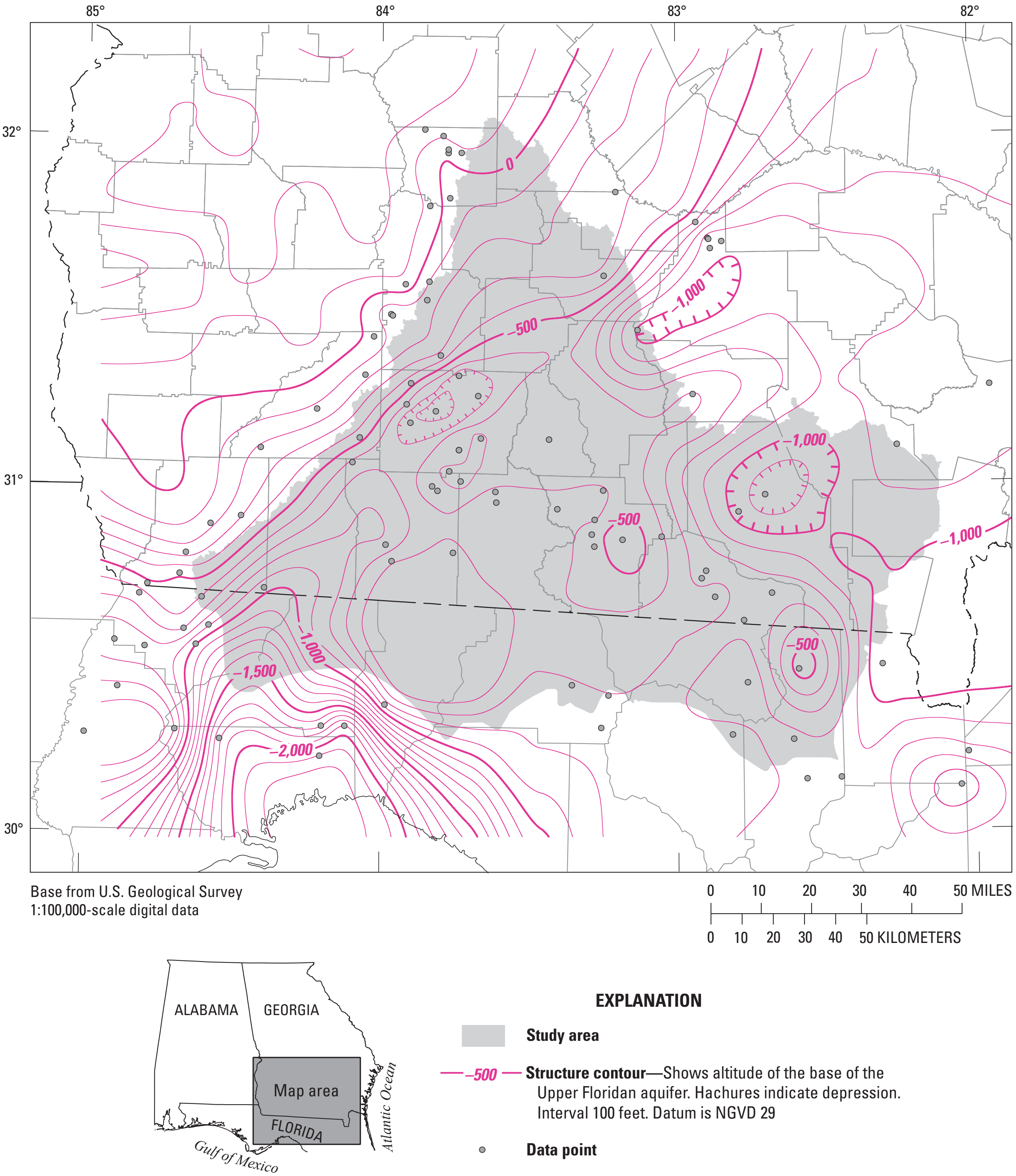


Figure 20. Altitude of the base of the Upper Floridan aquifer in the Aucilla–Suwannee–Ochlockonee River Basin.

Hydraulic Properties and the Effects of Limestone Dissolution and the Gulf Trough–Apalachicola Embayment on Groundwater Flow

Karst areas located along the Florida–Georgia State line and near Valdosta, Ga. (fig. 1) contain dissolution-enhanced hydraulic properties that facilitate groundwater flow and exchange with surface water. Limestone dissolution by water percolating through carbonate sediments enlarges subsurface pathways for groundwater flow, increasing hydraulic properties of aquifer transmissivity, hydraulic conductivity, storage coefficient, and specific yield in the Upper Floridan aquifer. Interconnected systems of solution channels and conduits, cavities, and enlarged pore space, joints, and fractures form the principal mechanisms for transmitting and storing large quantities of groundwater in the Upper Floridan aquifer in karst areas. Groundwater readily mixes and exchanges with surface water in karst areas where solution features increase the hydraulic connection of the Upper Floridan aquifer with streams and lakes. Ongoing limestone dissolution alters the landscape and reconfigures subsurface pathways, re-forming and re-orienting preferential directions of groundwater flow and enhancing groundwater and surface-water connection.

In contrast to dissolution-enhanced hydraulic properties that exist in karst areas, geologic structure and thick accumulation of clastic sediment and dense carbonate layers affect the hydraulic properties of the Upper Floridan aquifer in the Gulf Trough–Apalachicola Embayment region (fig. 6). The low water-transmitting and storage values for the Upper Floridan aquifer in the Gulf Trough region represent a limestone matrix nearly devoid of dissolution features and other groundwater-flow and storage enhancement. Joints or faults cut all or part of the Upper Floridan aquifer, juxtaposing low permeability sediment with the Upper Floridan aquifer (figs. 7–9), effectively decreasing the permeability of the aquifer and disrupting groundwater flow (Miller, 1986). The absence of secondary water-transmitting and storage features in the limestone creates an area of slow-moving groundwater, low storage capacity, and low well yield.

Transmissivity and Hydraulic Conductivity

Transmissivity of the Upper Floridan aquifer varies throughout the ASO River Basin according to changes in thickness and hydraulic conductivity because transmissivity is computed as the product of hydraulic conductivity and aquifer thickness. Generally, transmissivity increases with increased aquifer thickness (fig. 19) and (or) increased hydraulic conductivity. Geologic structure, depositional environment, and limestone dissolution affect the distribution of aquifer thickness and hydraulic conductivity within geohydrologic units constituting the Upper Floridan aquifer.

Hydraulic conductivity of the Upper Floridan aquifer increases northwestward and southeastward off the flanks of the Gulf Trough–Apalachicola Embayment, as the thick accumulation of low-permeability clastic, carbonate, and clayey sediments overlying the aquifer in the trough-embayment region diminishes. Up to 500 ft of low water-transmitting carbonates of the Byram Formation and Marianna Limestone supplant the high water-transmitting Suwannee and Ocala Limestones in the trough-embayment region (fig. 8). Northwest of the Gulf Trough–Apalachicola Embayment, hydraulic conductivity ranges from about 26–120 feet per day (ft/d) in Ben Hill County, Ga., to about 220–450 ft/d in Tift County, Ga., to an exceptional regional high value of about 5,700 ft/d in Decatur County, Ga. (Kellam and Gorday, 1990) (fig. 21*A*). In the trough-embayment region, Kellam and Gorday (1990) indicate typical hydraulic conductivity values in the range of about 0.7–140 ft/d. Two exceptions produced atypical values of hydraulic conductivity in the trough-embayment region: south of Moultrie, Colquitt County, Ga. (about 770 ft/d); and east of Cairo, Grady County, Ga. (about 5,800 ft/d), where wells tap highly productive zones in the Upper Floridan aquifer.

Limestone dissolution increases the water-bearing capacity of the Upper Floridan aquifer in karst areas along the Florida–Georgia State line where limestone exists at or near land surface. The aforementioned 5,700-ft/d estimate of hydraulic conductivity in Decatur County (fig. 21*A*) demonstrates the high water-yielding potential of the Upper Floridan aquifer caused by limestone dissolution. A 6-ft vertical zone of cavities and other solution features located within 130 ft of land surface produced nearly 90 percent of the groundwater pumped from the well associated with this large value of hydraulic conductivity, although aquifer thickness at this location totals about 350 ft (Torak and Painter, 2006). Transmissivity understandably attained a high value of 1,300,000 ft^2/d as a result of this hydraulic conductivity value (fig. 21*B*).

Aquifer transmissivity varies widely in the ASO River Basin, more in response to limestone dissolution than to changes in aquifer thickness. Transmissivity values in the range 100,000–200,000 ft^2/d (McConnell and Hacke, 1993) exist in karst areas of Valdosta, Ga. (fig. 21*B*), although less than 300 ft of aquifer thickness exists in this area (fig. 19). By comparison, aquifer thickness of 500 to 900 ft in the Gulf Trough–Apalachicola Embayment region produces aquifer transmissivity values that range from about 5 ft^2/d in Gadsden County, Fla. (Bush and Johnston, 1988), to 160 ft^2/d

in Tift County, Ga., to 390 ft^2/d in Grady County, Ga., and to about 3,000 ft^2/d in Colquitt and Thomas Counties, Ga. (Kellam and Gorday, 1990). On the northwestern flank of the trough-embayment region and within 10 mi north and west of the 160-ft^2/d transmissivity value in Tift County, Kellam and Gorday (1990) reported transmissivity values in the range 1,200–180,000 ft^2/d. Bush and Johnston (1988) reported a value of 1,300 ft^2/d in Leon County, Fla., just east of the Gulf Trough–Apalachicola Embayment.

Limestone dissolution enhances hydraulic conductivity and disrupts any regional trend in transmissivity defined solely by changes in aquifer thickness. Kellam and Gorday (1990) indicate the occurrence of a large void in aquifer material penetrated by a well in Grady County that yielded a hydraulic-conductivity value of about 5,800 ft/d (fig. 21*A*); this well produced a corresponding transmissivity value of 430,000 ft^2/d. Two wells in Berrien County, Ga., penetrate about 600–700 ft of aquifer thickness and produce transmissivity values of about 360,000 ft^2/d (Kellam and Gorday, 1990). The lithologic description of one of these wells lists a 17-ft zone of no samples located at the top of the Ocala Limestone (McFadden and others, 1986, p. 92), most likely the result of solution cavities, which caused poor sample return. By comparison, a well located in the Gulf Trough–Apalachicola Embayment region south of Moultrie, Colquitt County, Ga., produced a transmissivity value of about 89,000 ft^2/d from about 600–700 ft of aquifer thickness. Construction records associated with this well indicate that most of the production of about 600 gal/min was derived from a 40-ft zone of soft limestone penetrated at a depth of 425–465 ft below land surface (by S.B. Milligan, Jr., then resident engineer, E.P. McLean Engineering Company, to W.F. Ladson, then City Manager, City of Moultrie, Ga., written commun., January 29, 1949). Most likely, the Suwannee Limestone of the Upper Floridan aquifer supplied water to this well. Other high values of transmissivity in the range 100,000–600,000 ft^2/d, attributed to limestone dissolution, occur in Berrien, Coffee, and Cook Counties, Ga. (Kellam and Gorday, 1990), and in Hamilton County, Fla. (Ceryak and others, 1983).

Storage Coefficient and Specific Yield

Storage properties of the Upper Floridan aquifer vary by several orders of magnitude in the ASO River Basin and surrounding area depending on the degree of limestone dissolution and whether groundwater occurs under confined or unconfined conditions. Confined- (or artesian-) aquifer conditions use the storage coefficient and occur when the groundwater level exceeds the top of the aquifer; unconfined- or water-table-aquifer conditions use the specific yield and occur when the groundwater level lies below the top of the aquifer. Various degrees of semiconfined (leaky artesian) to confined conditions cause storage coefficient values to vary by several orders of magnitude in the Upper Floridan aquifer. This variability of storage coefficient values causes differences in vertical-leakage rates through the upper semiconfining unit during non-steady, or transient, groundwater flow. Results of aquifer testing in the study area and in coastal Georgia indicate that values for the confined (or artesian) storage property, or storage coefficient, range from 0.00004 to 0.04 (Clarke and others, 2005).

For unconfined, or water-table, conditions, the specific yield controls the release or uptake of water by the aquifer. In contrast to storage-coefficient values, a value of 0.1 derived from an aquifer-performance test in Bainbridge, Ga. (Sever, 1965), located a few miles to the west of the ASO River Basin (fig. 1), indicates unconfined conditions in the Upper Floridan aquifer.

The position of the groundwater level relative to the top of the aquifer determines which storage property controls the release or uptake of groundwater during transient groundwater flow. Seasonal or short-term water-level fluctuations can cause aquifer conversion between artesian and water-table conditions. Unconfined conditions also occur where erosion has removed the upper semiconfining unit and surficial aquifer system from overlying the Upper Floridan aquifer (fig. 15). Where erosion exposes the aquifer at or near land surface, the aquifer contains a water table that reflects a subdued expression of topography.

Pumping, climatic conditions, and exchange with surface water cause temporal variations in groundwater levels on local and regional scales throughout the basin which, in turn, can cause conversion from confined to unconfined, or from unconfined to confined conditions depending on the type, extent, and duration of hydrologic stress or change in stress imposed on the Upper Floridan aquifer. Transient groundwater flow occurs at the onset of hydrologic stress applied to the aquifer or whenever rates of existing hydrologic stress change, such as (1) during the initial stages of pumping or changes in pumping rates, (2) during changes in stream stage and (or) groundwater level that control groundwater and surface-water exchange, or (3) during changes in recharge by infiltration of precipitation or vertical leakage. Water is released from or taken up into storage in the aquifer according to the artesian or water-table storage properties as groundwater levels adjust to changes in hydrologic stress, such as those described.

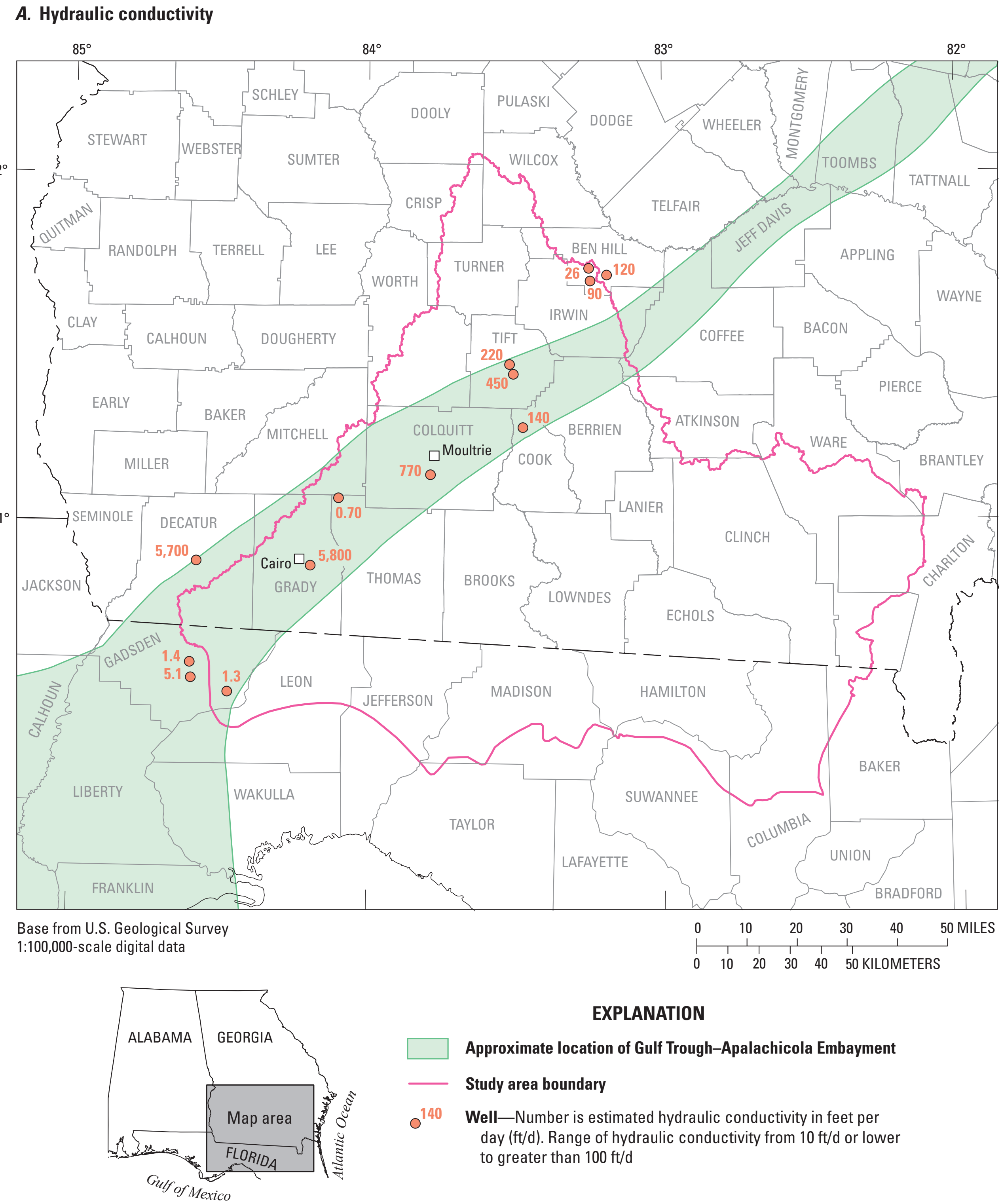


Figure 21. Hydraulic properties of the Upper Floridan aquifer in the Aucilla–Suwannee–Ochlockonee River Basin (*A*) hydraulic conductivity and (*B*) transmissivity (modified from Ceryak and others, 1983; Bush and Johnston, 1988; Kellam and Gorday, 1990; and McConnell and Hacke, 1993).

B. **Transmissivity**

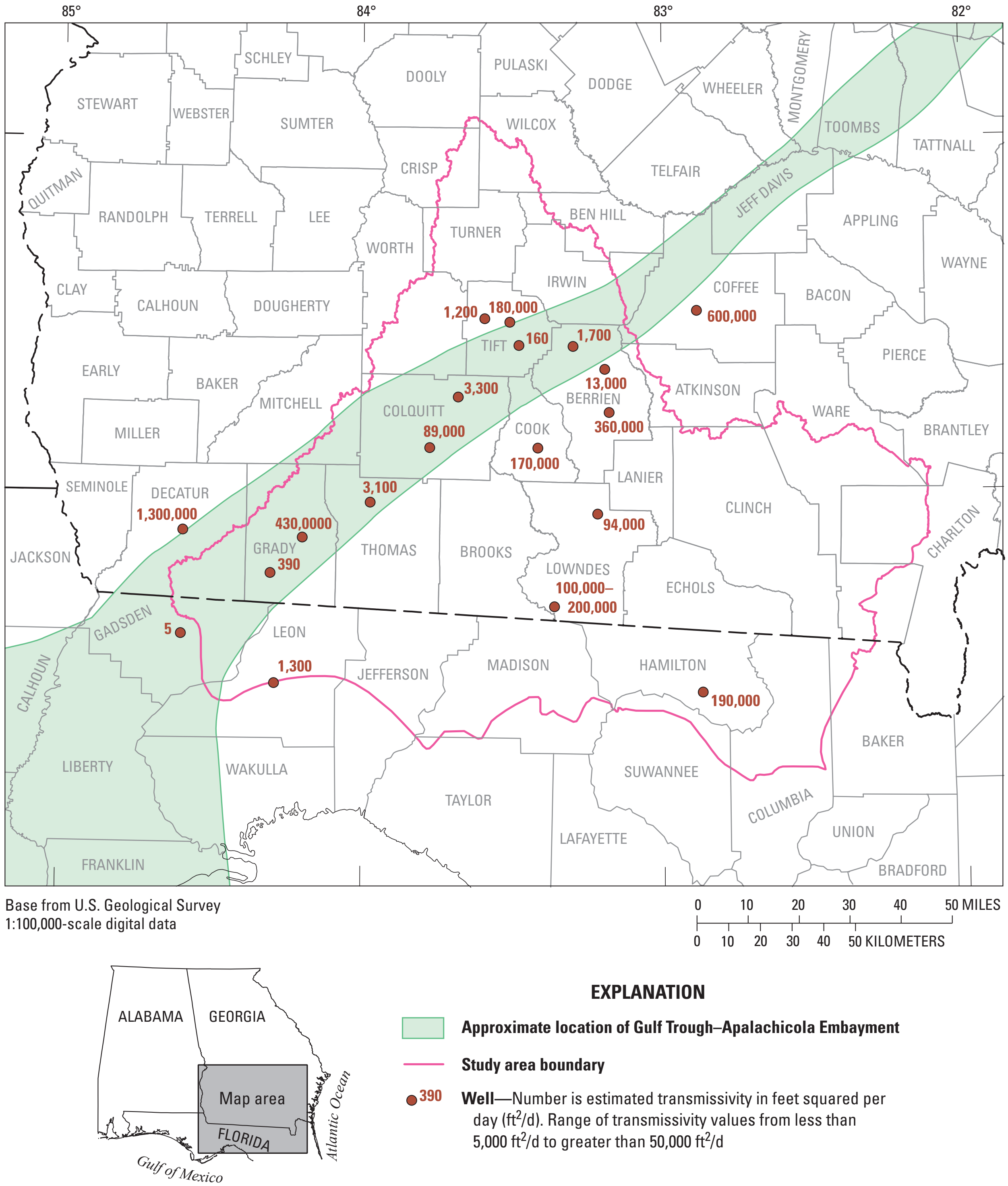


Figure 21. Hydraulic properties of the Upper Floridan aquifer in the Aucilla–Suwannee–Ochlockonee River Basin (*A*) hydraulic conductivity and (*B*) transmissivity (modified from Ceryak and others, 1983; Bush and Johnston, 1988; Kellam and Gorday, 1990; and McConnell and Hacke, 1993).—Continued

Groundwater Levels and Fluctuations

Annually, groundwater levels in the Upper Floridan aquifer respond to normal hydrologic stress, such as seasonal precipitation and groundwater pumping, and to unseasonable or abnormal hydrologic stress caused by climatic and (or) pumpage extremes. Groundwater levels attain a seasonal high during early spring because the combination of infiltrating precipitation, low irrigation demand, and low evapotranspiration rates raises groundwater levels from the low water-level conditions of the previous season (fig. 22). Groundwater levels decline from late spring to early fall in response to increased irrigation pumpage and evapotranspiration, and decreased infiltration of precipitation from rates in early spring. Summertime convective storms produce high-intensity, short-duration precipitation events that cause more runoff and less infiltration to recharge groundwater levels than the relatively long-duration, low-intensity storms associated with frontal passages during mid-fall to early spring. The long duration, low-intensity storms cause low runoff and high infiltration conducive to recharging groundwater levels. Precipitation during the growing season temporarily curtails irrigation pumpage and slows the seasonal decline in groundwater level until dry conditions cause pumping to resume. Groundwater levels rise by year's end and continue rising into the following spring in response to seasonal precipitation beginning during mid-fall and extending into early spring.

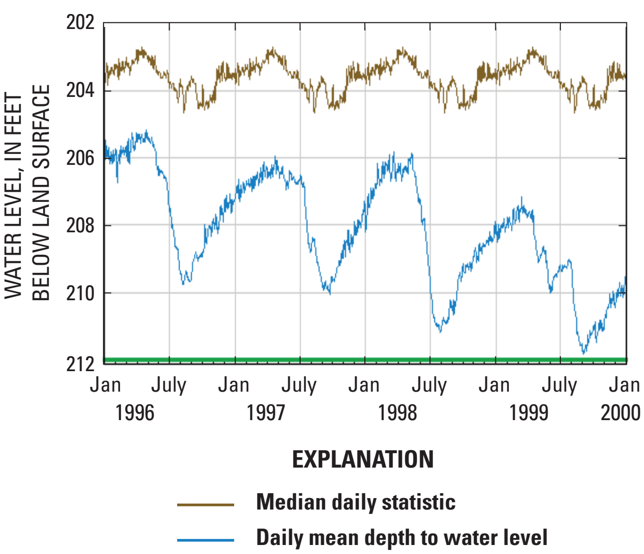


Figure 22. Hydrograph showing seasonal groundwater-level fluctuation in well 15L020, Sylvester, Georgia, 1996–1999.

In the absence of unseasonable climatic and/or pumpage variability, groundwater levels usually fluctuate within the range of previous years' levels, rising to nearly the same seasonal-high values each spring and declining to about the same seasonal-low values each fall. Daily median, or 50th percentile, groundwater levels, computed for the period of record and superposed on a hydrograph showing daily mean groundwater levels (fig. 22), define "normal" seasonal fluctuations and allow comparison of daily mean groundwater levels to a statistical representation of normal conditions. Small deviations from the median statistic indicate typical variations in groundwater levels caused by normal climatic variability and short-term changes in hydrologic stress. Consistently increasing or decreasing high or low groundwater levels in relation to the median daily statistic indicate a trend in groundwater levels that requires explanation with regard to changes in climate or hydrologic stress that might signal an irreversible groundwater-level condition. For example, the hydrograph of well 15L020 during 1996–1999 indicates a declining trend in groundwater level of about 6 ft in 4 years, or an average yearly groundwater-level decline of about 1.5 ft. The significance of this decline is evaluated with regard to a period of observation and hydrologic stresses that have changed during this time, as discussed below.

Hydrographs from continuous-recorder wells completed in the Upper Floridan aquifer depict varying magnitudes of seasonal groundwater-level fluctuations in the ASO River Basin (fig. 23). Unseasonable climate and (or) pumpage variations either amplify or diminish groundwater-level fluctuations from normal conditions, depending on the severity and duration of the climatic and (or) pumpage variation. Multiseason or multiyear deviations from normal climatic conditions and (or) pumping rates cause rising or declining groundwater-level trends, evidenced on the hydrographs as divergence of groundwater levels from median values. Rising or declining groundwater-level trends affect groundwater and surface-water exchange and recharge and discharge relations between hydrologic components that contribute to the water resources of the basin (fig. 13).

Consistent deviation from normal seasonal groundwater-level fluctuations could indicate a rising or declining trend in groundwater levels triggered by a corresponding increase or decrease in hydrologic stress on the Upper Floridan aquifer. Dry climatic conditions during the fall and winter hinder recovery of groundwater levels, and groundwater levels that do not recover from seasonal-low values in the fall begin the spring at a lower level than the previous year. Consistently dry conditions during periods of aquifer recharge—mid-fall through early spring—cause lower groundwater levels each spring than during the previous spring and could signal a declining groundwater-level trend. Low-groundwater-level conditions that occur during late spring continue throughout the year to perpetuate the declining groundwater-level trend.

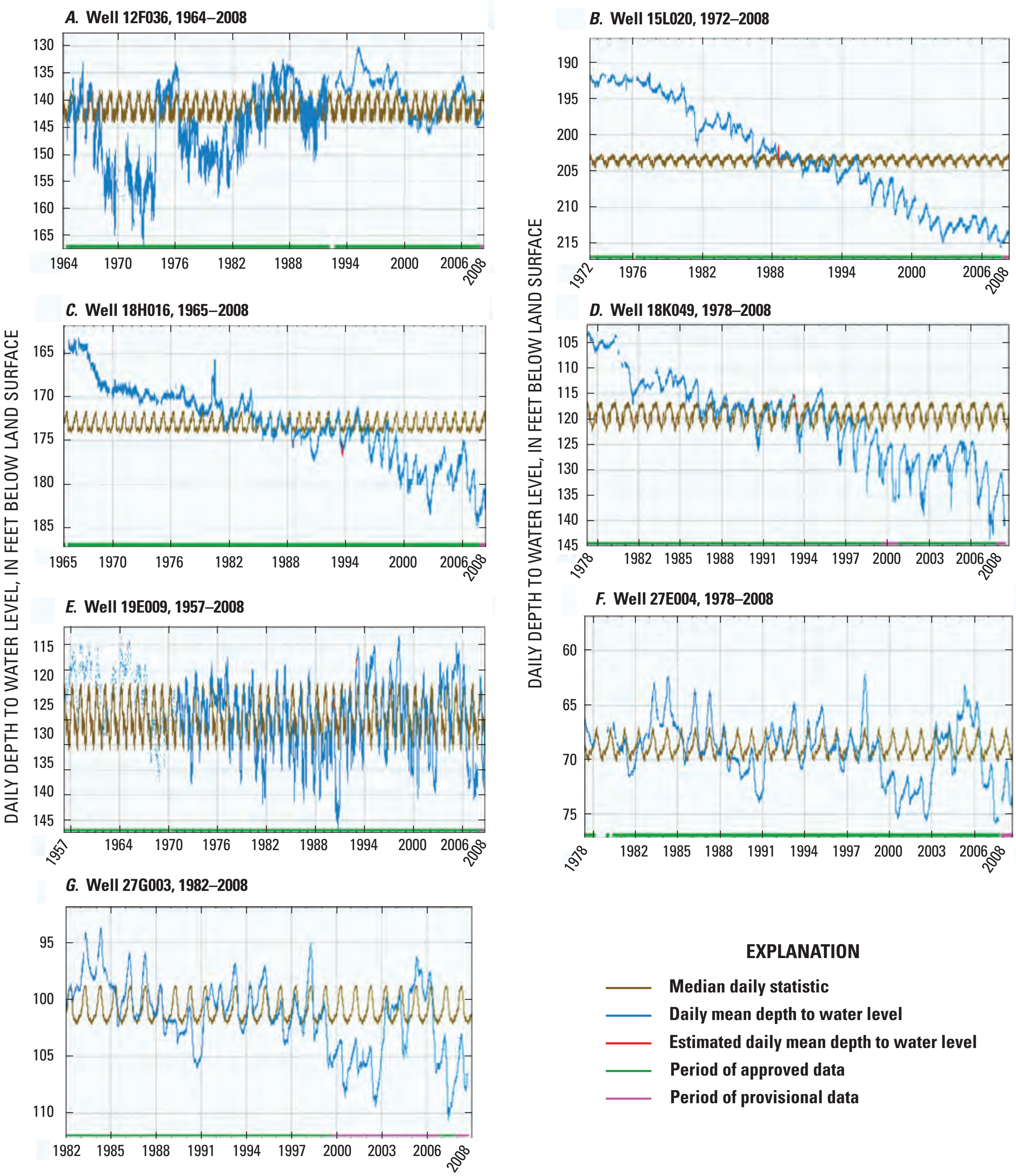


Figure 23. Hydrographs showing daily mean depth to water level and period-of-record median daily groundwater level for wells (*A*) 12F036, 1964–2008; (*B*) 15L020, 1972–2008; (*C*) 18H016, 1965–2008; (*D*) 18K049, 1978–2008; (*E*) 19E009, 1957–2008; (*F*) 27E004, 1978–2008; and (*G*) 27G003, 1982–2008.

The effectiveness of precipitation to raise groundwater levels the Upper Floridan aquifer varies in the basin, depending on the type and thickness of overlying sediment and degree of hydraulic connection of the aquifer with land surface or surface water (fig. 15). Although thickness of the overlying material can control water-level recovery by affecting infiltration of precipitation, regional pumpage and climatic conditions also influence water-level recovery. High-precipitation months do not necessarily generate high groundwater levels, especially in areas where relatively thick overburden hydraulically disconnects the aquifer from land surface and limits recharge by infiltration of precipitation. Similarly, the magnitude of precipitation that occurs near each well during the fall through early spring does not always affect the magnitude of seasonal water-level recovery if infiltrating precipitation first satisfies a thick unsaturated zone in the overburden before reaching the Upper Floridan aquifer.

Unseasonably frequent or high precipitation during the growing season can reduce or eliminate seasonal groundwater-level decline even in areas where a relatively thick upper semiconfining unit limits or prevents recharge to the aquifer. Irrigation pumping rates usually decrease during wet periods of the growing season, causing less pumpage-induced groundwater-level decline than during normal or dry periods. Climatic variation triggers changes in agricultural pumping rates, which increase during periods of low precipitation, lowering unseasonably low groundwater levels, and decrease during periods of high precipitation, reducing or eliminating groundwater-level declines.

Groundwater levels in continuous recorder wells completed in the Upper Floridan aquifer responded to regional drought during 1980–1981, 1986, 1998–2002, and 2006 (figs. 23*A*–*F*). The hydrograph of continuous recorder well 27G003 (fig. 23*G*) showed effects of regional drought conditions similar to groundwater levels in wells previously cited, except that the period of record began during 1982 and, therefore, did not exist to record drought conditions during 1980–1981. Some climatological stations recorded above-normal precipitation during a few months of 1986 and 2001, which were drought years, and during 1987 following the drought of 1986 (table 3, as noted). Conversely, all observation wells exhibited unseasonably high groundwater levels during 1987, although some climatological stations located near the observation wells recorded less-than-average precipitation.

Annual precipitation during 1986, 1987, and 2001, recorded at climatological stations located near continuous recorder wells, compared favorably with the period-of-record mean-annual precipitation (table 3), which seems to refute that drought conditions ever occurred during two of these years. Unseasonably high precipitation during specific months of these years skewed total annual precipitation to near mean-annual values. Groundwater levels seemed to respond more to regional climatic conditions than to local conditions, as evidenced by the low water levels recorded on well hydrographs during drought years (fig. 23).

Declining groundwater-level trends of any duration indicate a systematic lowering of the potentiometric surface of the Upper Floridan aquifer and a depletion of groundwater resources, compared with previous conditions (fig. 23). Abnormally dry climatic conditions reduce infiltration of precipitation to the Upper Floridan aquifer from conditions of normal precipitation, limiting aquifer recharge and causing unseasonably low groundwater levels in recharge areas of the Upper Floridan aquifer, such as along the northwestern basin boundary and in karst areas along the Georgia–Florida State line and to the south and east of the Gulf Trough–Apalachicola Embayment. Drought-induced increases to irrigation pumping rates cause declining groundwater-level trends wherever pumping stresses the Upper Floridan aquifer beyond its ability to recharge by regional groundwater flow, infiltration of precipitation, or induced surface-water leakage. Unseasonably low groundwater levels in aquifer-recharge areas, in turn, lower hydraulic gradients and regional groundwater-flow rates in downgradient, or outward, directions from the recharge area.

Rising groundwater-level trends of any duration can result from a reduction of hydrologic stress to the aquifer, such as above-normal precipitation sustained during several seasons or years and (or) pumpage reduction or relocation, and represent an accretion of groundwater resources. In a reverse process from that previously described for declining groundwater-level trends, precipitation that infiltrates areas favorable for recharge to the Upper Floridan aquifer (fig. 15) locally raises groundwater levels, increases regional groundwater flow out of recharge areas, and raises downgradient groundwater levels. Relocation of municipal pumpage at Cairo, Ga., for example, during October 1973 caused a 25-ft rise in the groundwater level in well 12F036 by February 1974 (fig. 23*A*). A declining trend during 1976–1982 negated this water-level increase; however, a rising trend in groundwater levels during the next 6 years restored water levels to the 1976 level by 1988. The hydrograph for well 15L020 (fig. 23*B*) depicts other groundwater-level trends during 1988–1991 (declining), 1991–1995 (rising), and 1995–2003 (declining), characterized by amplified seasonal water-level fluctuations that exceeded median values.

September 2006 Potentiometric Surface

Potentiometric contours of the Upper Floridan aquifer during September 2006 indicated complex patterns of groundwater flow in the ASO River Basin and across the basin boundary in the ACF River Basin (fig. 24). Groundwater generally flows southward to Florida and the Gulf of Mexico and eastward to coastal Georgia and the Atlantic Ocean from a groundwater divide located along the northern and western boundary of the ASO River Basin with the ACF River Basin (fig. 24*B*). Groundwater mounds near the Withlacoochee River in Brooks and Lowndes Counties, Ga., and groundwater depressions in southern Colquitt and Cook Counties, Ga., define diverging and converging groundwater-flow patterns, respectively, indicative of recharge and discharge, which alter the regional pattern of southward and eastward groundwater flow.

Table 3. Precipitation for selected years and climatological stations located in the Aucilla–Suwannee–Ochlokonee River Basin.

Station name	Station number (fig. 1)	Nearest observation well (fig. 1)	Precipitation, in inches				Remarks
			Mean annual	1986	1987	2001	
Ashburn 3 ENE	90406	15L020	48.3	48.21	63.18	43.04	Total precipitation during 2001 skewed by precipitation of 11.84 inches during March; data from Southeast Regional Climate Center, 2008e.
Cairo 2 N	91463	12F036	51.25	—	—	53.53	Precipitation of 11.34 and 15.67 inches occurred during March and June 2001, respectively; data from Southeast Regional Climate Center, 2008f.
Cordele	92266	15L020	44.86	31.12	38.82	43.87	Precipitation of 9.61, 10.58, and 8.55 inches occurred during March, June, and September 2001, respectively; data from Southeast Regional Climate Center, 2008c.
Folkston 9 SW	93465	27E004	52.64	58.66	48.1	41.29	Precipitation of 11.52 inches occurred during June 2001; data from Southeast Regional Climate Center, 2008g.
Homerville	94429	27G003	52.31	61.44	54.87	37.26	Precipitation of 8.03, 10.15, 9.31, and 8.28 inches occurred during February, June, July, and December 1986, respectively; precipitation of 8.28 and 9.22 inches occurred during July and September 1987, respectively; precipitation of 10.84 inches occurred during June 2001; data from Southeast Regional Climate Center, 2008h.
Lake City 2 E	84731	27E004	53.19	55.72	59.26	42.31	Precipitation of 10.34 and 12.89 inches occurred during August 1986 and 1987, respectively; precipitation of 9.95 inches occurred during September 2001; data from Southeast Regional Climate Center, 2008b.
Moultrie 2 ESE	96087	18H016	49.9	51.65	46.07	43.54	Precipitation of 11.84 inches occurred during March 2001; data from Southeast Regional Climate Center, 2008i.
Quitman 2 NW	97276	19E009	52.5	39.25	—	39.84	Precipitation of 15.4 inches occurred during June 2001; 11 days of precipitation missing during July 2001; data from Southeast Regional Climate Center, 2008j.
Tifton Exp Stn	98703	18K049	47.23	48.01	49.59	42.64	Precipitation of 15.14 inches occurred during June 2001; data from Southeast Regional Climate Center, 2008k.
Waycross 4 NE	99186	27G003	48.98	40.54	44.98	37.60	Precipitation of 8.73, 8.03, and 8.55 inches occurred during June, July, and September 2001, respectively; data from Southeast Regional Climate Center, 2008d.

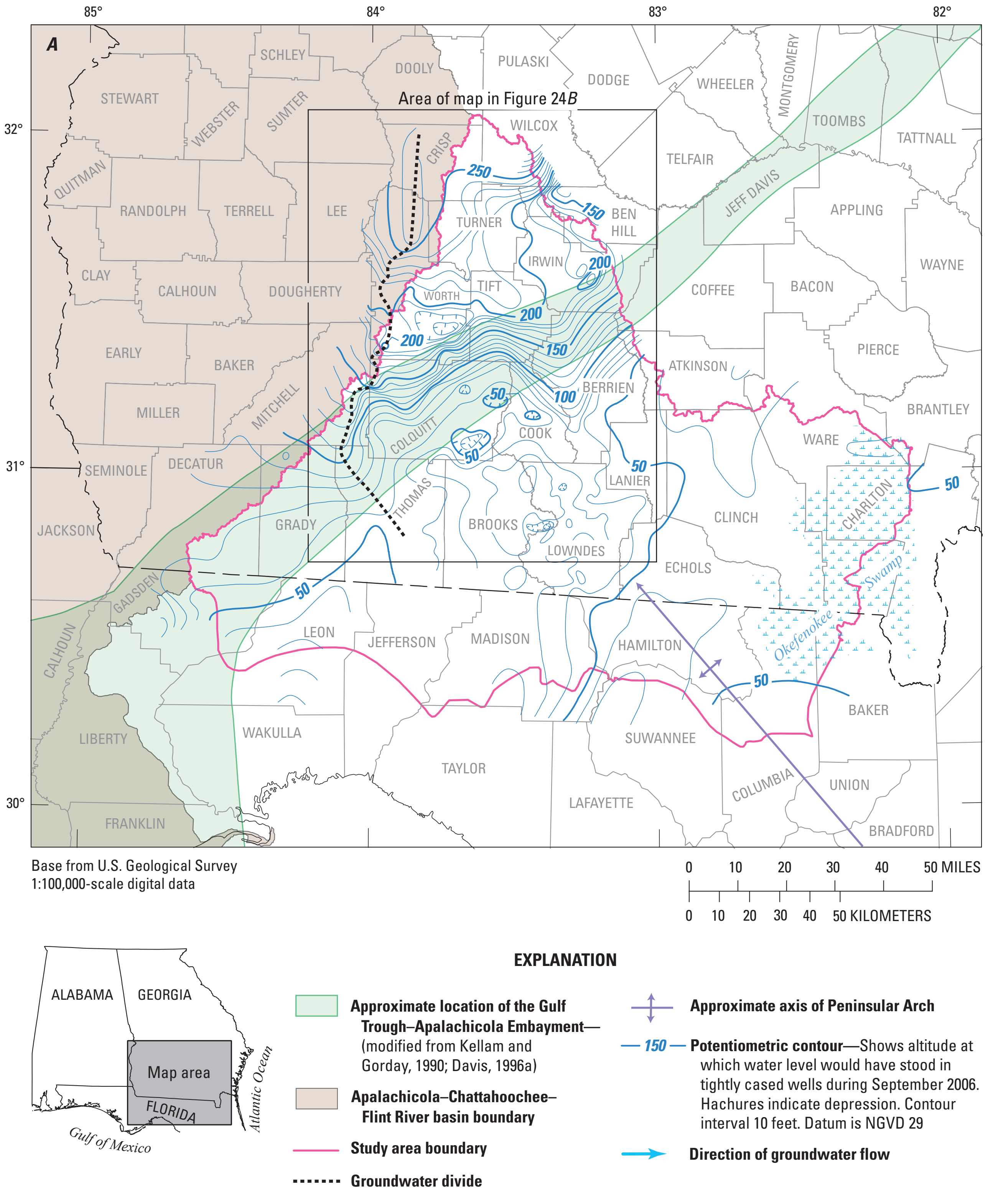


Figure 24. (*A*) Potentiometric surface of the Upper Floridan aquifer in southern Georgia and northern Florida, September 2006; and (*B*) enlarged view of the potentiometric surface of the Upper Floridan aquifer in southern Georgia, September 2006, showing groundwater divide and flow directions.

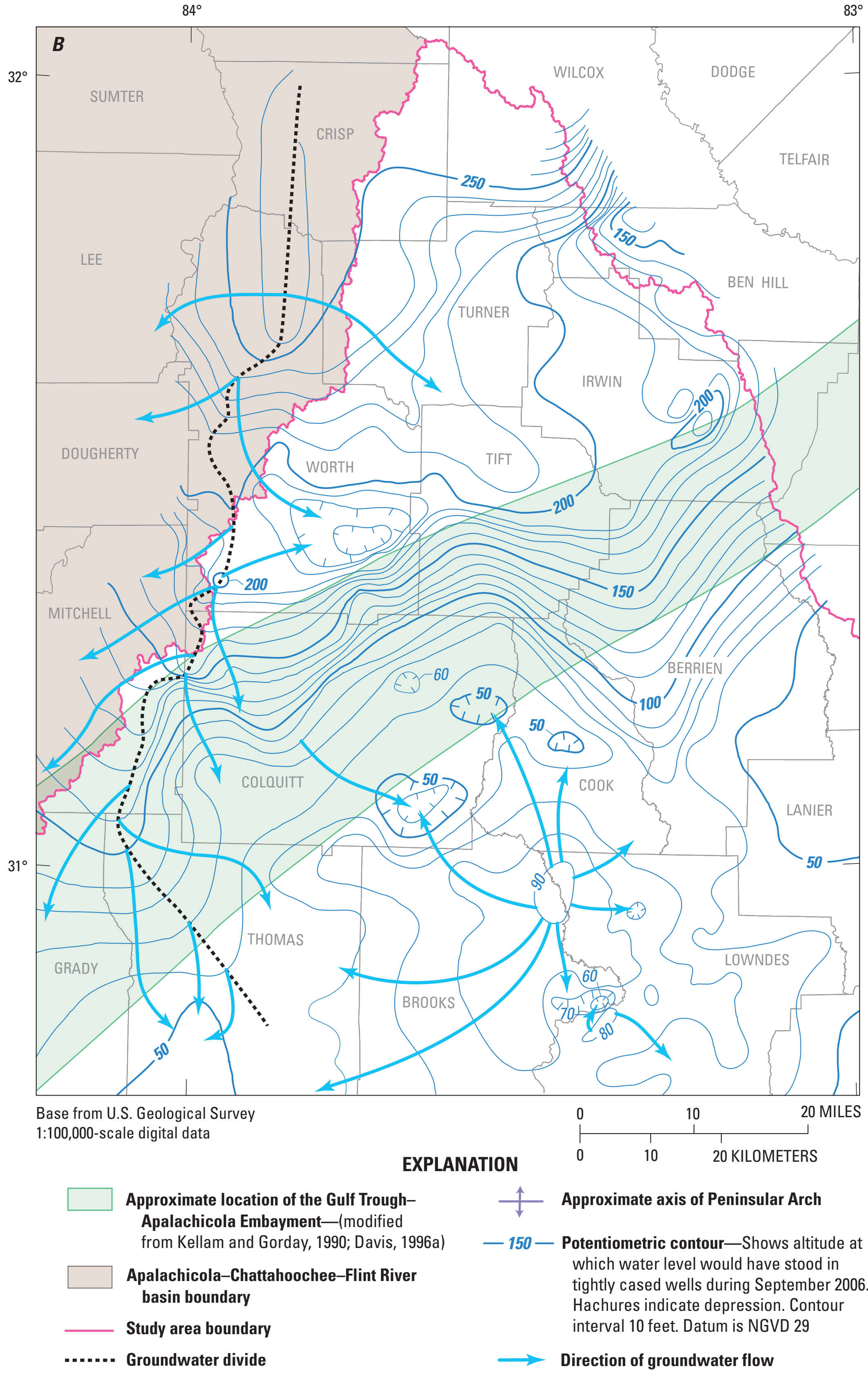


Figure 24. (*A*) Potentiometric surface of the Upper Floridan aquifer in southern Georgia and northern Florida, September 2006; and (*B*) enlarged view of the potentiometric surface of the Upper Floridan aquifer in southern Georgia, September 2006, showing groundwater divide and flow directions.—Continued

Southward bending of the 60–190-ft potentiometric contours established a groundwater divide east of the basin boundary in the ASO River Basin in Colquitt, Grady, Mitchell, Thomas, and southern Worth Counties (fig. 24*B*). In Decatur and Grady Counties, Ga., and in Gadsden and Leon Counties, Fla., the 60–90-ft potentiometric contours trend nearly east to west across the basin boundary defining southward groundwater flow from the ACF River Basin into the ASO River Basin (fig. 24*A*). The northwestern trend of the 100–150-ft potentiometric contours across the basin boundary indicates southwestward groundwater flow along the basin boundary in southern Mitchell County. The 160–190-ft potentiometric contours align more northward than the 100–150-ft contours, indicating westward groundwater flow across the basin boundary from the ASO River Basin into the ACF River Basin in northwestern Colquitt and southwestern Worth Counties.

The 210–260-ft potentiometric contours during September 2006 positioned the groundwater divide in the ACF River Basin west of the basin boundary in central Crisp and northern Worth Counties (fig. 24*B*). Groundwater flows eastward to southeastward into the ASO River Basin from the ACF River Basin in northern and central Worth County. The 200-ft potentiometric contour positioned the groundwater divide coincident with the basin boundary in southern Worth County where groundwater diverges from the divide and basin boundary and flows into both basins.

Tightly spaced 70–190-ft contours on the September 2006 potentiometric surface defined high hydraulic gradients but relatively slow-moving groundwater in the Gulf Trough–Apalachicola Embayment area (fig. 24*A*). Low hydraulic conductivity and transmissivity in the trough-embayment area (fig. 21) limit southeastward groundwater flow from recharge areas across the basin boundary in the ACF River Basin in the northwestern part of the study area.

Closed patterns of 40- and 50-ft cotours on the September 2006 potentiometric surface located southeast of the Gulf Trough–Apalachicola Embayment region in eastern Colquitt and Cook Counties defined depressions that indicate groundwater discharge (fig. 24*A*). The depression in southeastern Colquitt County coincides with northeastern extensions of the Ochlockonee fault and Barwick arch, as identified by Sever (1966) (fig. 9). Miocene folding and faulting displaced the Upper Floridan aquifer upward by as much as 190 ft on the southeastern side of the fault, juxtaposing the top unit of the aquifer (the Suwannee Limestone) with the low-water-bearing Tampa Limestone on the northwestern side of the fault. "Rocks on the southeast side of the fault [have been] upthrown with the amount of displacement increasing [from Thomas County] to the northeast" (Sever, 1966, p. 8). Sever (1966) described a condition in Thomas County during March 1964 where the groundwater level of the Suwannee Limestone was 10–20 ft higher than groundwater levels of the underlying Byram Formation, Marianna Limestone equivalent, and Ocala Limestone (fig. 4). Very little groundwater flowed across the Ochlockonee fault. Rather, groundwater flowed down the fault into underlying geologic units.

The depression in the September 2006 potentiometric surface in southeastern Colquitt County (fig. 24*A*) coincided with the location of a recharge mound during December 1969, where groundwater diverged from an area enclosed by 80- and 90-ft potentiometric contours (Zimmerman, 1977, fig. 5). A groundwater level of 80–90 ft during December 1969 coincided with the top altitude of the Upper Floridan aquifer in this area (fig. 16). Therefore, groundwater levels of 40–50 ft during September 2006 indicated that about 40–50 ft of aquifer dewatering had occurred since December 1969. Such dewatering can lead to depletion of the groundwater resource as saturated aquifer thickness decreases with increased dewatering. Other depressions in the September 2006 potentiometric surface seem to be pumpage related rather than indicative of vertically downward leakage from the Suwannee Limestone to deeper geologic units of the Upper Floridan aquifer.

Closed 80–90-ft contours of the September 2006 potentiometric surface located in Brooks and Lowndes Counties defined diverging groundwater flow indicative of recharge mounds in the Upper Floridan aquifer (fig. 24). In these areas, the aquifer lies near or slightly below land surface because of uplift by the northern extension of the Peninsular Arch and subsequent erosion of overlying sediments. Limestone dissolution formed sinkholes and other karst features in this area that promote infiltration of precipitation and surface-water exchange (Krause, 1979).

Sparse groundwater-level measurements in the eastern part of the study area during 2006 resulted in a general potentiometric surface defined by widely spaced 40- and 50-ft potentiometric contours (fig. 24*A*). This area contains the Okefenokee Swamp, where more than 300 ft of low-water-bearing clastic sediments overlie the Upper Floridan aquifer (fig. 15), limiting if not eliminating hydraulic connection of the aquifer with land surface and surface water.

Lower Confining Unit

The Lisbon Formation defines the lower confining unit of the Upper Floridan aquifer in the northern, western, and north-central parts of the study area (Miller, 1986). The carbonaceous clay and glauconitic limestone of the Lisbon Formation that, in turn, grades into micritic, low-permeability, finely pelletal limestone interbedded with fine-to-medium crystalline, slightly vuggy dolomite of the Avon Park Formation to the south and east in the ASO River Basin represents an important subregional confining unit within the Floridan aquifer system (Miller, 1986). These geologic units define the lower confining unit to the Upper Floridan aquifer (fig. 4) and create a hydrologic barrier to groundwater flow. The lower confining unit prevents poor-quality water in deeper water-bearing units from entering the Upper Floridan aquifer in the study area.

Thickness of the lower confining unit varies greatly in the ASO River Basin (figs. 7, 8, 10–12). At least 100 ft of the Lisbon Formation extends from the western boundary with the ACF River Basin, across the Gulf Trough–Apalachicola

Embayment region, northeastward to northern Coffee County, Ga., just to the northeast of the study area Miller (1986) (fig. 6). The lower confining unit increases in thickness southeastward from about 500 ft in Coffee County to more than 2,200 ft in Clinch County, Ga., in the eastern part of the study area. Thickness of the lower confining unit increases northeastward from about 200–300 ft in Madison County, Fla., to nearly 2,000 ft in Echols County, Ga. (figs. 10 and 12). The low stratigraphic position of these low permeable units in the southeastern part of the study area (fig. 12) creates the base of the Floridan aquifer system, above which a local confining unit about 100–150-ft thick separates the Upper Floridan aquifer from permeable units of the Lower Floridan aquifer.

Conclusions

The objectives addressed in this report are restated from the section "Purpose and Scope" prior to each conclusion.

1. *Describe the lithologic and hydraulic properties of the Upper Floridan aquifer and hydraulically connected geologic units that would enable assessment of water exchange between Upper Floridan aquifer and other geohydrologic units and surface water.*

Tectonic forces underlying the Coastal Plain played a major role in determining the type of sediment in the 20,000-ft sequence of clastic and carbonate sediments deposited in the ASO River Basin. Structural control of sedimentation also affected the geohydrology and water exchange of geohydrologic units with surface water. Differential compaction and limestone dissolution and collapse affected the accumulation and lithology of late-middle Eocene and younger sediments constituting the surficial aquifer system, Upper Floridan aquifer, and intervening upper semiconfining unit. An early Mesozoic uplift, the Peninsular Arch, established various depocenters along its flanks and dominated sedimentation patterns throughout most of the study area. Deposition and accumulation of more than 300 ft of low-permeability clastic sediments on the northeastern flank of the Peninsular Arch in the Southeast Georgia Embayment and Suwannee Strait, and along the northwestern flank of the Arch in the Gulf Trough–Apalachicola Embayment, virtually isolated the Upper Floridan aquifer from land surface and recharge by infiltrating precipitation. Burial of limestone beneath thick clastic overburden in these regions virtually eliminated the potential for ongoing karst processes, resulting in low aquifer hydraulic conductivity and storage coefficient despite increased aquifer thickness of more than 900 ft. Accumulation of up to 500 ft of low-water-bearing Oligocene carbonates in the Gulf Trough–Apalachicola Embayment stratigraphically and hydraulically separated two principal water-bearing strata of the Upper Floridan aquifer—the Oligocene Suwannee Limestone and the late Eocene Ocala Limestone. Conversely, uplift and faulting associated with the Peninsular Arch thinned overlying clastic sediments and exposed the Suwannee Limestone of the Upper Floridan aquifer to land surface near the Florida–Georgia State line, creating a karst region of active limestone dissolution and vigorous exchange of groundwater with surface water.

The Ochlockonee fault and Barwick arch produce more than 100 ft of uplift on the southeastern flank of the Gulf Trough–Apalachicola Embayment, juxtaposing the top of the Upper Floridan aquifer (Suwannee Limestone) with low-water-bearing geologic units of the overlying upper semiconfining unit in Colquitt and Thomas Counties, Ga. Contours of the altitude of geologic units prepared by previous investigators for Colquitt County demonstrate structural control of the top of the Upper Floridan aquifer; disparate values of the aquifer-top altitude within short distances result from deposition and faulting rather than limestone dissolution. Similar data disparities for the top altitude of the Upper Floridan aquifer in Cook County result from variable lithology and water-bearing characteristics of the early Miocene Tampa Limestone, which either transmits water as the top geologic unit of the Upper Floridan aquifer or semiconfines the underlying aquifer, depending on location. Close inspection of geohydrologic data in other counties in the ASO River Basin indicates similar variability of water-transmitting characteristics and presence of geologic units constituting the top of the Upper Floridan aquifer.

2. *Develop a hydrogeologic framework and conceptual model for evaluating agricultural pumpage and groundwater and surface-water exchange between the Upper Floridan aquifer and other geohydrologic units connected to surface water.*

Various hydrologic processes contribute to groundwater flow in the ASO River Basin, conveying water to pumped wells and facilitating groundwater and surface-water exchange between the Upper Floridan aquifer and other geohydrologic units connected to surface water. Recharge to the Upper Floridan aquifer occurs by infiltration of precipitation, vertical leakage through the surficial aquifer system and undifferentiated overburden, inflow across stream channels or lake bottoms, and regional flow. Discharge processes include vertical leakage, outflow across stream channels or lake bottoms, regional flow, and well pumpage. Geohydrologic units containing these processes consist of the surficial aquifer system, upper semiconfining unit, Upper Floridan aquifer, and lower confining unit. Hydraulic gradients and properties of aquifer transmissivity and storage govern the rate of groundwater flow to pumped wells.

Climate and pumpage changes create complex and dynamic relations with groundwater levels and with groundwater and surface-water exchange in the ASO River Basin. Groundwater levels recover during late fall and winter from declines incurred during the growing season (spring through early fall) caused by high evapotranspiration and runoff, low infiltration of precipitation, and irrigation pumpage. Low evapotranspiration and crop demand during the fall, winter, and early spring coupled with infiltration of precipitation and little runoff contribute to raising groundwater levels. Droughts require additional agricultural irrigation pumpage from normal irrigation pumping rates to maintain crop production; increased irrigation pumping rates lower groundwater levels more than would occur during a growing season having normal precipitation. Extended dry or drought conditions lower groundwater levels from normal water-level conditions by reducing recharge to the Upper Floridan aquifer from infiltration of precipitation, from vertical leakage through the upper semiconfining unit and (or) the surficial aquifer system, and from regional flow. Abnormally large groundwater-level declines reduce the base flow of streams and either limit or eliminate hydraulic connection of the aquifer with the stream. Most of the continuous-recorder hydrographs indicate abnormally low groundwater levels during the following years of extremely dry conditions or drought: 1980–81, 1986, 1998–2002, and 2006.

3. *Present an overview of 2006 groundwater-level and streamflow hydrologic conditions.*

Groundwater levels and streamflows measured during September 2006 provide an overview of then-current hydrologic conditions. Water-table conditions occurred in two areas of the ASO River Basin: north and west of the Gulf Trough–Apalachicola Embayment region, and south and east of the trough-embayment region but west of the Okefenokee Basin. To the north and west of the trough-embayment region, headwater streams to the Alapaha, Little, and Withlacoochee Rivers incise through relatively thin overburden, further reducing overlying sediment thickness to the Upper Floridan aquifer and enhancing groundwater and surface-water exchange and aquifer recharge. South and east of the trough-embayment region, more than 40 ft of aquifer dewatering occurred since the late 1960s in southeastern Colquitt County, as defined by the area contained within the 40-ft potentiometric contour of the September 2006 potentiometric surface. Here, and in Cook and Thomas Counties, Ga., uplift of Coastal Plain sediments associated with the Peninsular Arch and erosion of Oligocene and younger geologic units positioned the Upper Floridan aquifer near or just below land surface. In karst areas of Brooks and Lowndes Counties, this uplift created a recharge area, water-table conditions, and active groundwater and surface-water exchange along the Withlacoochee River near Valdosta, Ga.

The Upper Floridan aquifer exhibited artesian-aquifer conditions during September 2006 in two distinct areas of the ASO River Basin—along the trace of the Gulf Trough–Apalachicola Embayment and in the Okefenokee Basin and Swamp. The low-water-transmitting ability of the Upper Floridan aquifer in the trough-embayment region limits groundwater flow, resulting in elevated groundwater levels and artesian conditions in this area. Groundwater levels declined about 100 ft in 20 mi across the trough-embayment region from the northwest to the southeast in northern Colquitt and southern Tift and Worth Counties. Confinement of the Upper Floridan aquifer with up to 300 ft of overburden consisting of the surficial aquifer and upper semiconfining unit causes hydraulic separation of the Upper Floridan aquifer with land surface, limiting recharge, spring discharge, and surface-water exchange from affecting the potentiometric surface and possibly creating water-table conditions. In the Okefenokee Basin and Swamp, limited groundwater development and more than 300 ft of low-water-transmitting overburden limited interaction of the Upper Floridan aquifer with land surface and streams, allowing artesian conditions to exist during September 2006.

4. *Explain hydrologic concepts of the groundwater and surface-water exchange mechanisms that control causal relations between groundwater pumpage in the Upper Floridan aquifer, climatic variations, groundwater-level decline, reductions in streamflow and springflow, and changes in interbasin flow.*

Groundwater levels in the Upper Floridan aquifer and streamflows fluctuate seasonally and exhibit long-term decline in response to complex interactions of natural and human-induced hydrologic stress imposed on the water resources of the ASO River Basin. Changes in groundwater and surface-water withdrawal, climatic conditions, and the degree and areal extent of hydraulic connection of the aquifer with land surface and surface water combine to influence groundwater levels and streamflows. Groundwater levels resolve and manifest hydrologic stresses into a unique temporal record: the groundwater hydrograph. Likewise, streamflow and streamflow hydrographs reflect and resolve to varying degrees the combined effects of hydrologic stresses imposed on the groundwater- and surface-water-flow system.

The effect of climate on groundwater levels in the Upper Floridan aquifer varies depending on the potential of the overlying sediment to provide recharge to the aquifer by vertical leakage or by infiltration of precipitation. Increased precipitation above normal amounts raises groundwater levels in the Upper Floridan aquifer above normal, or median, values and increases groundwater recharge and hydrologic processes that deliver water to streams and wells. High-precipitation months do not necessarily coincide with groundwater-level increases shown on hydrographs, however, and the magnitude of precipitation that occurs near each well during fall and winter does not seem to affect the magnitude of groundwater-level increases. Storage properties and moisture conditions of the aquifer and overburden sediments can dampen the response of groundwater levels to recharge from infiltration of precipitation in the same manner as storage properties delay pumpage-induced groundwater-level decline.

Increased hydrologic stress caused by dry climatic conditions and (or) increased pumpage initiated a steady groundwater-level decline along the northwestern boundary of the ASO River Basin in Worth County, Ga., during the mid-1970s that extended through the mid-2000s. Increases in center-pivot irrigation systems during the mid-to-late 1990s and drought conditions during the mid-1980s and 1998–2002 contributed to groundwater-level declines indicated on hydrographs of wells located in the northwestern and central parts of the study area.

Groundwater-level declines lower the hydraulic gradient toward the ASO River Basin from recharge areas northwest of the basin boundary in the adjacent ACF River Basin and reduce the potential for regional groundwater to flow southeastward across the Gulf Trough–Apalachicola Embayment. Low-water-bearing clastic sediments overlying the Upper Floridan aquifer in the Gulf Trough–Apalachicola Embayment and the low-water transmitting properties of the aquifer in the trough-embayment region divide the ASO River Basin into distinct regions of groundwater flow.

The trough-embayment region restricts recharge in the northwestern parts of the ASO River Basin from flowing southeastward as regional groundwater flow and isolates groundwater-level changes that occur on either side. Water-level declines in the trough-embayment region associated with relatively heavy pumping in Colquitt and Tift Counties, Ga., cause local depressions in the potentiometric surface that seem isolated from water levels on the distal side of the trough-embayment region, about 15–20 mi to the northwest. Areas southeast of the trough-embayment region receive insufficient recharge by regional groundwater flow from the northwest, resulting in pumpage-induced groundwater-level declines. Vertical downward leakage of groundwater from the Suwannee Limestone of the Upper Floridan aquifer to deeper limestone units in southeastern Colquitt County, Ga., has caused 40–50 ft of groundwater-level decline and aquifer dewatering since December 1969.

Relatively low aquifer transmissivity in the Gulf Trough–Apalachicola Embayment region not only limits the effects of pumpage to a local area, but amplifies pumpage-induced groundwater-level changes near pumped wells. For example, the groundwater-level rise during late 1973 to early 1974 in the trough-embayment region near Cairo, Grady County, Ga., represented a local response to relocation of municipal pumpage about 2 mi east of the city. Groundwater-level changes in the trough-embayment region provide unreliable information about groundwater-level trends in other parts of the Upper Floridan aquifer, such as northwest and southeast of the trough-embayment region, as demonstrated by distinct groundwater-level trends on hydrographs of continuous-recorder wells located in these areas.

Groundwater levels exhibited a basin-wide response to regional hydrologic stress imposed on the Upper Floridan aquifer. Hydrographs recorded lowering of groundwater levels in and downgradient from recharge areas in response to extremely dry conditions that occurred during 1980–1981, 1986, 1998–2002, and 2006.

In contrast to pumpage- and drought-induced groundwater-level decline, above-average precipitation following drought conditions raised groundwater levels in recharge areas in the northwestern and south-central parts of the basin. The groundwater-level rise, in turn, raised the potentiometric surface of the Upper Floridan aquifer in the Okefenokee Basin, although several hundred feet of low-permeability clastic sediments hydraulically isolate the aquifer from infiltrating precipitation and surface-water interaction there. Groundwater-level fluctuations in the eastern part of the ASO River Basin also indicate a strong relation to fluctuations that occur in wells completed in the Upper Floridan aquifer located along the coast.

Declining groundwater-level trends indicate a systematic lowering of the potentiometric surface of the Upper Floridan aquifer and a depletion of groundwater resources, compared with previous conditions. Abnormally dry climatic conditions limit aquifer recharge by infiltration of precipitation from conditions of normal precipitation, causing unseasonably low groundwater levels in recharge areas of the ASO River Basin, such as along the northwestern basin boundary, in karst areas along the Georgia–Florida State line, and south and east of the Gulf Trough–Apalachicola Embayment. Drought-related increases in irrigation pumpage and pumpage associated with increased agricultural, industrial, and (or) municipal development has the potential to cause declining trends in groundwater levels in the Upper Floridan aquifer as pumpage and climatic stress exceed the ability to replenish groundwater resources by regional groundwater flow, infiltration of precipitation, and (or) surface-water leakage. Unseasonably low groundwater levels in aquifer-recharge areas stressed by dry climatic conditions and pumpage cause a lowering of hydraulic gradients and regional groundwater-flow rates in downgradient, or outward, directions from the recharge area. This hydrologic condition has occurred in the Gulf Trough–Apalachicola Embayment region, where dry climatic conditions and increased agricultural pumpage lowered groundwater levels northwest of the trough-embayment region, reducing the potential for groundwater to flow across the trough-embayment region to recharge southeastern parts of the basin.

Groundwater-level decline affects streamflow by reducing hydraulic gradients to streams, thus reducing groundwater discharge to (or base flow of) streams. As groundwater levels attempt to equilibrate to agricultural groundwater withdrawal from the previous growing season, similar effects occur during the current growing season, compounding residual groundwater-level decline and contributing toward a temporal trend of groundwater-level and streamflow decline.

Long-term, groundwater-level decline in the northwestern part of the basin portends diminished water-resource potential for future development. Excessive groundwater-level decline can lower the potentiometric surface of the Upper Floridan aquifer below the top of the geohydrologic unit, which reduces aquifer transmissivity from that associated with artesian conditions, creating water-table and aquifer-dewatering conditions. Aquifer dewatering can degrade groundwater resources by reducing saturated thickness of the aquifer, compacting water-bearing units (subsidence), and collapsing solution-enlarged features that once transmitted groundwater prior to dewatering.

References Cited

1,000 Friends of Florida, 2006, accessed November 16, 2006, at *http://www.1000friendsofflorida.org/PUBS/Apalachee/aucilla.asp*.

Albertson, P.N., and Torak, L.J., 2002, Simulated effects of ground-water pumpage on stream-aquifer flow in the vicinity of federally protected species of freshwater mussels in the lower Apalachicola–Chattahoochee–Flint River Basin (Subarea 4), southeastern Alabama, northwestern Florida, and southwestern Georgia: U.S. Geological Survey Water-Resources Investigations Report 02–4016, 48 p.

Applin, P.L., 1951, Preliminary report on buried pre-Mesozoic rocks in Florida and adjacent states: U.S. Geological Survey Circular 91, 20 p.

Applin, E.R., and Applin, P.L., 1964, Logs of selected wells in the coastal plains of Georgia: Georgia Geological Survey Bulletin Number 74, 229 p.

Applin, P.L., and Applin, E.R., 1944, Regional subsurface stratigraphy and structure of Florida and southern Georgia: Bulletin of the American Association of Petroleum Geologists, v. 28, no. 12, p. 1673–1742.

Arthur, J.D., and Rupert, F.R., 1989, Selected geomorphic features of Florida, *in* The lithostratigraphy and hydrostratigraphy of the Floridan aquifer system in Florida, field trip guidebook T185, Tampa to Tallahassee, Florida, July 1–7, 1989: American Geophysical Union, p. T185:10–14.

Banks, J.E., and Hunter, M.E., 1973, Post-Tampa, pre-Chipola sediments exposed in Liberty, Gadsden, Leon, and Wakulla Counties, Florida: Gulf Coast Association of Geological Societies Transactions, v. 25, p. 122–142.

Bush, P.W., and Johnston, R.H., 1988, Ground-water hydraulics, regional flow, and ground-water development of the Floridan aquifer system in Florida and in parts of Georgia, South Carolina, and Alabama: U.S. Geological Survey Professional Paper 1403–C, 80 p.

Carter, R.F., and Johnson, A.M.F., 1974, Use of water in Georgia, 1970, with projections to 1990: Georgia Department of Natural Resources, Hydrologic Report 2, 74 p.

Ceryak, Ron, 1977, Hydrogeology of a river basin in a karst terrain, Alapaha River, Hamilton County, Florida: Suwannee River Water Management District Information Circular Series IC–5, 20 p.

Ceryak, Ron, Knapp, M.S., and Burnson, Terry, 1983, The geology and water resources of the upper Suwannee River Basin, Florida: Florida Bureau of Geology Report of Investigations No. 87, 165 p.

Chen, C.S., 1965, The regional lithostratigraphic analysis of Paleocene and Eocene rocks of Florida: Florida Geological Survey Bulletin 45, 105 p.

Clark, W.Z., and Zisa, A.C., 1976, Physiographic map of Georgia: Georgia Geologic Survey, OM–8.

Clarke, J.S., Leeth, D.C., Taylor-Harris, DáVette, Painter, J.A., and Labowski, J.L., 2005, Summary of hydraulic properties of the Floridan aquifer system in coastal Georgia and adjacent parts of South Carolina and Florida: U.S. Geological Survey Scientific Investigations Report 2004–5264, 54 p.

Cooke, C.W., 1939, Scenery of Florida interpreted by a geologist: Florida Geological Survey Bulletin 17, 118 p.

Cooke, C.W., 1943, Geology of the Coastal Plain of Georgia: U.S. Geological Survey Bulletin 941, 121 p.

Cox, J.A., Baker, W.W., and Engstrom, R.T., 2001, Red-cockaded woodpeckers in the Red Hills region—A GIS-based assessment: Wildlife Society Bulletin, v. 29, no. 4, p. 1278–1288.

Crandall, C.A., Katz, B.G., and Hirten, J.J., 1999, Hydrochemical evidence for mixing of river water and groundwater during high-flow conditions, lower Suwannee River basin, Florida, USA: Hydrogeology Journal, v. 7, no. 5, p. 454–467.

Dall, W.H., and Harris, G.D., 1892, Correlation papers—Neogene: U.S. Geological Survey Bulletin 9, 197 p.

Davis, Hal, 1996a, Hydrogeologic investigation and simulation of ground-water flow in the Upper Floridan aquifer of north-central Florida and southwestern Georgia and delineation of contributing areas for selected city of Tallahassee, Florida, water-supply wells: U.S. Geological Survey Water-Resources Investigations Report 95–4296, 61 p.

Davis, M.B., 1996b, Eastern old-growth forests: prospects for rediscovery and recovery: Washington, D.C., Island Press, 400 p.

Davis, S.N., and DeWiest, R.J.M., 1966, Hydrogeology: New York, John Wiley and Sons, Inc., 463 p.

Falls, W.F., Harrelson, L.G., Conlon, K.J., and Petkewich, M.D., 2005, Hydrogeology, water quality, and water-supply potential of the Lower Floridan aquifer, coastal Georgia, 1999–2002: U.S. Geological Survey Scientific Investigations Report 2005–5124, 89 p., 1 pl.

Fanning, J.L., 1997, Water use in Georgia by county for 1995: Georgia Geologic Survey Information Circular 101, 95 p.

Fanning, J.L., 2003, Water use in Georgia by county for 2000 and water-use trends for 1980–2000: Georgia Geologic Survey Information Circular 106, 176 p.

Fanning, J.L., Doonan, G.A., and Montgomery, L.T., 1992, Water use in Georgia by county for 1990: Georgia Geologic Survey Information Circular 90, 98 p.

Fenneman, N.M., 1938, Physiography of the eastern United States: New York, McGraw-Hill, Inc., 714 p.

Florida Geological Survey, 1986, Hydrogeological units of Florida, compiled by the Southeastern Geological Society Ad Hoc Committee on Florida Hydrostratigraphic Unit Definition: Florida Geological Society Special Publication 28, 9 p.

Gelbaum, Carol, 1978, The geology and groundwater of the Gulf Trough: Georgia Geologic Survey Bulletin 93, p. 38–47.

Gelbaum, Carol, and Howell, Julian, 1982, The geohydrology of the Gulf Trough, *in* Arden, P.D., Beck, B.F., and Morrow, Elanore, eds., Proceedings of the Second Symposium on the Geology of the Southeastern Coastal Plain: Georgia Geologic Survey Information Circular 53, p. 140–153.

Georgia Department of Environmental Protection, 2008, Georgia Comprehensive State-wide Water Management Plan, accessed on August 19, 2009, at *http://www.georgiawatercouncil.org/Files_PDF/water_plan_20080109.pdf*.

Harrison, K.A., 2001, Agricultural irrigation trends in Georgia, *in* Hatcher, K.J. ed., Proceedings of the 2001 Georgia Water Resources Conference, March 26–27, 2001, Athens, Georgia, The University of Georgia, Institute of Ecology, p. 114–117.

Harrison, K.A., and Tyson, Anthony, 1999, Agricultural irrigation trends in Georgia, *in* Hatcher, K.J. ed., Proceedings of the 1999 Georgia Water Resources Conference, March 30–31, 1999, Athens, Georgia, The University of Georgia, Institute of Ecology, p. 421–424.

Hendry, C.W., Jr., and Sproul, D.R., 1966, Geology and groundwater resources of Leon County, Florida: Florida Geological Survey Bulletin 47, 178 p.

Herrick, S.M., 1961, Well logs of the Coastal Plain of Georgia: Georgia Geologic Survey Bulletin 70, 462 p.

Herrick, S.M., and Vorhis, R.C., 1963, Subsurface geology of the Georgia Coastal Plain: Georgia Geological Survey Information Circular 25, 67 p.

Hine, A.C., Brooks, G.R., Davis, R.A., Jr., Doyle, L.J., Gelfenbaum, G., Locker, S.D., Twichell, D.C., and Weisberg, R.H., 2001, A summary of findings of the West-Central Florida Coastal Studies Project: U.S. Geological Survey Open-File Report 01–303, 41 p., accessed December 8, 2006, at *http://pubs.usgs.gov/of/2001/of01-303/pdf.html*.

Huddlestun, P.F., 1988, A revision of the lithostratigraphic units of the Coastal Plain of Georgia: Georgia Geologic Survey Bulletin 104, 162 p.

Jones, L.E., and Torak, L.J., 2004, Simulated effects of impoundment of Lake Seminole on ground-water flow in the Upper Floridan aquifer in southwestern Georgia and adjacent parts of Alabama and Florida: U.S. Geological Survey Scientific Investigations Report 2004–5077, 18 p., accessed September 13, 2005, at *http://pubs.usgs.gov/sir/2004/5077/pdf/SIR2004-5077.pdf*.

Jones, L.E., and Torak, L.J., 2006, Simulated effects of seasonal ground-water pumpage for irrigation on hydrologic conditions in the lower Apalachicola–Chattahoochee–Flint River Basin, southwestern Georgia and parts of Alabama and Florida, 1999–2002: U.S. Geological Survey Scientific Investigations Report 2006–5234, 106 p.

Jordan, Louise, 1954, Oil possibilities in Florida: Oil and Gas Journal, v. 53, no. 28, p. 370–375.

Katz, B.G., 1992, Hydrochemistry of the Upper Floridan aquifer, Florida: U.S. Geological Survey Water-Resources Investigations Report 91–4196, 37 p.

Katz, B.G., 1998, Using delta 18O and delta D to quantify groundwater/surface-water interactions in karst systems of Florida, *in* Proceedings of the 1998 National Water Quality Monitoring Conference, July 7–9, Reno, Nevada, 14 p.

Katz, B.G., DeHan, R.S., Hirten, J.J., and Catches, J.S., 1997, Interactions between ground water and surface water in the Suwannee River basin, Florida: Journal of the American Water Resources Association, v. 33, no. 6, p. 1237–1254.

Katz, B.G., Lee, T.M., Plummer, L.N., and Busenberg, Eurybiades, 1995a, Chemical evolution of groundwater near a sinkhole lake, northern Florida; 1, Flow patterns, age of groundwater, and influence of lake water leakage: Water Resources Research, v. 31, no. 6, p. 1549–1564.

Katz, B.G., Plummer, L.N., Busenberg, Eurybiades, Reves, K.M., Jones, B.F., and Lee, T.M., 1995b, Chemical evolution of groundwater near a sinkhole lake, northern Florida; 2, Chemical patterns, mass transfer modeling, and rates of mass transfer reactions: Water Resources Research, v. 31, no. 6, p. 1565–1584.

Kellam, M.F., and Gorday, L.L., 1990, Hydrogeology of the Gulf Trough–Apalachicola Embayment area, Georgia: Georgia Geologic Survey Bulletin 94, 74 p.

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

Leitman, H.M., Sohm, J.E., and Franklin, M.A., 1984, Wetland hydrology and tree distribution of the Apalachicola River flood plain, Florida: U.S. Geological Survey Water-Supply Paper 2196–A, 52 p.

Leve, G.W., 1968, The Floridan aquifer in northeast Florida: Ground Water, v. 6, no. 2, p. 19–29.

Litts, Thomas, Thomas, Adrian, and Welch, Roy, 2001, Mapping irrigated lands in southwest Georgia: The University of Georgia, Center for Remote Sensing and Mapping Science, Department of Geography, Final Report, Cooperative Agreement No. 649–990205, 56 p.

MacNeil, F.S., 1947, Geologic map of the Tertiary and Quaternary Formations of Georgia: U.S. Geological Survey Oil and Gas Inventory (Preliminary) Map 72, 1 sheet, scale 1:500,000.

Matthews, S.E., Hester, W.G., and O'Byrne, M.P., 1980, Ground-water data for Georgia, 1979: U.S. Geological Survey Open-File Report 80–501, 93 p.

Matthews, S.E., and Krause, R.E., 1984, Hydrogeologic data from the U.S. Geological Survey test wells near Waycross, Ware County, Georgia: U.S. Geological Survey Water-Resources Investigations Report 83–4204, 29 p.

McCallie, S.W., 1898, A preliminary on the artesian-well system of Georgia: Georgia Geologic Survey Bulletin 7, 214 p.

McCallie, S.W., 1908, A preliminary report on the underground waters of Georgia: Georgia Geological Survey Bulletin 15, 360 p.

McConnell, J.B., and Hacke, C.M., 1993, Hydrogeology, water quality, and water-resources development potential of the Upper Floridan aquifer in the Valdosta area, south-central Georgia: U.S. Geological Survey Water-Resources Investigations Report 93–4044, 44 p.

McFadden, S.S., Hetrick, J.H., Kellam, M.F., Rodenbeck, S.A., and Huddlestun, P.F., 1986, Geologic data of the Gulf Trough area, Georgia: Georgia Geologic Survey Information Circular 56, 345 p.

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.

Miller, J.A., 1988, Geohydrologic data from the Floridan aquifer system in Florida and in parts of Georgia, South Carolina, and Alabama: U.S. Geological Survey Open-File Report 88–86, 678 p., accessed April 30, 2009, at *http://pubs.er.usgs.gov/djvu/OFR/1988/ofr_88_86.djvu*.

Miller, J.A., 1990, Ground-water atlas of the United States, Section 6, Alabama, Florida, Georgia, and South Carolina: U.S. Geological Survey Hydrologic Atlas HA 730–G, 28 p.

Mineral Gallery, 2008, The mineral monazite, accessed June 27, 2008, at *http://www.galleries.com/minerals/phosphat/monazite/monazite.htm*.

Moore, W.E., 1955, Geology of Jackson County, Florida: Florida Geological Survey Bulletin 37, 101 p.

Mosner, M.S., 2002, Stream-aquifer relations and the potentiometric surface of the Upper Floridan aquifer in the lower Apalachicola–Chattahoochee–Flint River Basin in parts of Georgia, Florida, and Alabama, 1999–2000: U.S. Geological Survey Water-Resources Investigations Report 02–4244, 45 p., accessed September 13, 2005, at *http://ga.water.usgs.gov/pubs/wrir/wrir02-4244/*.

National Oceanic and Atmospheric Administration, 2002, Climatological data annual summary, 2001: National Oceanic and Atmospheric Administration, v. 105, no. 13, 28 p.

National Oceanic and Atmospheric Administration, 2008, Web Climate Services, accessed February 14, 2008, at *http://www.ncdc.noaa.gov/oa/climate/stationlocator.html*.

National Oceanic and Atmospheric Administration, 2009, National Climate Data Center, Locate Weather Station, accessed March 26, 2009, at *http://www4.ncdc.noaa.gov/cgi-win/wwcgi.dll?WWDI~getstate~USA*.

Patterson, S.H., and Herrick, S.M., 1971, Chattahoochee anticline, Apalachicola Embayment, Gulf Trough, and related structural features, southwestern Georgia—Fact or fiction: Georgia Geologic Survey Information Circular 41, 16 p.

Payne, D.F., Rumman, M.A., and Clarke, J.S., 2005, Simulation of groundwater flow in coastal Georgia and adjacent parts of South Carolina and Florida—Predevelopment, 1980, and 2000: U.S. Geological Survey Scientific Investigations Report 2005–5089, 91 p., accessed June 2, 2009, at *http://pubs.water.usgs.gov/sir2005-5089*.

Pierce, R.R., Barber, N.L., and Stiles, H.R., 1984, Georgia irrigation, 1970–80—A decade of growth: U.S. Geological Survey Water-Resources Investigations Report 83–4177, 29 p.

Pittman, J.R., and Berndt, M.P., 2003, Occurrence of herbicide degradation compounds in streams and ground water in agricultural areas of southern Georgia, 2002: *in* Hatcher, K.J. ed., Proceedings of the 2003 Georgia Water Resources Conference, April 23–24, 2003, Athens, Georgia, The University of Georgia, Institute of Ecology, 4 p., accessed March 6, 2009, at *http://ga.water.usgs.gov/pubs/other/gwrc2003/pdf/Berndt-GWRC2003.pdf*.

Planert, Michael, 2007, Simulation of regional ground-water flow in the Suwannee River Basin, northern Florida and southern Georgia: U.S. Geological Survey Scientific Investigations Report 2007–5031, 56 p.

Plummer, L.N., Busenberg, Eurybiades, Drenkard, Stefan, Schlosser, Peter, Ekwurzel, Brenda, Weppernig, Ralf, McConnell, J.B., and Michel, R.L., 1998a, Flow of river water into a karstic limestone aquifer; 2, Dating the young fraction in groundwater mixtures in the upper Floridan aquifer near Valdosta, Georgia: Applied Geochemistry, v. 13, no. 8, p. 1017–1043.

Plummer, L.N., Busenberg, Eurybiades, McConnell, J.B., Drenkard, Stefan, Schlosser, Peter, and Michel, R.L., 1998b, Flow of river water into a karstic limestone aquifer; 1, Tracing the young fraction in groundwater mixtures in the upper Floridan aquifer near Valdosta, Georgia: Applied Geochemistry, v. 13, no. 8, p. 995–1015.

Pratt, T.R., Richards, C.J., Milla, K.A., Wagner, J.R., Johnson, J.L., and Curry, R.J., 1996, Hydrogeology of the Northwest Florida Water Management District: Northwest Florida Water Management District Water Resources Special Report 96–4, 98 p.

Priest, Sherlyn, 2004, Evaluation of ground-water contribution to streamflow in coastal Georgia and parts of Florida and South Carolina: U.S. Geological Survey Scientific Investigations Report 2004–5265, 46 p., accessed June 2, 2009, at *http://pubs.usgs.gov/sir/2004/5265/*.

Puri, H.S., 1953, Contribution to the study of the Miocene of the Florida Panhandle: Florida Geological Survey Bulletin 36, 345 p.

Puri, H.S., and Vernon, R.O., 1964, Summary of the geology of Florida and a guidebook to the classic exposures: Florida Geological Survey Special Publication 5, revised, 312 p.

Raulston, Marvin, Johnson, Cindy, Webster, Kirk, Purdy, Carolyn, and Ceryak, Ron, 1998, Suwannee River Water Management District, *in* Fernald, E.A., and Purdum, E.D., eds., Water Resources Atlas of Florida: Tallahassee, Florida, Florida State University, Institute of Public Affairs, p. 194–213.

Rupert, F.R., 1990, Geology of Gadsden County, Florida: Florida Geological Survey Bulletin 62, 61 p.

Samet, J.M., and Nero, A.V., 1989, Indoor radon and lung cancer: The New England Journal of Medicine, v. 320, no. 9, p. 591–594.

Schmidt, Walter, 1984, Neogene stratigraphy and geologic history of the Apalachicola Embayment, Florida: Florida Bureau of Geology Bulletin 57, 96 p.

Schwaner, T.D., and Mount, R.H., 1970, Notes on the distribution, habits, and ecology of the salamander *Phaeognathus hubrichti* Highton: Copeia, v. 1970, no. 3, p. 571–573.

Scott, T.M., 1986, The lithostratigraphic relationships of the Chattahoochee, St. Marks, and Torreya formations, eastern Florida Panhandle [abs.]: Florida Academy of Sciences, Florida Scientist, v. 49, supplement 1.

Scott, T.M., 1992, A geological overview of Florida: Florida Geological Survey Open-File Report 50, 78 p.

Sever, C.W., 1964, Relation of economic deposits of attapulgite and fuller's earth to geologic structure in southwestern Georgia: U.S. Geological Survey Professional Paper 501–B, p. B116–B118.

Sever, C.W., 1965, Ground-water resources and geology of Seminole, Decatur and Grady Counties, Georgia: U.S. Geological Survey Water-Supply Paper 1809–Q, 30 p.

Sever, C.W., 1966, Reconnaissance of the ground water and geology of Thomas County, Georgia: Georgia Geological Survey Information Circular 34, 14 p.

Sever, C.W., and Herrick, S.M., 1967, Tertiary stratigraphy and geohydrology in southwestern Georgia: U.S. Geological Survey Professional Paper 575–B, p. 50–53.

Sever, C.W., 1972, Ground-water resources and geology of Cook County, Georgia: U.S. Geological Survey Open-file Report (unnumbered), 40 p.

Southeast Regional Climate Center, 2008a, Tallahassee WSO AP, Florida (088758), accessed February 19, 2008, at *http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?fl8758*.

Southeast Regional Climate Center, 2008b, Lake City 2 E, Florida, (084731), accessed February 19, 2008, at *http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?fl4731*.

Southeast Regional Climate Center, 2008c, Cordele, Georgia (092266), accessed February 19, 2008, at *http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?ga2266*.

Southeast Regional Climate Center, 2008d, Waycross 4 NE, Georgia (099186), accessed February 19, 2008, at *http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?ga9186*.

Southeast Regional Climate Center, 2008e, Ashburn 3 ENE, Georgia (090406), accessed July 9, 2008, at *http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?ga0406*.

Southeast Regional Climate Center, 2008f, Cairo 2 N, Georgia (091463), accessed July 9, 2008, at *http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?ga1463*.

Southeast Regional Climate Center, 2008g, Folkston 9 SW, Georgia (093465), accessed July 9, 2008, at *http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?ga3465*.

Southeast Regional Climate Center, 2008h, Homerville, Georgia (094429), accessed July 10, 2008, at *http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?ga4429*.

Southeast Regional Climate Center, 2008i, Moultrie 2 ESE, Georgia (096087), accessed July 9, 2008, at *http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?ga6087*.

Southeast Regional Climate Center, 2008j, Quitman 2 NW, Georgia (097276), accessed July 9, 2008, at *http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?ga7276*.

Southeast Regional Climate Center, 2008k, Tifton Exp Stn, Georgia (098703), accessed July 9, 2008, at *http://www.sercc.com/cgi-bin/sercc/cliMAIN.pl?ga8703*.

Sprinkle, C.L., 1989, Geochemistry of the Floridan Aquifer System in Florida and in parts of Georgia, South Carolina, and Alabama: U.S. Geological Survey Professional Paper 1403–I, 105 p.

Stephenson, L.W., and Veatch, J.O., 1915, Underground waters of the Coastal Plain of Georgia and a discussion of the quality of the waters, by R.B. Dole: U.S. Geological Survey Water-Supply Paper 341, 539 p.

Stokes, W.R., III, McFarlane, R.K., and Buell, G.R., 1990, Water resources data, Georgia, water year 1989: U.S. Geological Survey Water Data Report GA–89–1, 513 p.

Thomson, M.T., Herrick, S.M., and Brown, Eugene, 1956, Availability and use of water in Georgia: Georgia Geologic Survey Bulletin 65, 329 p.

Torak, L.J., Crilley, D.M., and Painter, J.A., 2006, Physical and hydrochemical evidence of lake leakage near Jim Woodruff Lock and Dam and assessment of karst features in and near Lake Seminole, southwestern Georgia and northwestern Florida: U.S. Geological Survey Scientific Investigations Report 2005–5084, 90 p.

Torak, L.J., Davis, G.S., Strain, G.A., and Herndon, J.G., 1996, Geohydrology and evaluation of stream-aquifer relations in the Apalachicola–Chattahoochee–Flint River Basin, southeastern Alabama, northwestern Florida, and southwestern Georgia: U.S. Geological Survey Water-Supply Paper 2460, 94 p.

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

Torak, L.J., and Painter, J.A., 2006, Geohydrology of the lower Apalachicola–Chattahoochee–Flint River Basin, southwestern Georgia, northwestern Florida, and southeastern Alabama: U.S. Geological Survey Scientific Investigations Report 2006–5070, 80 p., accessed June 2, 2009, at *http://pubs.usgs.gov/sir/2006/5070/*.

Turlington, M.C., Fanning, J.L., and Doonan, G.A., 1987, Water use in Georgia by county for 1985: Georgia Geologic Survey Information Circular 81, 109 p.

U.S. Geological Survey, 2006, NAWQA Program—Georgia–Florida Coastal Plain Drainages (GAFL) study unit, Georgia-Florida Coastal Plain Publications, accessed on April 2, 2010, at *http://fl.water.usgs.gov/NAWQA/*.

U.S. Geological Survey, 2008, National Elevation Dataset, accessed on August 6, 2008, at *http://ned.usgs.gov/*.

Vorhis, R.C., 1972, Geohydrology of Sumter, Dooly, Pulaski, Lee, Crisp, and Wilcox Counties, Georgia: U.S. Geological Survey Hydrologic Atlas HA–435, 2 sheets.

Wait, R.L., 1960, Source and quality of ground water in southwestern Georgia: Georgia Geologic Survey Information Circular 18, 43 p.

Wakulla County Tourist Development Council, 2007, The Rivers of Wakulla, accessed November 16, 2006, at *http://www.wakullacounty.org/wakulla-32.htm*.

Winston, G.O., 1976, Florida's Ocala Uplift is not an uplift: Bulletin of the American Association of Petroleum Geologists, v. 60, no. 6, p. 992–994.

Yon, J.W., 1966, Geology of Jefferson County, Florida: Florida Bureau of Geology Bulletin 48, 119 p.

Zimmerman, E.A., 1977, Ground-water resources of Colquitt County, Georgia: U.S. Geological Survey Open-File Report 77–56, 41 p.

Appendix. Geohydrologic Data

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

County	Well name	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet above NAVD 88)	Well depth (feet)	Hole depth (feet)
Florida						
Alachua	FLA-BRA-1[g]	29.63084595	–82.29292489	132	3,167	3,167
Baker	FLA-BA-1[g]	30.48772863	–82.320641592	124	3,348	3,348
Baker	FLA-BA-2[g]	30.43913052	–82.292940415	116	902	902
Baker	FLA-BA-4[g]	30.25993411	–82.272038242	158	722	722
Bradford	FLA-BRA-2[g]	29.93914104	–82.109527365	165	283	283
Bradford	FLA-BRA-3[g]	30.13773875	–82.062330567	175	3,171	3,171
Clay	FLA-CL-7[g]	30.06273955	–82.033128393	175	3,439	3,439
Columbia	FLA-BA-3[g]	30.16273460	–82.460941324	145	3,043	3,043
Columbia	FLA-CO-1[g]	30.47522165	–82.59984844	124	4,285	4,285
Columbia	FLA-CO-3[g]	30.15853306	–82.57484386	164	2,828	2,828
Columbia	FLA-CO-4[g]	30.06413507	–82.595643121	115	2,929	2,929
Columbia	FLA-CO-9[g]	30.27272922	–82.618146147	144	3,198	3,198
Duval	FLA-DUV-2[g]	30.23353829	–82.037331871	85	3,521	3,521
Gadsden	AT180[n]	30.69019166	–84.805919259	174	—	—
Gadsden	City of Quincy No. 2[g]	30.59852791	–84.579910278	150	1,346	—
Gadsden	FLA-GA-10[g]	30.53849362	–84.785716052	262	4,223	4,223
Gadsden	FLA-GA-11[g]	30.54439511	–84.614912247	197	4,196	4,196
Gadsden	McDonald No 1[n]	30.58991623	–84.656028748	284	4,223	—
Gadsden	O-347[n]	30.68119297	–84.596913653	294	—	—
Gadsden	Owenby Farm oil test[n]	30.54186249	–84.561019897	201	7,028	7,028
Gadsden	W-12078[n]	30.60409575	–84.468208678	198	—	—
Gadsden	W-15468[n]	30.67439477	–84.409607133	210	447	447
Gadsden	W-15795[n]	30.51959753	–84.464307553	200	402	402
Gadsden	W-1768[n]	30.58989286	–84.777716913	291	4,240	4,240
Gadsden	W-3276[n]	30.58419443	–84.614912807	279	—	—
Gadsden	W-3504[n]	30.62769572	–84.414106806	240	692	692
Gadsden	W-3577[n]	30.55630493	–84.886581421	—	—	4,025
Gadsden	W-3776[n]	30.54659347	–84.780716153	256	—	—
Gadsden	W-4404[n]	30.65629243	–84.690515977	295	—	—
Gadsden	W-4925[n]	30.56189494	–84.604912226	216.60	185	4,185
Gadsden	W-4[n]	30.60019467	–84.573011883	149.75	898	898
Gadsden	W-5201[n]	30.60599358	–84.656014246	288.17	467	467
Gadsden	W-7472[n]	30.55439553	–84.570711213	255	472	472
Gadsden	W-7528[n]	30.58079655	–84.431606979	230	442	442
Hamilton	FLA-HAM-1[g]	30.43632120	–82.770651692	128	1,418	1,418

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

Well name	Top altitude, Upper Floridan aquifer	Bottom altitude, Upper Floridan aquifer	Top altitude, Tampa Limestone	Top altitude, Suwannee Limestone	Top altitude, Ocala Limestone	Top altitude, Lisbon or Avon Park Formation	Top altitude, Tallahatta Formation	Top altitude, Wilcox Group
	Feet above or below NAVD 88							
Florida								
FLA-BRA-1[g]	–63	–938	—	—	—	—	—	—
FLA-BA-1[g]	–196	–1,089	—	—	—	—	—	—
FLA-BA-2[g]	–272	—	—	—	—	—	—	—
FLA-BA-4[g]	–150	—	—	—	—	—	—	—
FLA-BRA-2[g]	–101	—	—	—	—	—	—	—
FLA-BRA-3[g]	–189	–533	—	—	—	—	—	—
FLA-CL-7[g]	–226	–642	—	—	—	—	—	—
FLA-BA-3[g]	–68	–884	—	—	—	—	—	—
FLA-CO-1[g]	–57	–467	—	—	—	—	—	—
FLA-CO-3[g]	—	–838	—	—	—	—	—	—
FLA-CO-4[g]	35	–885	—	—	—	—	—	—
FLA-CO-9[g]	–22	–828	—	—	—	—	—	—
FLA-DUV-2[g]	—	–764	—	—	—	—	—	—
AT180[n]	60	–634	—	—	—	—	—	—
City of Quincy No. 2[g]	–185	—	—	—	—	—	—	—
FLA-GA-10[g]	142	–830	—	—	—	—	—	—
FLA-GA-11[g]	—	–988	—	—	—	—	—	—
McDonald No 1[n]	–286	–696	—	—	—	—	—	—
O-347[n]	–100	–600	—	—	—	—	—	—
Owenby Farm oil test[n]	–279	—	—	—	—	—	—	—
W-12078[n]	–219	—	—	—	—	—	—	—
W-15468[n]	–205	—	—	—	—	—	—	—
W-15795[n]	–160	—	—	—	—	—	—	—
W-1768[n]	–80	—	—	—	—	—	—	—
W-3276[n]	–258	—	—	—	—	—	—	—
W-3504[n]	–266	—	—	—	—	—	—	—
W-3577[n]	–135	–845	—	—	—	—	—	—
W-3776[n]	–208	—	—	—	—	—	—	—
W-4404[n]	–77	—	—	—	—	—	—	—
W-4925[n]	–303	—	—	—	—	—	—	—
W-4[n]	–230	–880	—	—	—	—	—	—
W-5201[n]	–179	—	—	—	—	—	—	—
W-7472[n]	–180	—	—	—	—	—	—	—
W-7528[n]	–179	—	—	—	—	—	—	—
FLA-HAM-1[g]	10	–878	—	—	—	—	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

County	Well name	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet above NAVD 88)	Well depth (feet)	Hole depth (feet)
			Florida			
Jefferson	FLA-JEF-1[g]	30.37350382	–83.983187522	39	7,913	7,913
Leon	FLA-LN-1[g]	30.31190320	–84.116591778	30	6,520	6,520
Leon	FLA-LN-2[g]	30.31190240	–84.194894845	17	10,466	10,466
Leon	FLA-LN-4[g]	30.38739714	–84.645710696	41	525	525
Leon	Hopkins Plant #3[g]	30.45519829	–84.397956848	138	406	425
Leon	Lake Talquin core[n]	30.41130829	–84.599906921	95	422	422
Leon	W-6599[n]	30.38759714	–84.645010682	61	525	525
Leon	W-6902[n]	30.51829888	–84.324302177	80	158	158
Leon	W-6937[n]	30.59269903	–84.05459255	245	248	248
Leon	W-6998[n]	30.58849858	–84.151296202	237	227	227
Leon	W-7181[n]	30.58459822	–84.227999085	249	262	262
Liberty	AT095[n]	30.29119736	–84.982915394	52	—	—
Liberty	O-83[n]	30.37819684	–84.68691154	89	—	—
Liberty	O-93[n]	30.42219591	–84.874915112	173	—	—
Liberty	W-15497[n]	30.59579365	–84.901618615	245	302	302
Liberty	W-15498[n]	30.57689391	–84.897718089	264	504	504
Liberty	W-15499[n]	30.58269394	–84.914118434	255	501	501
Liberty	W-15500[n]	30.50619569	–84.975916911	212	348	348
Liberty	W-15501[n]	30.54489483	–84.95071781	245	404	404
Liberty	W-6025[n]	30.42919634	–84.97791626	168	—	—
Liberty	W-6901[n]	30.46909605	–84.979316546	82	527	527
Madison	FLA-MAD-1[g]	30.40021588	–83.236563825	86	3,333	3,333
Madison	FLA-MAD-2[g]	30.43021249	–83.358167708	102	5,385	5,385
Madison	FLA-MAD-3[g]	30.30691821	–83.260663294	84	3,450	3,450
Suwannee	FLA-LAF-1[g]	30.14462146	–83.230460443	43	4,235	4,235
Suwannee	FLA-SUW-4[g]	30.28632600	–82.822050206	152	3,572	3,572
Suwannee	FLA-SUW-6[g]	30.20022274	–83.133157457	85	3,819	3,819
Suwannee	FLA-SUW-7[g]	30.07382990	–82.826248372	86	3,139	3,139
Taylor	FLA-TAY-4[g]	29.95521819	–83.439864512	57	4,877	4,877
Taylor	FLA-TAY-7[g]	30.02801141	–83.812377031	126	3,036	7,502
Union	FLA-UN-2[g]	30.04193712	–82.531541396	126	3,036	3,036
Wakulla	FLA-WAK-1[g]	30.22520347	–84.19989402	28	5,766	5,766
Wakulla	FLA-WAK-2[g]	30.27379969	–84.533206441	85	11,735	11,735
Wakulla	O-75[n]	30.30019819	–84.682910219	75	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

Well name	Top altitude, Upper Floridan aquifer	Bottom altitude, Upper Floridan aquifer	Top altitude, Tampa Limestone	Top altitude, Suwannee Limestone	Top altitude, Ocala Limestone	Top altitude, Lisbon or Avon Park Formation	Top altitude, Tallahatta Formation	Top altitude, Wilcox Group
	Feet above or below NAVD 88							
Florida								
FLA-JEF-1[g]	29	–860	—	—	—	—	—	—
FLA-LN-1[g]	20	–1,895	—	—	—	—	—	—
FLA-LN-2[g]	—	–1,685	—	—	—	—	—	—
FLA-LN-4[g]	–87	—	—	—	—	—	—	—
Hopkins Plant #3[g]	35	—	—	—	—	—	—	—
Lake Talquin core[n]	–289	—	—	—	—	—	—	—
W-6599[n]	–291	—	—	—	—	—	—	—
W-6902[n]	–51	—	—	—	—	—	—	—
W-6937[n]	8	—	—	—	—	—	—	—
W-6998[n]	19	—	—	—	—	—	—	—
W-7181[n]	11	—	—	—	—	—	—	—
AT095[n]	–120	–680	—	—	—	—	—	—
O-83[n]	–220	—	—	—	—	—	—	—
O-93[n]	–195	–680	—	—	—	—	—	—
W-15497[n]	–56	—	—	—	—	—	—	—
W-15498[n]	–98	—	—	—	—	—	—	—
W-15499[n]	–69	—	—	—	—	—	—	—
W-15500[n]	–136	—	—	—	—	—	—	—
W-15501[n]	–157	—	—	—	—	—	—	—
W-6025[n]	–50	—	—	—	—	—	—	—
W-6901[n]	–218	—	—	—	—	—	—	—
FLA-MAD-1[g]	—	–703	—	—	—	—	—	—
FLA-MAD-2[g]	102	–707	—	—	—	—	—	—
FLA-MAD-3[g]	—	–764	—	—	—	—	—	—
FLA-LAF-1[g]	43	—	—	—	—	—	—	—
FLA-SUW-4[g]	—	–768	—	—	—	—	—	—
FLA-SUW-6[g]	55	—	—	—	—	—	—	—
FLA-SUW-7[g]	—	–761	—	—	—	—	—	—
FLA-TAY-4[g]	57	—	—	—	—	—	—	—
FLA-TAY-7[g]	11	—	—	—	—	—	—	—
FLA-UN-2[g]	11	–980	—	—	—	—	—	—
FLA-WAK-1[g]	—	–2,102	—	—	—	—	—	—
FLA-WAK-2[g]	–110	–1,770	—	—	—	—	—	—
O-75[n]	–250	–710	—	—	—	—	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

County	Well name	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet above NAVD 88)	Well depth (feet)	Hole depth (feet)
			Georgia			
Atkinson	22J001[g]	31.26687050	–82.9498672485352	217	4,296	4,296
Ben Hill	18N001[e]	31.77240372	–83.4084930419922	365	240	240
Ben Hill	18N002[n]	31.81101418	–83.4237747192383	378	202	202
Ben Hill	18N003[e]	31.79684830	–83.4348831176758	374	215	215
Ben Hill	19J009[n]	31.27361107	–83.2694473266602	255	217	217
Ben Hill	19M001[n]	31.71546364	–83.2618179321289	357	612	—
Ben Hill	19M025[n]	31.74583244	–83.2925033569336	369	310	310
Ben Hill	19M026[n]	31.74111176	–83.2602767944336	372	310	310
Ben Hill	19M027[n]	31.68972206	–83.3011093139648	354	370	370
Ben Hill	19M028[n]	31.70750046	–83.2641677856445	335	716	716
Ben Hill	19M029[b]	31.70555496	–83.2750015258789	355	390	390
Ben Hill	19N003[e]	31.75657272	–83.2965469360352	361	310	310
Ben Hill	20M002[n]	31.71740913	–83.244873046875	354.56	825	825
Ben Hill	20M003[n]	31.71768570	–83.244873046875	359.28	739	750
Ben Hill	20M007[e]	31.71185303	–83.1682052612305	345	368	368
Ben Hill	20M008[e]	31.65879822	–83.2390441894531	334	420	420
Ben Hill	20N002[e]	31.83101654	–83.1579284667969	197	390	390
Ben Hill	20N004[e]	31.77546120	–83.2201538085937	251	232	232
Ben Hill	21N002[n]	31.77601814	–83.1059799194336	262	240	240
Berrien	19H024[n]	31.20742035	–83.2548751831055	222.13	333	333
Berrien	19J002[b]	31.29944420	–83.2569427490234	252	317	317
Berrien	19K002[e]	31.46333122	–83.3467025756836	311	575	—
Berrien	19K003[e]	31.46806145	–83.3380966186523	308	500	500
Berrien	19K004[f]	31.41388893	–83.2744445800781	319	530	530
Berrien	20G005[e]	31.09325600	–83.2118225097656	214	310	310
Berrien	20H002[e]	31.15880966	–83.2373733520508	224	340	340
Berrien	20H003[e]	31.20964241	–83.2309875488281	239.60	485	485
Berrien	20J001[n]	31.36575127	–83.2273788452148	276	500	—
Berrien	20K002[e]	31.38380623	–83.22265625	291	550	550
Berrien	20K005[n]	31.37991714	–83.2193222045898	285	580	580
Brantley	29J002[g]	31.25916672	–82.0552749633789	69	850	850
Brantley	30H021[g]	31.1875	–81.9655532836914	75	950	950
Brantley	30J005[g]	31.28972244	–81.9499969482422	42	4,513	4,513
Brantley	31H017[g]	31.14644432	–81.8580093383789	60	764	—
Brooks	16D001[n]	30.73305511	–83.7347259521484	178	180	180

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

Well name	Top altitude, Upper Floridan aquifer	Bottom altitude, Upper Floridan aquifer	Top altitude, Tampa Limestone	Top altitude, Suwannee Limestone	Top altitude, Ocala Limestone	Top altitude, Lisbon or Avon Park Formation	Top altitude, Tallahatta Formation	Top altitude, Wilcox Group
	Feet above or below NAVD 88							
				Georgia				
22J001[g]	–22	–597	—	—	—	—	—	—
18N001[e]	185	—	—	185	—	—	—	—
18N002[n]	248	—	248	218	—	—	—	—
18N003[e]	164	—	—	164	—	—	—	—
19J009[n]	215	—	215	165	75	—	—	—
19M001[n]	169	—	169	67	—	—	—	—
19M025[n]	189	—	189	129	—	—	—	—
19M026[n]	232	—	232	162	—	—	—	—
19M027[n]	164	—	164	104	4	—	—	—
19M028[n]	165	—	165	103	15	–263	—	—
19M029[b]	165	—	165	95	–5	—	—	—
19N003[e]	221	—	221	181	61	—	—	—
20M002[n]	150	—	150	103	10	–275	–365	—
20M003[n]	149	—	149	103	19	–271	–361	—
20M007[e]	75	—	—	75	–5	—	—	—
20M008[e]	104	—	—	104	–6	—	—	—
20N002[e]	99	—	—	99	–18	—	—	—
20N004[e]	121	—	—	121	41	—	—	—
21N002[n]	142	—	142	92	52	—	—	—
19H024[n]	—	—	—	—	—	—	—	—
19J002[b]	82	—	82	—	—	—	—	—
19K002[e]	—	—	—	–129	—	—	—	—
19K003[e]	—	—	—	–162	—	—	—	—
19K004[f]	37	—	37	–54	–161	—	—	—
20G005[e]	—	—	—	–16	—	—	—	—
20H002[e]	—	—	—	–16	—	—	—	—
20H003[e]	30	—	30	–20	–205	—	—	—
20J001[n]	30	—	30	–73	–189	—	—	—
20K002[e]	1	—	1	–119	–199	—	—	—
20K005[n]	16	—	16	–113	–237	—	—	—
29J002[g]	–511	—	—	—	—	—	—	—
30H021[g]	–550	—	—	—	—	—	—	—
30J005[g]	–478	–843	—	—	—	—	—	—
31H017[g]	–555	—	—	—	—	—	—	—
16D001[n]	93	—	93	73	—	—	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

County	Well name	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet above NAVD 88)	Well depth (feet)	Hole depth (feet)
			Georgia			
Brooks	16D003[n]	30.71027756	–83.6811141967773	192	220	220
Brooks	16D004[n]	30.66416740	–83.6369476318359	105	147	147
Brooks	16D006[e]	30.74214172	–83.6626586914062	196	220	220
Brooks	16D007[n]	30.68527794	–83.6577758789062	135	196	196
Brooks	16D010[n]	30.67936516	–83.6868286132812	170	180	292
Brooks	16E001[n]	30.83186150	–83.7171096801758	225	226	226
Brooks	16E002[n]	30.85213661	–83.7348861694336	232	231	231
Brooks	16E004[n]	30.78111076	–83.6697235107422	138	153	153
Brooks	16E006[e]	30.75805473	–83.6719436645508	193	225	225
Brooks	16F003[n]	30.99629974	–83.7201690673828	245	265	265
Brooks	16F006[e]	30.88388824	–83.7074966430664	228	240	240
Brooks	16F009[e]	30.88074875	–83.6362762451172	230	230	230
Brooks	16F016[e,f]	30.94055557	–83.7350006103516	220	748	748
Brooks	16F017[g]	30.94056129	–83.7350006103516	200	335	335
Brooks	16G009[e]	31.01768875	–83.7229461669922	251.83	300	300
Brooks	16G042[e,f]	31.01638794	–83.7311019897461	260	856	856
Brooks	16Q004[n]	31.03417015	–83.6277770996094	225	482	482
Brooks	17D001[e]	30.69361115	–83.5366668701172	203	205	205
Brooks	17D002[n]	30.72138977	–83.6102752685547	155	200	200
Brooks	17D008[n]	30.68222237	–83.5202789306641	204	201	201
Brooks	17E004[e]	30.82611084	–83.5961074829102	230	250	250
Brooks	17E008[e]	30.80277824	–83.5580520629883	142	200	200
Brooks	17E009[e]	30.86833382	–83.5250015258789	212	218	218
Brooks	17E012[n]	30.78380775	–83.5640487670898	183	304	304
Brooks	17E027[e]	30.79972267	–83.6005554199219	165	200	200
Brooks	17F007[e]	30.91685867	–83.5798873901367	202	186	186
Brooks	17F008[e]	30.89833260	–83.5272216796875	238	250	250
Brooks	17F009[n]	30.95574570	–83.6110000610352	200	3,850	3,850
Brooks	17F013[n]	30.98638916	–83.6144409179687	161	821	821
Brooks	17G003[n]	31.00769043	–83.5143280029297	257	228	—
Brooks	18D001[e]	30.66222191	–83.495002746582	163	200	200
Brooks	18D002[n]	30.69305611	–83.4769439697266	194	310	310
Brooks	18E001[e]	30.81908607	–83.4893264770508	244	205	205
Brooks	18E002[n]	30.80305481	–83.4738922119141	180	156	156
Brooks	18E014[n]	30.86936378	–83.3945999145508	173	180	180

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

Well name	Top altitude, Upper Floridan aquifer	Bottom altitude, Upper Floridan aquifer	Top altitude, Tampa Limestone	Top altitude, Suwannee Limestone	Top altitude, Ocala Limestone	Top altitude, Lisbon or Avon Park Formation	Top altitude, Tallahatta Formation	Top altitude, Wilcox Group
	Feet above or below NAVD 88							
Georgia								
16D003[n]	72	—	72	62	—	—	—	—
16D004[n]	73	—	73	54	—	—	—	—
16D006[e]	106	—	106	76	—	—	—	—
16D007[n]	70	—	70	53	—	—	—	—
16D010[n]	90	—	90	65	–48	—	—	—
16E001[n]	125	—	125	80	—	—	—	—
16E002[n]	147	—	147	117	—	—	—	—
16E004[n]	98	—	98	68	—	—	—	—
16E006[e]	108	—	108	83	—	—	—	—
16F003[n]	130	—	130	75	—	—	—	—
16F006[e]	138	—	138	108	—	—	—	—
16F009[e]	60	—	60	40	—	—	—	—
16F016[e,f]	—	—	100	71	–43	–524	—	—
16F017[g]	57	—	—	—	—	—	—	—
16G009[e]	162	—	162	102	—	—	—	—
16G042[e,f]	—	–490	—	61	–104	–490	—	—
16Q004[n]	285	—	—	—	—	—	—	—
17D001[e]	118	—	118	98	—	—	—	—
17D002[n]	65	—	65	55	—	—	—	—
17D008[n]	84	—	84	74	—	—	—	—
17E004[e]	70	—	70	50	—	—	—	—
17E008[e]	62	—	—	62	—	—	—	—
17E009[e]	102	—	102	42	—	—	—	—
17E012[n]	88	—	88	33	–7	—	—	—
17E027[e]	105	—	—	105	—	—	—	—
17F007[e]	102	—	—	102	—	—	—	—
17F008[e]	138	—	138	88	—	—	—	—
17F009[n]	—	–675	—	—	—	–675	—	—
17F013[n]	100	–622	100	86	–46	–622	—	—
17G003[n]	117	—	117	—	—	—	—	—
18D001[e]	83	—	83	63	—	—	—	—
18D002[n]	94	—	94	19	–114	—	—	—
18E001[e]	129	—	129	74	—	—	—	—
18E002[n]	120	—	120	60	—	—	—	—
18E014[n]	141	—	141	111	—	—	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

County	Well name	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet above NAVD 88)	Well depth (feet)	Hole depth (feet)
			Georgia			
Brooks	18F006[e,f]	30.94435883	–83.4996032714844	223	296	296
Brooks	18F007[e]	30.88463974	–83.4509887695312	238	220	220
Brooks	18F008[e]	30.93027687	–83.4822235107422	175	182	182
Brooks	18F023[n]	30.87853050	–83.4293212890625	224	236	238
Charlton	30E010[g]	30.79333305	–81.9933319091797	25	4,578	4,578
Clinch	23F001[g]	30.92854309	–82.7979202270508	167	3,848	3,848
Clinch	23G005[g]	31.01944351	–82.8016662597656	182	570	570
Clinch	23H001[g]	31.15187263	–82.8637542724609	205	4,232	4,232
Clinch	24E002[g]	30.85576820	–82.7212448120117	139	4,088	4,088
Clinch	24F006[g]	30.97722244	–82.7083358764648	162	3,410	3,410
Clinch	26E001[g]	30.78355408	–82.4406814575195	110	4,588	4,588
Coffee	20K017[g]	31.45138931	–83.1350021362305	280	4,340	4,340
Coffee	22M004[g]	31.71268654	–82.8940353393555	308	4,130	4,130
Coffee	22M005[g]	31.68546677	–82.8887557983398	260	4,151	4,151
Coffee	22M006[k]	31.71546555	–82.897087097168	295	3,556	3,556
Coffee	22N004[g]	31.76129723	–82.9401473999023	193	—	1,903
Coffee	23L020[g]	31.52416992	–82.8555603027344	245	650	650
Coffee	23M001[g]	31.70610809	–82.8499984741211	300	1,605	1,605
Coffee	24L005[g]	31.51583290	–82.6350555419922	195	—	—
Colquitt	14G010[n]	31.07907486	–83.8948974609375	274	400	400
Colquitt	14G016[g]	31.06879807	–83.9612808227539	303	385	—
Colquitt	14H001[a,e,g]	31.18490791	–83.9012832641602	287	650	4,916
Colquitt	14H006[g]	31.22101784	–83.9921188354492	280	426	426
Colquitt	14H008[n]	31.13629723	–83.9579544067383	307	850	850
Colquitt	14H013[n]	31.19796181	–83.9398956298828	290	460	460
Colquitt	14H026[e,g]	31.23777771	–83.913330078125	348	6,901	6,901
Colquitt	14J011[n]	31.31907082	–83.9454574584961	360	240	240
Colquitt	14J036[e]	31.29833412	–83.8988876342773	350	1,142	1,142
Colquitt	15G044[g]	31.04527855	–83.7694473266602	238	835	835
Colquitt	15H007[n]	31.16768646	–83.7860107421875	317	752	1,000
Colquitt	15H033[e,g]	31.15851974	–83.8323974609375	305	780	797
Colquitt	15H038[e,f]	31.23277855	–83.82861328125	306	840	840
Colquitt	15H066[e]	31.21805573	–83.8152770996094	290	1,321	1,321
Colquitt	15H067[e,g]	31.21694374	–83.815559387207	290	790	790
Colquitt	15J003[n]	31.31879425	–83.8690643310547	340	380	380

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

Well name	Top altitude, Upper Floridan aquifer	Bottom altitude, Upper Floridan aquifer	Top altitude, Tampa Limestone	Top altitude, Suwannee Limestone	Top altitude, Ocala Limestone	Top altitude, Lisbon or Avon Park Formation	Top altitude, Tallahatta Formation	Top altitude, Wilcox Group
	Feet above or below NAVD 88							
Georgia								
18F006[e,f]	129	—	129	76	—	—	—	—
18F007[e]	168	—	168	148	—	—	—	—
18F008[e]	85	—	—	85	—	—	—	—
18F023[n]	166	—	166	141	—	—	—	—
30E010[g]	–385	—	—	—	—	—	—	—
23F001[g]	–173	–1,043	—	—	—	—	—	—
23G005[g]	–176	—	—	—	—	—	—	—
23H001[g]	–109	—	—	—	—	—	—	—
24E002[g]	–195	—	—	—	—	—	—	—
24F006[g]	–233	–1,143	—	—	—	—	—	—
26E001[g]	–220	—	—	—	—	—	—	—
20K017[g]	–119	–1,005	—	—	—	—	—	—
22M004[g]	–140	–946	—	—	—	—	—	—
22M005[g]	–173	–955	—	—	—	—	—	—
22M006[k]	–100	–935	–65	–176	–765	–935	—	–1,325
22N004[g]	–97	–607	—	—	—	—	—	—
23L020[g]	–155	—	—	—	—	—	—	—
23M001[g]	–175	–960	—	—	—	—	—	—
24L005[g]	–250	—	—	—	—	—	—	—
14G010[n]	—	—	14	—	—	—	—	—
14G016[g]	—	—	20	—	—	—	—	—
14H001[a,e,g]	–103	–783	—	–103	–173	–783	—	–888
14H006[g]	11	—	—	11	–21	—	—	—
14H008[n]	–158	—	—	—	—	—	—	—
14H013[n]	22	—	—	—	—	—	—	—
14H026[e,g]	–62	–602	—	–62	–152	–602	—	—
14J011[n]	184	—	—	—	—	—	—	—
14J036[e]	34	–464	—	34	–348	–464	–765	—
15G044[g]	62	–476	96	62	–12	–555	—	—
15H007[n]	–143	—	—	—	—	—	—	—
15H033[e,g]	–107	—	—	–107	–276	—	—	—
15H038[e,f]	–90	—	—	–91	–135	—	—	—
15H066[e]	—	–870	—	—	–686	–870	—	—
15H067[e,g]	–106	–349	65	–106	–145	–349	—	—
15J003[n]	13	—	—	—	—	—	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

County	Well name	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet above NAVD 88)	Well depth (feet)	Hole depth (feet)
			Georgia			
Colquitt	15J013[n]	31.27879524	–83.8168411254883	370	640	640
Colquitt	16G043[g]	31.10638809	–83.7372207641602	270	770	770
Colquitt	16G044[e]	31.10638809	–83.7372207641602	270	908	908
Colquitt	16H014[e,g]	31.18768501	–83.7457275390625	305	579	579
Colquitt	16H077[g]	31.13999939	–83.663330078125	245	868	868
Colquitt	16H078[e]	31.13999939	–83.663330078125	245	870	870
Colquitt	16J002[n]	31.26712990	–83.6857299804687	370	705	817
Colquitt	16J004[e,f]	31.26194382	–83.6727752685547	330	1,213	1,213
Colquitt	17J015[e,f,g]	31.31129646	–83.5776672363281	333	1,017	1,047
Cook	17G008[n]	31.12102127	–83.5354385375977	225.68	330	—
Cook	17H013[n]	31.19166756	–83.5208358764648	200	140	140
Cook	17H025[e]	31.22083282	–83.5041656494141	222	300	300
Cook	18G018[e,f]	31.04602623	–83.3943252563477	244.42	308	—
Cook	18G019[g]	31.04444504	–83.3986129760742	231	230	230
Cook	18H002[n]	31.14269066	–83.4240493774414	238.14	386	—
Cook	18H003[e]	31.22296906	–83.4046020507812	274.22	291	—
Cook	18H005[n]	31.13796997	–83.4259948730469	240.82	375	—
Cook	18H008[e]	31.12750053	–83.4188919067383	230.12	359	359
Cook	18H015[g,l]	31.16852379	–83.4334945678711	236.29	407	—
Cook	18H016[e]	31.13713455	–83.4340515136719	241.42	865	865
Cook	18H033[g]	31.14046860	–83.4282150268555	240.11	393	393
Cook	18H036[e]	31.21102333	–83.4490509033203	263.77	210	223
Cook	18H040[e]	31.23583412	–83.4700012207031	268	315	320
Cook	18J001[n]	31.25657654	–83.4629364013672	263.61	288	—
Cook	18J003[e]	31.27324295	–83.4615478515625	286.12	501	—
Cook	18J011[f]	31.27083397	–83.4661102294922	291.26	382	382
Cook	18J027[e,f]	31.33472252	–83.4408340454102	298	580	580
Cook	18J046[e]	31.28858948	–83.4926910400391	295	360	360
Crisp	15N001[n]	31.82684326	–83.7698974609375	364	—	5,008
Crisp	15P001[n]	31.96017456	–83.7748947143555	340	540	816
Crisp	15P003[n]	31.93406296	–83.764892578125	317	265	265
Crisp	15P007[n]	31.97045136	–83.7746124267578	316	600	677
Crisp	15P020[n]	31.98888969	–83.788330078125	287	75	75
Crisp	15Q011[n]	32.00933838	–83.7918395996094	336	—	255
Crisp	15Q016[n]	32.02999878	–83.8522186279297	330	170	170

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

Well name	Top altitude, Upper Floridan aquifer	Bottom altitude, Upper Floridan aquifer	Top altitude, Tampa Limestone	Top altitude, Suwannee Limestone	Top altitude, Ocala Limestone	Top altitude, Lisbon or Avon Park Formation	Top altitude, Tallahatta Formation	Top altitude, Wilcox Group
	Feet above or below NAVD 88							
Georgia								
15J013[n]	–86	—	—	—	—	—	—	—
16G043[g]	48	–396	—	—	—	—	—	—
16G044[e]	—	–591	—	—	–120	–591	—	—
16H014[e,g]	–195	—	—	–135	–233	—	—	—
16H077[g]	65	–497	—	—	—	—	—	—
16H078[e]	—	—	—	—	–81	–588	—	—
16J002[n]	–95	—	—	–95	–139	–334	—	—
16J004[e,f]	–144	–740	—	–144	–176	–740	—	—
17J015[e,f,g]	–290	—	—	–290	—	—	—	—
17G008[n]	86	—	86	26	—	—	—	—
17H013[n]	82	—	82	—	—	—	—	—
17H025[e]	22	—	22	–18	—	—	—	—
18G018[e,f]	–8	—	91	6	—	—	—	—
18G019[g]	31	—	101	18	—	—	—	—
18H002[n]	67	—	67	40	—	—	—	—
18H003[e]	144	—	144	—	—	—	—	—
18H005[n]	59	—	59	32	—	—	—	—
18H008[e]	11	—	11	–10	—	—	—	—
18H015[g,l]	52	—	79	50	—	—	—	—
18H016[e]	47	–286	81	39	–178	–624	—	—
18H033[g]	40	—	117	29	—	—	—	—
18H036[e]	77	—	77	—	—	—	—	—
18H040[e]	38	—	38	–30	—	—	—	—
18J001[n]	30	—	30	–17	—	—	—	—
18J003[e]	36	—	36	26	–174	—	—	—
18J011[f]	49	—	49	–29	—	—	—	—
18J027[e,f]	–76	—	–76	—	—	—	—	—
18J046[e]	55	—	55	—	—	—	—	—
15N001[n]	—	–41	—	—	—	—	—	—
15P001[n]	241	30	—	—	—	—	—	—
15P003[n]	227	—	—	—	—	—	—	—
15P007[n]	281	61	—	—	—	—	—	—
15P020[n]	242	—	—	—	—	—	—	—
15Q011[n]	236	106	—	—	—	—	—	—
15Q016[n]	280	162	—	—	—	—	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

County	Well name	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet above NAVD 88)	Well depth (feet)	Hole depth (feet)
			Georgia			
Crisp	16P001[n]	31.93406487	–83.7318344116211	363	290	290
Crisp	16P006[n]	31.91693878	–83.6650009155273	359	260	260
Crisp	16P007[n]	31.96100807	–83.7304458618164	423	610	—
Crisp	17P002[n]	31.93212128	–83.6179428100586	460	310	—
Decatur	07D014[n]	30.71805573	–84.7794418334961	280	795	830
Decatur	08D093[n]	30.74833298	–84.6719436645508	300	300	—
Decatur	08E018[b,i]	30.80852318	–84.6513061523437	87	—	6,152
Decatur	09E002[g]	30.79166985	–84.5555648803711	302	442	442
Decatur	09E517[h,m]	30.76324654	–84.5365829467773	287	486	486
Decatur	09F016[n]	30.89268875	–84.5699157714844	130	485	—
Decatur	09F019[a]	30.97879791	–84.5315780639648	122	3,717	3,717
Decatur	10D002[l,m]	30.74741554	–84.4868545532227	311	905	—
Decatur	10D021[l,m]	30.70833397	–84.3886108398437	270	4,195	4,195
Decatur	10F160[n]	30.91611099	–84.4677810668945	140	420	420
Decatur	10G001[n]	31.02296448	–84.3871307373047	141	160	160
Echols	22D002[g]	30.73687935	–82.9229125976562	146	3,916	3,916
Echols	22D003[g]	30.68305588	–82.8786087036133	181	3,953	3,953
Echols	22E001[g]	30.75826645	–82.9098587036133	171	—	4,185
Echols	23C001[g]	30.61632729	–82.7826309204102	135	4,003	4,003
Echols	27D001[g]	30.69388962	–82.2947235107422	132	4,062	4,062
Grady	11F083[n]	30.88611031	–84.3194351196289	238	482	482
Grady	12E064[n]	30.87471962	–84.1761016845703	271	427	—
Grady	12E046[l,m]	30.76297188	–84.220458984375	165	226	226
Grady	12F018[e]	30.87528038	–84.1916656494141	181	1,206	1,206
Grady	12F020[n]	30.87685776	–84.2060089111328	238	650	—
Grady	12F022[n]	30.87769127	–84.2118453979492	239.36	586	586
Grady	12F025[k]	30.87602425	–84.2176818847656	208	540	540
Grady	12F030[k]	30.87741280	–84.2107315063477	241	671	870
Grady	12F035[n]	30.98296547	–84.1601791381836	285	595	595
Grady	12F036[e,k]	30.87657928	–84.2143478393555	204.54	467	971
Grady	12G028[n]	31.00388908	–84.2055587768555	307	550	550
Irwin	18L002[n]	31.54879761	–83.3937683105469	322	280	—
Irwin	18L029[n]	31.60693932	–83.4593963623047	352	204	204
Irwin	18L030[n]	31.61333084	–83.4772033691406	330	200	200
Irwin	18M002[n]	31.72934914	–83.4146041870117	367	230	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

Well name	Top altitude, Upper Floridan aquifer	Bottom altitude, Upper Floridan aquifer	Top altitude, Tampa Limestone	Top altitude, Suwannee Limestone	Top altitude, Ocala Limestone	Top altitude, Lisbon or Avon Park Formation	Top altitude, Tallahatta Formation	Top altitude, Wilcox Group
	Feet above or below NAVD 88							
Georgia								
16P001[n]	231	—	—	—	—	—	—	—
16P006[n]	309	—	—	—	—	—	—	—
16P007[n]	329	80	—	—	—	—	—	—
17P002[n]	280	—	—	—	—	—	—	—
07D014[n]	—	–520	—	—	—	—	—	—
08D093[n]	–50	–475	—	—	—	—	—	—
08E018[b,i]	87	–258	—	87	—	–258	–723	—
09E002[g]	–20	—	—	–20	–135	—	—	—
09E517[h,m]	–135	—	–48	–135	—	—	–748	—
09F016[n]	51	–175	—	—	—	—	—	—
09F019[a]	—	—	—	—	—	—	—	–748
10D002[l,m]	–287	—	–123	–287	–388	—	—	—
10D021[l,m]	–320	–955	–190	–320	–630	–955	–1,305	—
10F160[n]	23	–290	—	—	—	—	—	—
10G001[n]	56	—	—	—	—	—	—	—
22D002[g]	–69	–727	—	—	—	—	—	—
22D003[g]	—	–663	—	—	—	—	—	—
22E001[g]	–28	–732	—	—	—	—	—	—
23C001[g]	–30	–771	—	—	—	—	—	—
27D001[g]	–124	–756	—	—	—	—	—	—
11F083[n]	–167	—	—	—	—	—	—	—
12E064[n]	—	—	–63	—	—	—	—	—
12E046[l,m]	–45	—	–5	–45	—	—	—	—
12F018[e]	–261	—	–78	–261	—	–931	—	—
12F020[n]	–261	—	—	–261	—	—	—	—
12F022[n]	–255	—	20	–255	—	—	—	—
12F025[k]	—	—	–50	—	—	—	—	—
12F030[k]	–268	—	–53	–268	—	—	—	—
12F035[n]	–187	—	25	–187	—	—	—	—
12F036[e,k]	–266	—	–41	–266	—	—	—	—
12G028[n]	7	—	167	7	—	—	—	—
18L002[n]	162	—	162	122	—	—	—	—
18L029[n]	262	—	262	192	—	—	—	—
18L030[n]	240	—	240	170	—	—	—	—
18M002[n]	227	—	227	177	—	—	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

County	Well name	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet above NAVD 88)	Well depth (feet)	Hole depth (feet)
			Georgia			
Irwin	18M021[n]	31.64332962	–83.4535980224609	358	256	256
Irwin	18M022[n]	31.63083076	–83.3764038085937	371	402	402
Irwin	19L034[n]	31.58611107	–83.2538986206055	313	280	280
Irwin	19L035[n]	31.50583076	–83.2791976928711	330	340	340
Irwin	19L036[n]	31.53888893	–83.2538986206055	328	310	310
Irwin	19M023[n]	31.63861084	–83.2758026123047	357	301	301
Irwin	19M024[n]	31.65971947	–83.3581008911133	380	300	300
Irwin	20L002[e]	31.56296921	–83.1801528930664	300	380	—
Irwin	20L003[n]	31.59519005	–83.2473754882812	338	637	—
Irwin	20L026[n]	31.59499931	–83.1750030517578	284	280	280
Irwin	20L027[e]	31.60778046	–83.2489013671875	353	696	—
Irwin	21L001[e]	31.54880333	–83.0804290771484	292	620	—
Irwin	21M019[n]	31.62999916	–83.0556030273437	335	494	494
Lowndes	18F029[g]	30.93667030	–83.4063873291016	243	5,246	5,246
Lowndes	19E001[n]	30.82881355	–83.2815399169922	215	408	408
Lowndes	19E004[b]	30.82909012	–83.2823715209961	211.30	367	818
Lowndes	19E005[n]	30.86158943	–83.2837600708008	226.33	348	348
Lowndes	19E006[n]	30.85992432	–83.2857055664062	213.88	334	339
Lowndes	19E007[n]	30.86242294	–83.2884826660156	195	230	230
Lowndes	19E008[n]	30.84047890	–83.2920989990234	191	126	—
Lowndes	19E011[d]	30.82520294	–83.2804260253906	197	400	—
Lowndes	19E014[n]	30.79159164	–83.262092590332	197	200	200
Lowndes	19E017[n]	30.80659103	–83.2990417480469	223	251	251
Lowndes	19E018[n]	30.84103394	–83.2990417480469	195	220	228
Lowndes	19E026[n]	30.83464623	–83.3151550292969	192	213	213
Lowndes	19E043[d,g]	30.86381149	–83.2909851074219	178	965	1,014
Lowndes	19E082[d]	30.83964539	–83.3209838867187	203	193	193
Lowndes	19E101[d]	30.87490082	–83.2882766723633	206	—	—
Lowndes	19F020[g]	30.98297310	–83.3698806762695	225	360	363
Lowndes	19F099[g]	30.90603447	–83.2809829711914	191	—	5,004
Lowndes	19F140[g]	30.99028015	–83.2522201538086	157	8,550	8,550
Lowndes	20E043[g]	30.84833145	–83.1877822875977	201	4,985	4,985
Lowndes	20F004[g]	30.97770119	–83.2040405273437	224	342	—
Lowndes	21E006[g]	30.85693932	–83.0563888549805	171	5,052	5,052
Mitchell	12H008[n]	31.22434807	–84.215461730957	165	341	346

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

Well name	Top altitude, Upper Floridan aquifer	Bottom altitude, Upper Floridan aquifer	Top altitude, Tampa Limestone	Top altitude, Suwannee Limestone	Top altitude, Ocala Limestone	Top altitude, Lisbon or Avon Park Formation	Top altitude, Tallahatta Formation	Top altitude, Wilcox Group
	Feet above or below NAVD 88							
Georgia								
18M021[n]	226	—	226	204	—	—	—	—
18M022[n]	169	—	169	139	29	—	—	—
19L034[n]	143	—	143	103	—	—	—	—
19L035[n]	160	—	160	90	—	—	—	—
19L036[n]	148	—	148	58	—	—	—	—
19M023[n]	167	—	167	117	—	—	—	—
19M024[n]	200	—	280	130	—	—	—	—
20L002[e]	70	—	70	0	—	—	—	—
20L003[n]	248	—	248	128	–32	—	—	—
20L026[n]	104	—	—	104	34	—	—	—
20L027[e]	153	–343	153	108	42	—	—	—
21L001[e]	–98	—	–98	–308	—	—	—	—
21M019[n]	30	—	30	–85	—	—	—	—
18F029[g]	66	–660	—	—	—	—	—	—
19E001[n]	60	—	—	60	—	—	—	—
19E004[b]	106	–549	106	21	–159	–549	—	—
19E005[n]	70	—	70	19	–101	—	—	—
19E006[n]	27	—	27	11	—	—	—	—
19E007[n]	30	—	30	10	—	—	—	—
19E008[n]	92	—	92	70	—	—	—	—
19E011[d]	7	—	7	–18	–183	—	—	—
19E014[n]	27	—	27	17	—	—	—	—
19E017[n]	—	—	0	–6	—	—	—	—
19E018[n]	82	—	82	59	—	—	—	—
19E026[n]	69	—	69	42	—	—	—	—
19E043[d,g]	41	–538	41	–2	–198	–538	—	—
19E082[d]	80	—	80	48	—	—	—	—
19E101[d]	46	—	46	13	–234	—	—	—
19F020[g]	23	—	—	—	—	—	—	—
19F099[g]	—	–605	—	—	—	—	—	—
19F140[g]	—	–606	—	—	—	—	—	—
20E043[g]	–12	–428	—	—	—	—	—	—
20F004[g]	95	—	—	—	—	—	—	—
21E006[g]	–38	–591	—	—	—	—	—	—
12H008[n]	115	–125	—	—	—	—	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

County	Well name	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet above NAVD 88)	Well depth (feet)	Hole depth (feet)
			Georgia			
Mitchell	13H004[n]	31.17193794	–84.0455627441406	319	316	316
Mitchell	13J003[n]	31.26296043	–84.0210113525391	372	575	575
Mitchell	13J009[n]	31.32250023	–84.053337097168	272	497	497
Mitchell	13J010[n]	31.32268143	–84.0532379150391	270	43	48
Mitchell	13J012[n]	31.30624962	–84.0525817871094	287	—	—
Mitchell	13K001[n]	31.43267822	–84.02490234375	275	382	386
Pierce	28J010[g]	31.34138870	–82.1488876342773	108	875	875
Pierce	28J011[g]	31.27222252	–82.149169921875	75	810	810
Thomas	10G314[n]	31.11244392	–84.4037475585937	140	370	370
Thomas	13E002[e]	30.96722221	–84.0430526733398	264	423	423
Thomas	13E010[f]	30.75297165	–84.0265579223633	195	204	—
Thomas	13F019[e]	30.88352394	–84.0535049438477	228	240	—
Thomas	13F023[e]	30.99963188	–84.1187896728516	275	408	—
Thomas	13F024[g]	30.98685455	–84.0774002075195	230	446	—
Thomas	13F025[f]	30.97111130	–84.0511093139648	271	637	637
Thomas	13G003[e]	31.04129791	–84.0696182250977	304	905	—
Thomas	13G006[e,f,i]	31.07129669	–84.0918426513672	345	832	1,560
Thomas	13G019[e]	31.07097244	–84.0953521728516	330	—	1,439
Thomas	13H008[b,f,i]	31.14129639	–84.0701751708984	330	7,490	7,490
Thomas	14E016[g,i]	30.83361053	–83.9823913574219	258	1,635	1,635
Thomas	14E047[e,g]	30.78638840	–83.9622192382812	267	6,672	6,672
Thomas	14F015[e,g]	30.92435646	–83.9712829589844	238	325	—
Thomas	15E017[f]	30.81083298	–83.7563858032227	205	904	904
Thomas	15F016[f]	30.98916626	–83.8088912963867	238	1,206	1,206
Thomas	15G011[e,g]	31.01157761	–83.8685073852539	252	383	385
Thomas	15G043[g]	31.00194359	–83.8272247314453	248	801	801
Tift	15K021[a,b]	31.45750046	–83.8333282470703	355	585	585
Tift	16J005[e]	31.35833359	–83.6483306884766	295	—	—
Tift	16J031[n]	31.33416748	–83.6399993896484	273	1,170	1,170
Tift	16K010[c]	31.38444519	–83.628059387207	325	352	352
Tift	17J004[f]	31.33944511	–83.5936126708984	325	705	705
Tift	17J042[d,e]	31.35416603	–83.5833282470703	324	490	490
Tift	17K007[n]	31.49333382	–83.5458297729492	332	260	260
Tift	17K038[c,e]	31.48388863	–83.529167175293	392	500	500
Tift	17K111[n]	31.44444466	–83.5930557250977	338	350	350

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

Well name	Top altitude, Upper Floridan aquifer	Bottom altitude, Upper Floridan aquifer	Top altitude, Tampa Limestone	Top altitude, Suwannee Limestone	Top altitude, Ocala Limestone	Top altitude, Lisbon or Avon Park Formation	Top altitude, Tallahatta Formation	Top altitude, Wilcox Group
	Feet above or below NAVD 88							
Georgia								
13H004[n]	12	—	—	—	—	—	—	—
13J003[n]	130	—	—	—	—	—	—	—
13J009[n]	227	–167	—	—	—	—	—	—
13J010[n]	224	—	—	—	—	—	—	—
13J012[n]	204	—	—	—	—	—	—	—
13K001[n]	218	–39	—	—	—	—	—	—
28J010[g]	–424	—	—	—	—	—	—	—
28J011[g]	–420	—	—	—	—	—	—	—
10G314[n]	75	–210	—	—	—	—	—	—
13E002[e]	–131	—	29	–131	—	—	—	—
13E010[f]	35	—	—	35	0	—	—	—
13F019[e]	—	—	78	—	—	—	—	—
13F023[e]	—	—	40	—	—	—	—	—
13F024[g]	–170	—	-8	–170	—	—	—	—
13F025[f]	–241	—	—	–241	—	—	—	—
13G003[e]	–201	—	—	–201	-499	—	—	—
13G006[e,f,i]	–139	–470	13	–139	–241	–451	—	—
13G019[e]	—	–615	60	–114	–465	–615	—	—
13H008[b,f,i]	–40	–460	100	–40	–65	–460	–620	–895
14E016[g,i]	67	–767	213	67	–36	–767	—	—
14E047[e,g]	—	–618	—	—	—	–618	–1,018	–1,368
14F015[e,g]	–48	—	—	–48	—	—	—	—
15E017[f]	120	–582	135	79	–75	–582	—	—
15F016[f]	109	–552	143	109	–38	–552	—	—
15G011[e,g]	–70	—	30	–70	—	—	—	—
15G043[g]	89	–537	142	89	–25	–537	—	—
15K021[a,b]	85	—	220	85	15	—	—	—
16J005[e]	—	—	—	—	—	—	—	—
16J031[n]	–28	—	—	–28	–95	–357	—	—
16K010[c]	17	—	199	17	—	—	—	—
17J004[f]	–36	—	—	–36	-88	—	—	—
17J042[d,e]	–146	—	—	–146	—	—	—	—
17K007[n]	202	—	—	202	—	—	—	—
17K038[c,e]	138	—	—	138	—	—	—	—
17K111[n]	168	—	—	168	18	—	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

County	Well name	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet above NAVD 88)	Well depth (feet)	Hole depth (feet)
			Georgia			
Tift	17L001[n]	31.54935074	–83.5346069335937	370	260	—
Tift	17L002[n]	31.50416756	–83.5016632080078	390	350	350
Tift	17L003[n]	31.50333405	–83.5430526733398	350	208	208
Tift	17L004[n]	31.51861191	–83.559440612793	371	260	260
Tift	17L005[n]	31.56944466	–83.575553894043	360	170	170
Tift	17L006[n]	31.52194405	–83.5777740478516	352	210	210
Tift	17L010[n]	31.54194450	–83.5280532836914	355	408	408
Tift	17L011[n]	31.52888870	–83.5727767944336	360	320	320
Tift	17L012[n]	31.56212616	–83.6093368530273	311	280	—
Tift	17L014[n]	31.50129509	–83.6215591430664	334	250	—
Tift	17L015[n]	31.51749992	–83.5663909912109	360	220	220
Tift	17L062[c,e]	31.50416756	–83.5541687011719	395	—	—
Tift	18K001[f]	31.41435242	–83.4898834228516	352	610	—
Tift	18K003[n]	31.54796410	–83.4537734985352	322	540	—
Tift	18K073[b,e]	31.45138931	–83.4944458007812	330	501	501
Tift	18L006[n]	31.50333405	–83.4225006103516	320	250	250
Tift	18L012[n]	31.52694511	–83.4250030517578	300	220	220
Tift	18L031[n]	31.53166580	–83.4861145019531	335	270	270
Turner	16M001[n]	31.73712349	–83.6512756347656	399	350	—
Turner	16M002[n]	31.68388939	–83.6447219848633	397	220	220
Turner	16M008[n]	31.65601349	–83.6315536499023	410	375	—
Turner	16M010[n]	31.70517921	–83.6565551757812	430	485	—
Turner	16M011[n]	31.70656967	–83.6546096801758	430	648	—
Turner	16M013[b]	31.69712448	–83.6465606689453	430	650	—
Turner	16M020[n]	31.67818832	–83.6387329101562	404	501	—
Turner	16M021[b]	31.69545746	–83.640998840332	402	770	770
Turner	16M022[n]	31.67073631	–83.636833190918	380	525	525
Turner	16M052[n]	31.66500092	–83.7344436645508	370	320	320
Turner	16M053[n]	31.62833405	–83.7186126708984	390	240	240
Turner	16M054[n]	31.63611031	–83.7236099243164	402	402	402
Turner	16M055[n]	31.66861153	–83.6324996948242	388	250	250
Turner	16M056[n]	31.66444397	–83.7291641235352	395	270	270
Turner	16N015[n]	31.75305557	–83.6816635131836	386	225	225
Turner	16N016[n]	31.75138855	–83.6630554199219	360.38	565	565
Turner	17L008[n]	31.61018181	–83.5437774658203	352	220	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

Well name	Top altitude, Upper Floridan aquifer	Bottom altitude, Upper Floridan aquifer	Top altitude, Tampa Limestone	Top altitude, Suwannee Limestone	Top altitude, Ocala Limestone	Top altitude, Lisbon or Avon Park Formation	Top altitude, Tallahatta Formation	Top altitude, Wilcox Group
	Feet above or below NAVD 88							
				Georgia				
17L001[n]	170	—	200	170	—	—	—	—
17L002[n]	150	—	250	150	—	—	—	—
17L003[n]	170	—	280	170	—	—	—	—
17L004[n]	191	—	—	191	—	—	—	—
17L005[n]	270	—	—	270	—	—	—	—
17L006[n]	192	—	292	192	—	—	—	—
17L010[n]	179	—	—	179	69	—	—	—
17L011[n]	180	—	300	180	—	—	—	—
17L012[n]	201	—	—	—	—	—	—	—
17L014[n]	254	—	234	174	—	—	—	—
17L015[n]	190	—	300	190	—	—	—	—
17L062[c,e]	195	—	—	195	—	—	—	—
18K001[f]	–60	—	–6	–46	–171	—	—	—
18K003[n]	22	—	—	22	–138	—	—	—
18K073[b,e]	74	—	206	74	–66	—	—	—
18L006[n]	140	—	—	140	—	—	—	—
18L012[n]	105	—	—	105	—	—	—	—
18L031[n]	205	—	—	205	—	—	—	—
16M001[n]	199	—	—	199	—	—	—	—
16M002[n]	227	—	—	227	—	—	—	—
16M008[n]	190	—	220	190	110	—	—	—
16M010[n]	150	—	—	150	30	—	—	—
16M011[n]	302	—	—	169	12	—	—	—
16M013[b]	218	—	—	218	40	—	—	—
16M020[n]	235	—	—	235	–51	—	—	—
16M021[b]	150	—	—	150	17	–268	—	—
16M022[n]	219	—	—	219	–90	—	—	—
16M052[n]	190	—	190	165	—	—	—	—
16M053[n]	210	—	210	180	—	—	—	—
16M054[n]	167	—	—	167	—	—	—	—
16M055[n]	228	—	—	228	—	—	—	—
16M056[n]	243	—	—	243	—	—	—	—
16N015[n]	281	—	—	281	—	—	—	—
16N016[n]	226	—	—	226	–110	—	—	—
17L008[n]	242	—	242	198	—	—	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

County	Well name	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet above NAVD 88)	Well depth (feet)	Hole depth (feet)
Georgia						
Turner	17L009[n]	31.61240578	–83.5368347167969	335	220	—
Turner	17L063[n]	31.60916710	–83.5749969482422	325	130	130
Turner	17L064[n]	31.59722137	–83.5963897705078	358	260	260
Turner	17L065[n]	31.61305618	–83.5008316040039	330	336	336
Turner	17M007[n]	31.71462440	–83.5712738037109	382	242	—
Turner	17M043[n]	31.67944527	–83.6216659545898	390	270	270
Turner	17M045[n]	31.67944527	–83.6202774047852	377	470	470
Turner	17M046[n]	31.72138977	–83.5430526733398	380	220	220
Turner	17M047[n]	31.67138863	–83.5919418334961	400	235	235
Turner	17M048[n]	31.63972282	–83.616943359375	385	250	250
Turner	17N001[n]	31.78573608	–83.5073852539062	382	194	194
Turner	17N002[n]	31.81323433	–83.6007232666016	365	51	260
Turner	18N011[n]	31.83555603	–83.4974975585937	351	220	220
Turner	18N012[n]	31.82250023	–83.4888916015625	350	176	176
Turner	33H016[n]	31.12717438	–81.5550994873047	365	780	780
Ware	24P010[g]	31.97972298	–82.6466674804687	121	701	701
Ware	27G003[g]	31.11855698	–82.2654037475586	150	1,856	1,970
Wilcox	17P008[n]	31.96805573	–83.5469436645508	405	160	160
Wilcox	17P009[n]	31.91361046	–83.5572204589844	371	196	196
Wilcox	17P010[n]	31.95277786	–83.5752792358398	351	—	200
Wilcox	17P011[n]	31.98444366	–83.5758361816406	352	—	56
Wilcox	17P012[n]	31.92861176	–83.5008316040039	365	175	175
Wilcox	17P013[n]	31.96361160	–83.5663909912109	372	225	225
Wilcox	17Q020[l]	32.11294937	–83.5037841796875	273	293	293
Wilcox	17Q021[l]	32.10972214	–83.5038909912109	278	210	210
Wilcox	18P001[b,g]	31.95045471	–83.4576644897461	367	335	—
Wilcox	18P006[n]	31.97888947	–83.4944458007812	415	255	255
Wilcox	20N005[n]	31.84851646	–83.2082061767578	167	642	—
Wilcox	20N010[n]	31.86722183	–83.2286148071289	292	173	173
Wilcox	20N017[n]	31.84693909	–83.2133026123047	170	—	—
Worth	14J003[n]	31.33490372	–83.9640655517578	382	280	280
Worth	14J006[c]	31.37138939	–83.9397201538086	412	250	250
Worth	14K001[f]	31.44434738	–83.8782348632812	430	454	454
Worth	14K003[n]	31.46351242	–83.9149017333984	431	370	370
Worth	14K005[e]	31.40768051	–83.9662933349609	409	—	280

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

Well name	Top altitude, Upper Floridan aquifer	Bottom altitude, Upper Floridan aquifer	Top altitude, Tampa Limestone	Top altitude, Suwannee Limestone	Top altitude, Ocala Limestone	Top altitude, Lisbon or Avon Park Formation	Top altitude, Tallahatta Formation	Top altitude, Wilcox Group
	Feet above or below NAVD 88							
				Georgia				
17L009[n]	203	—	—	203	—	—	—	—
17L063[n]	205	—	205	—	—	—	—	—
17L064[n]	238	—	—	238	128	—	—	—
17L065[n]	215	—	—	215	102	—	—	—
17M007[n]	122	—	—	122	—	—	—	—
17M043[n]	230	—	—	230	—	—	—	—
17M045[n]	257	—	—	257	27	—	—	—
17M046[n]	170	—	—	170	—	—	—	—
17M047[n]	250	—	—	260	—	—	—	—
17M048[n]	245	—	—	245	—	—	—	—
17N001[n]	242	—	282	242	—	—	—	—
17N002[n]	343	—	—	—	—	—	—	—
18N011[n]	251	—	—	251	—	—	—	—
18N012[n]	284	—	—	284	—	—	—	—
33H016[n]	175	—	—	175	–130	—	—	—
24P010[g]	–349	—	—	—	—	—	—	—
27G003[g]	–456	–840	—	—	—	—	—	—
17P008[n]	265	—	—	265	—	—	—	—
17P009[n]	281	—	—	281	—	—	—	—
17P010[n]	271	—	—	271	—	—	—	—
17P011[n]	296	—	—	296	—	—	—	—
17P012[n]	213	—	—	213	—	—	—	—
17P013[n]	252	—	—	252	—	—	—	—
17Q020[l]	153	—	—	153	—	—	—	—
17Q021[l]	178	—	—	178	—	—	—	—
18P001[b,g]	190	—	—	190	102	—	—	—
18P006[n]	295	—	—	295	—	—	—	—
20N005[n]	141	–283	—	110	52	–283	–356	—
20N010[n]	212	—	—	212	—	—	—	—
20N017[n]	95	—	—	95	—	—	—	—
14J003[n]	162	—	—	—	—	—	—	—
14J006[c]	202	—	—	202	—	—	—	—
14K001[f]	226	—	—	226	162	—	—	—
14K003[n]	238	60	—	238	—	60	—	—
14K005[e]	187	—	—	187	—	—	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

County	Well name	Latitude (decimal degrees)	Longitude (decimal degrees)	Land-surface altitude (feet above NAVD 88)	Well depth (feet)	Hole depth (feet)
			Georgia			
Worth	14K053[n]	31.40830612	–83.9116363525391	385	500	600
Worth	14K054[n]	31.49323273	–83.9615707397461	315	465	465
Worth	14K055[n]	31.49323273	–83.9615707397461	315	83	87
Worth	14K058[n]	31.49323082	–83.9615707397461	315	—	—
Worth	14L002[c,e]	31.54990005	–83.8776779174805	430	460	460
Worth	14L003[b,e]	31.58350945	–83.9407348632812	335	—	315
Worth	14L007[e]	31.55156708	–83.9162902832031	355	180	180
Worth	14L009[n]	31.58323288	–83.9182357788086	288	238	238
Worth	14L012[n]	31.55073357	–83.9212875366211	355	—	—
Worth	14L030[n]	31.54601097	–83.8818435668945	390	—	214
Worth	14M001[n]	31.64295387	–83.9157333374023	263	215	215
Worth	14M008[n]	31.71850967	–83.888786315918	289	102	102
Worth	14N001[n]	31.82795143	–83.9218444824219	278	325	325
Worth	14N014[n]	31.76055527	–83.9191665649414	250	110	110
Worth	15J015[e]	31.36518288	–83.8551788330078	400	—	320
Worth	15J017[b,e]	31.37240410	–83.8551788330078	412	—	300
Worth	15K003[n]	31.43934822	–83.818229675293	391	—	240
Worth	15K004[g]	31.37879372	–83.7987899780273	348	—	802
Worth	15L004[f]	31.58934593	–83.8435134887695	412	402	402
Worth	15L005[n]	31.51823616	–83.8193435668945	380	178	178
Worth	15L020[n]	31.52962494	–83.8210067749023	420	450	738
Worth	15L021[n]	31.53767967	–83.8457336425781	380	536	536
Worth	15L032[n]	31.59055519	–83.8383331298828	410	520	520
Worth	15L035[n]	31.58936119	–83.836669921875	410	430	430
Worth	15N003[n]	31.80775070	–83.8363037109375	285	50	57
Worth	15N005[n]	31.80805588	–83.8363876342773	281	260	260
Worth	15N006[n]	31.80791664	–83.8323059082031	288	210	210
Worth	16J030[e]	31.32028008	–83.7375030517578	288	5,568	5,568
Worth	16J047[e]	31.35472298	–83.6972198486328	340	440	440
Worth	16K011[e]	31.40157127	–83.7037811279297	362	620	—
Worth	16K013[e]	31.42407227	–83.7096176147461	375	610	—
Worth	16L011[e]	31.55073547	–83.7746200561523	332	210	—
Worth	16L019[n]	31.51268196	–83.7382278442383	380	—	717

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

[Accuracy of land-surface altitude varies based on method of measurement. Values reported to hundredths of a foot represent measurement made by surveying or global positioning techniques; —, no data available]

Well name	Top altitude, Upper Floridan aquifer	Bottom altitude, Upper Floridan aquifer	Top altitude, Tampa Limestone	Top altitude, Suwannee Limestone	Top altitude, Ocala Limestone	Top altitude, Lisbon or Avon Park Formation	Top altitude, Tallahatta Formation	Top altitude, Wilcox Group
	Feet above or below NAVD 88							
Georgia								
14K053[n]	360	—	—	360	318	—	—	—
14K054[n]	210	–150	—	—	—	—	—	—
14K055[n]	228	—	—	—	—	—	—	—
14K058[n]	224	–145	—	—	—	—	—	—
14L002[c,e]	222	—	—	222	146	53	—	—
14L003[b,e]	245	—	—	—	245	—	—	—
14L007[e]	285	—	—	285	—	—	—	—
14L009[n]	234	56	—	234	180	56	—	—
14L012[n]	—	—	—	—	—	—	—	—
14L030[n]	222	—	—	222	—	—	—	—
14M001[n]	119	—	—	—	—	—	—	—
14M008[n]	226	—	—	226	—	—	—	—
14N001[n]	226	—	—	226	164	—	—	—
14N014[n]	220	—	—	220	200	—	—	—
15J015[e]	100	—	—	100	—	—	—	—
15J017[b,e]	132	—	—	132	—	—	—	—
15K003[n]	175	—	—	—	175	—	—	—
15K004[g]	96	–331	—	96	17	–331	–434	—
15L004[f]	184	—	—	—	184	25	—	—
15L005[n]	224	—	—	224	—	—	—	—
15L020[n]	230	—	—	230	—	—	—	—
15L021[n]	250	–146	—	—	—	—	—	—
15L032[n]	230	–100	—	—	230	–100	—	—
15L035[n]	240	—	—	—	—	—	—	—
15N003[n]	230	—	—	—	230	—	—	—
15N005[n]	228	70	—	—	—	—	—	—
15N006[n]	248	—	—	—	248	—	—	—
16J030[e]	–98	–718	—	–98	—	–718	—	—
16J047[e]	–50	—	—	–50	—	—	—	—
16K011[e]	2	—	—	2	—	—	—	—
16K013[e]	1	—	—	1	—	—	—	—
16L011[e]	242	—	—	242	—	—	—	—
16L019[n]	—	—	—	–46	–180	—	—	—

Table A–1. Geohydrologic data for the Aucilla–Suwannee–Ochlockonee River Basin.—Continued

Footnotes

[a] Applin and Applin, 1964.

[b] Herrick, 1961.

[c] Kellam and Gorday, 1990.

[d] Mcconnell and Hacke, 1993.

[e] McFadden and others, 1986.

[f] Miller, 1986.

[g] Miller, 1988.

[h] Sever, 1964.

[i] Sever, 1965.

[j] Sever, 1966.

[k] Sever and Herrick, 1967.

[l] Stephenson and Veatch, 1915.

[m] Torak and Painter, 2006.

[n] Data on file at the U.S. Geological Survey, Georgia Water Science Center, Atlanta, Georgia.

Manuscript approved for publication, April 8, 2010

Edited by Kimberly A. Waltenbaugh

Graphics by Bonnie J. Turcott

Layout by Caryl J. Wipperfurth

For more information concerning the research in this report, contact

USGS Georgia Water Science Center
3039 Amwiler Road
Atlanta, Georgia 30360

telephone: 770-903-9100
http://ga.water.usgs.gov

Torak and others—**Geohydrology of the Aucilla–Suwannee–Ochlockonee River Basin, South-Central Georgia and Adjacent Parts of Florida**—Scientific Investigations Report 2010–5072