THE MONITORING AND MODELING APPROACH TO SUPPORT GROUND-WATER MANAGEMENT IN GEORGIA

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Abstract. *Modeling* and monitoring are essential tools that provide critical information needed by resource managers to help formulate policy and to make sound management decisions. *Monitoring* can be used to determine potential problems and assess the effectiveness of management practices; and *Modeling* can be used to provide a basis for simulation of water-management options and possible future conditions. This paper provides an overview of ground-water resource issues and monitoring and modeling activities being conducted by the U.S. Geological Survey to assess ground-water resource issues in Georgia. Results derived from these activities are being used by State and local agencies to support water-policy development and water-management decisions.

INTRODUCTION

Freshwater resources of Georgia have come under increasing demand as population and agriculture have grown. Accurate hydrologic information enables water managers to make science-based decisions regarding allocation of available resources and to provide a basis for limitation of ground-water withdrawal. The U.S. Geological Survey (USGS)—in cooperation with Federal, State, and local agencies—operates monitor-well networks and performs digital modeling studies to assess ground-water resources in Georgia. These data and studies provide much of the supporting information needed to provide for optimal development and protection of water resources.

GROUND-WATER ISSUES IN GEORGIA

Ground-water pumping is the most important human activity that affects the amount of ground water in storage and the rate of discharge from an aquifer (Taylor and Alley, 2001). Ground-water storage is depleted within the area of influence of pumping, causing water levels in the aquifer to decline, and form a cone of depression around the well. In areas having a high density of pumped wells, multiple cones of depression coalesce, producing water-level declines across a large area. These declines may alter ground-water flow directions, reduce flow to streams, capture water from a stream or adjacent aquifer, or alter ground-water quality. During 2000, ground water provided 1.45 billion gallons per day, or 22 percent of the total freshwater used (including thermoelectric) in the State (Fanning, 2003). Development of ground-water resources throughout Georgia has led to a variety of water-management issues including (Fig. 1).

- In coastal Georgia, pumpage from the Upper Floridan aquifer has resulted in water-level decline and encroachment of seawater into the aquifer at the northern end of Hilton Head Island, South Carolina, and saltwater intrusion into the aquifer from underlying brine-filled strata at Brunswick, Georgia.
- In southwestern Georgia, increased irrigation pumpage from the Upper Floridan aquifer could reduce flow of mainstem and tributary streams and adversely affect the ecosystem in the lower part of the Apalachicola–Chattahoochee–Flint (ACF) River Basin.
- In south-central Georgia, increased pumpage for irrigation and public supply has caused unprecedented ground-water-level declines and the potential for pumpage-induced streamflow and springflow reduction in the Aucilla–Suwannee–Ochlockonee (ASO) River Basin.
- In the northernmost Coastal Plain, pumpage has resulted in rapidly declining ground-water levels and the potential for pumpage-induced streamflow reduction and aquifer dewatering.
- In the Piedmont and Blue Ridge of northern Georgia, there is concern over the sustainability of ground-water resources and the effect of ground-water pumping on surface-water resources.

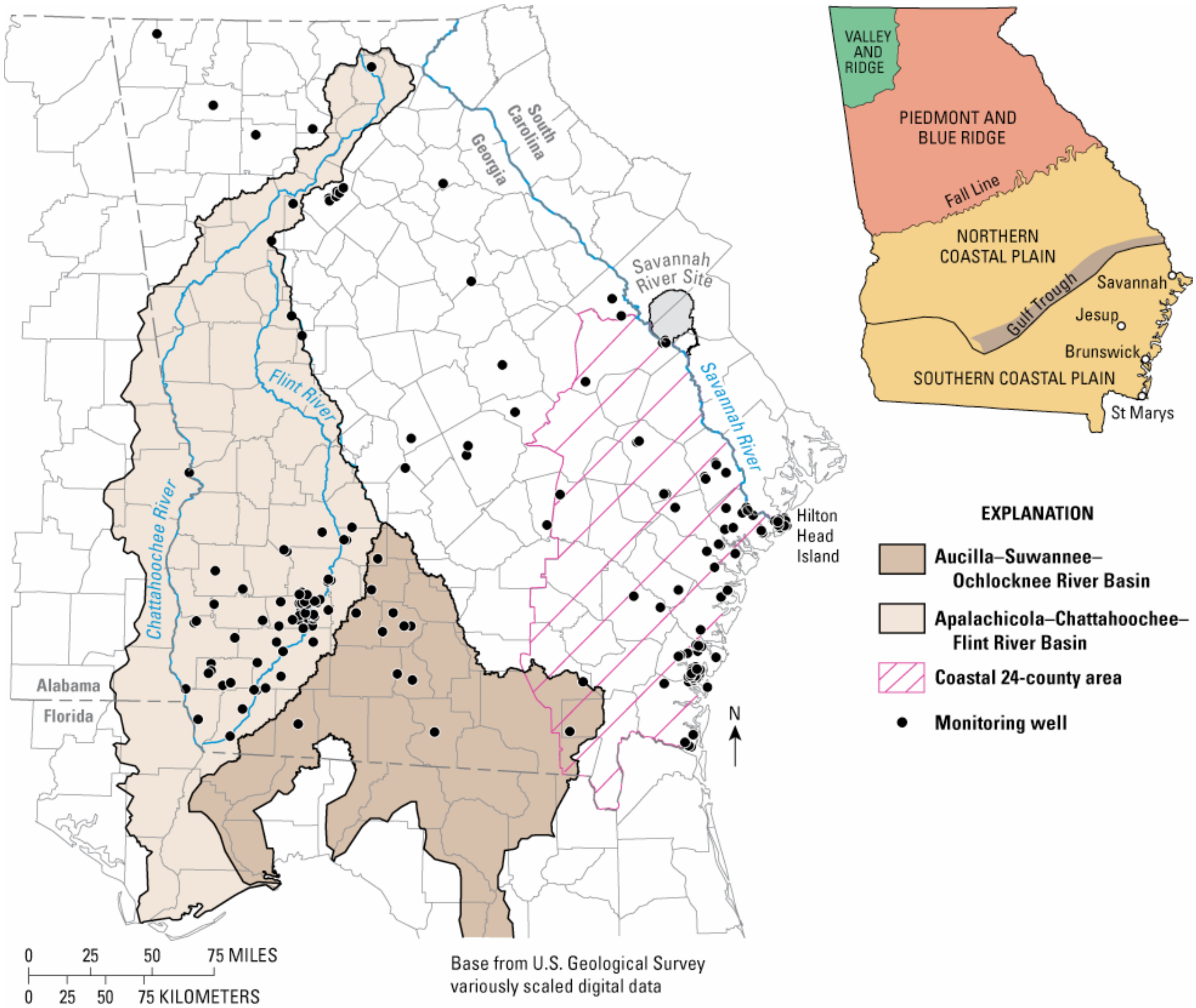

Figure 1. Areas of Georgia facing ground-water issues, physiographic provinces, and U.S. Geological Survey ground-water monitoring network. See text for description of issues.

THE MONITORING AND MODELING APPROACH TO SUPPORT GROUND-WATER MANAGEMENT

Modeling and monitoring are essential tools that provide critical information needed by resource managers to help formulate policy and to make sound management decisions. Monitoring can be used to determine potential problems and assess the effectiveness of management practices; and modeling can be used to provide a basis for simulation of water-management options and possible future conditions.

Ground-Water Monitoring Network

Ground-water-level and ground-water-quality data are essential for water-resource assessment and management; these data provide information needed to evaluate changes in the resource over time, to develop ground-water models and forecast trends, and design, implement, and monitor the effectiveness of ground-water management and protection programs. The ground-water monitoring network in Georgia consists of 170 wells that continuously monitor ground-water levels, 20 of which are equipped with real-time satellite telemetry (Fig. 1). Most of the wells are located in the Coastal Plain in the southern part of the State where ground-water pumping stress is high. The ground-water monitoring network is sparse in northern Georgia and the ASO River Basin, making it difficult to provide informed decisions regarding water resources in these areas.

In addition to ground-water-level monitoring, the USGS collects and analyzes ground-water samples for nitrate concentration in the Albany area, and for chloride concentration in the Brunswick, Savannah, and Camden County areas.

Ground-Water Models

The USGS—in cooperation with Federal, State, and local agencies—has been developing digital models to help assess hydrologic conditions and flow processes since the 1970s. The most recent studies involving ground-water models include an investigation of stream-lake-aquifer interconnection in the ACF River Basin of southwest Georgia and adjacent parts of Alabama and Florida (Jones and Torak, 2006); an assessment of ground-water flow and saltwater intrusion in the 24-county coastal area of Georgia and adjacent parts of South Carolina and Florida (Payne and others, 2005; Provost and others, 2006; Payne and others, 2006); and a particle-tracking analysis of ground-water flow near the Savannah River Site area southeast of Augusta, Ga. (Cherry, 2006).

Examples of the Monitoring and Modeling Approach

The Georgia Environmental Protection Division (GaEPD) has implemented use of monitoring and modeling to address a variety of water-resource issues in Georgia. Several examples demonstrate how monitoring and modeling activities conducted by the USGS have been used by GaEPD to support policy development and to track the effectiveness of water-management decisions.

Brunswick Area Chloride Contamination. Saltwater contamination of the Upper Floridan aquifer in a 2-square-mile area of downtown Brunswick has limited development of the ground-water supply. The USGS has worked with the City of Brunswick since the early 1960s to monitor and assess the effect of ground-water development on saltwater contamination of the Floridan aquifer system. Data from an 88-well network—sampled on an annual basis to monitor changes in saltwater contamination—indicate that although concentrations of chloride fluctuate within the contaminated area, the extent of contamination has remained largely stable since the early 1980s (Fig. 2). The GaEPD has used this information to guide formulation of the State's water-management strategy for the area (Georgia Environmental Protection Division, 2006b). Because the extent of the contaminated area is generally stable, the water-management strategy provides for additional ground-water pumping in Glynn County in an area beyond a yet-to-be-determined buffer surrounding the contaminated area. A ground-water model is being used to establish the areal extent of the surrounding buffer, and to determine the optimum distribution of pumping throughout the county. To provide an early warning regarding possible lateral saltwater migration toward existing pumping locations, selected wells surrounding the area of contamination are being equipped with real-time satellite telemetry, whereby ground-water levels and specific conductance (a surrogate for chloride concentration) will be monitored.

Ground-Water Withdrawal in Coastal Georgia. The interim water-management strategy to alleviate saltwater intrusion for the 24-county coastal area (Fig. 1) capped pumping from the Upper Floridan aquifer in the Savannah and Brunswick areas at 1997 rates (Georgia Environmental Protection Division, 1997). Ground-water monitoring and water-use data, and digital models of ground-water flow (Payne and others, 2005) and solute-transport (Provost and others, 2006) were used to assess the effects of these restrictions on ground-water levels and chloride contamination in the Hilton Head Island, South Carolina area. During 1997-2000, pumping in the modeled area increased, with most of the increase occurring north of the Gulf Trough, a low-permeability geologic feature that acts as a natural hydraulic boundary; pumping decreased in the Savannah and Brunswick, Ga. areas, and in the Hilton Head Island area, S.C. Data from the monitoring network and model simulations indicate that these pumping changes resulted in water-level declines where pumping increased, and rises where pumping decreased (Fig. 3). Only minor growth of the area of chloride contamination near Hilton Head Island was simulated during this period (Payne and others, 2006). Long-term ground-water-level monitoring documented the water-level recovery during 1997–2000, which State water managers used to evaluate the effectiveness of the interim strategy on ground-water conditions in the coastal area.

Monitoring data and simulation results enabled the GaEPD to make decisions regarding ground-water withdrawal permitting in the coastal area. Greater quantities of withdrawal were permitted in areas where pumping had a diminished effect on ground-water levels in the Savannah–Hilton Head Island area and thus a reduced potential for causing saltwater contamination. In the southern part of the coastal area, shutdown of a major paper mill during October 2002 provided a unique opportunity to observe water-level recovery throughout the coastal area following a period of prolonged high-rate pumping (Peck and others, 2005). Cessation of 35.6 million gallons per day (Mgal/d) pumping at the Durango Paper Company in St. Marys, Camden County, resulted in water-level rises in wells completed in the Floridan aquifer system of as much as 140 feet (ft) near the center of pumping, becoming less pronounced in outlying areas of the county (from 5 to 10 ft). To further assess the effect of this pumping decrease on ground-water levels, the calibrated ground-water-flow model for coastal Georgia (Payne and others, 2005) was used to simulate changes resulting from the shutdown (Payne and others, 2006). The reduction in pumpage resulted in a simulated water-level recovery of 1–2 ft at distances as far as 100 miles, with less than 1 ft recovery near Hilton Head Island (Fig. 4). This diminished response shown through both monitoring and simulation demonstrated that pumping in the southern part of the coastal area had little effect on ground-water levels outside of the Camden County area, which enabled GaEPD to loosen restrictions on ground-water withdrawal in that area.

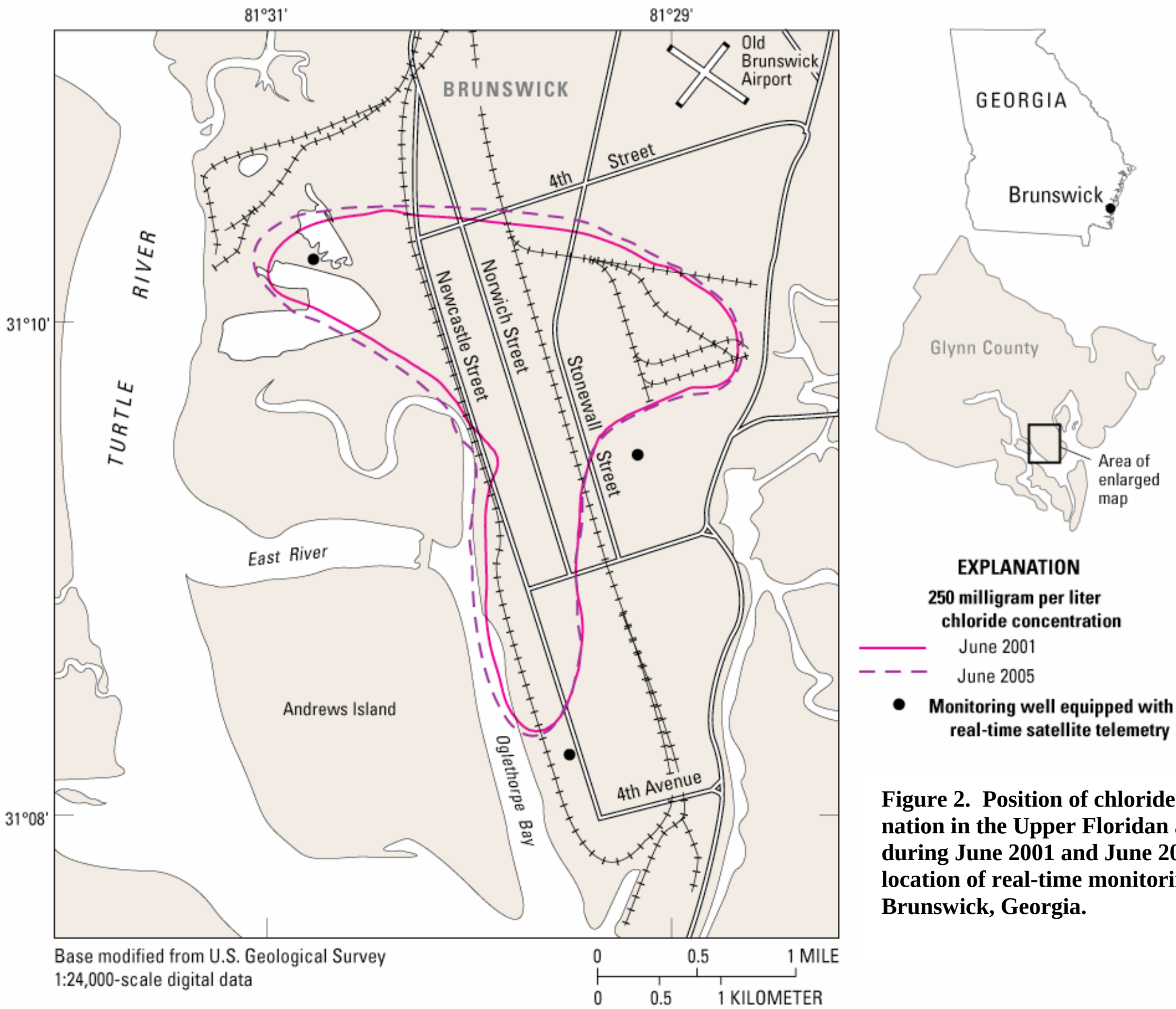

Figure 2. Position of chloride contamination in the Upper Floridan aquifer during June 2001 and June 2005 and the location of real-time monitoring wells at Brunswick, Georgia.

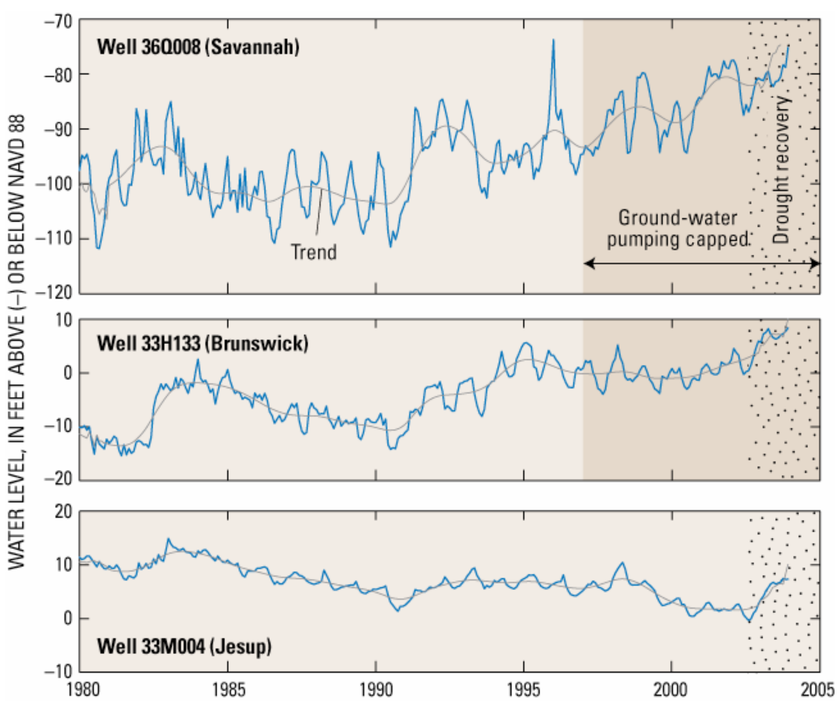

Figure 3. Water-level trends in selected monitoring wells completed in the Upper Floridan aquifer, coastal Georgia, 1980–2005. Well locations shown on figure 4 (vertical coordinate information is referenced to the North American Vertical Datum of 1988—NAVD 88).

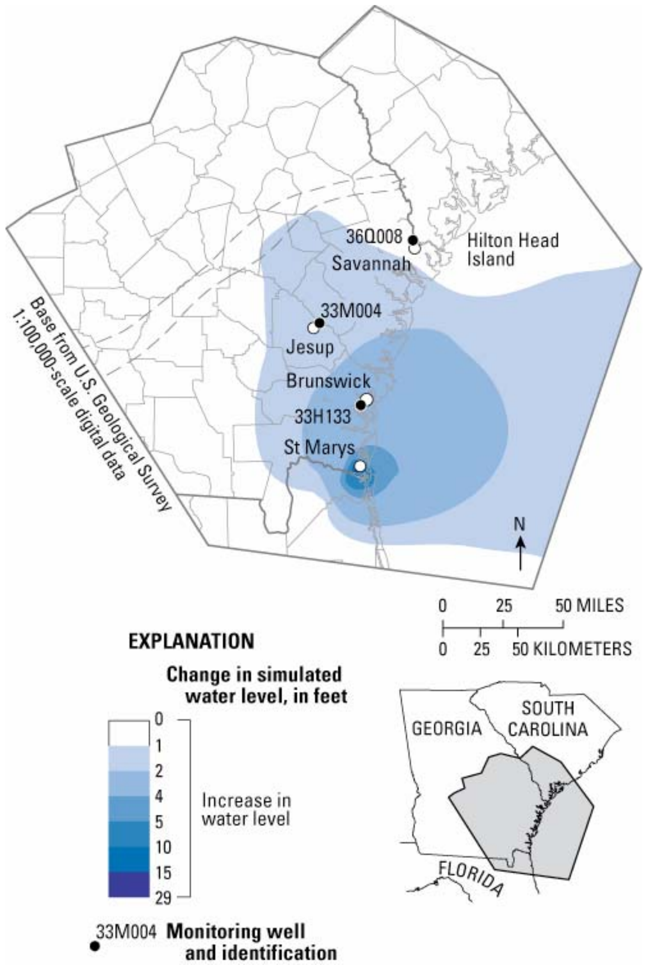

Figure 4. Simulated water-level rise in the Upper Floridan aquifer from Durango Paper Company shutdown, 2002, and locations of selected monitoring wells in coastal Georgia (modified from Payne and others, 2006).

Effects of Seasonal Irrigation Pumpage on Streamflow in the Lower ACF River Basin. Ground- and surface-water resources are highly connected in the lower ACF River Basin of southwestern Georgia (Fig. 1). Data from USGS streamflow gages and ground-water-level monitoring wells demonstrate stream-aquifer interconnection and how increased irrigation pumpage has influenced hydrologic conditions in the lower ACF River Basin (Fig. 5). Well 11J012 is about 0.8 mile east of the Flint River and shows a pronounced response to changes in Flint River stage. Well 10K005, is near a tributary stream farther from the river (about 15 miles) and shows little response to streamflow, but a pronounced response to irrigation pumpage. These data, combined with results of model simulations, provide insight into areas where the Upper Floridan aquifer is influenced by irrigation pumpage and hydraulically connected to streams, which could require special permitting considerations to minimize streamflow reductions during dry periods.

To quantify the effects of seasonal irrigation pumpage on stream-aquifer flow and the source of water pumped for irrigation during 2001–2002, a transient ground-water flow model was developed for the lower ACF River Basin (Jones and Torak, 2006). Model development was facilitated by expansion of ground- and surface-water monitoring in the lower ACF basin. Simulation results provided information on stream reaches most affected by irrigation pumpage and helped guide development of the Flint River Basin Regional Water Development and Conservation Plan (Flint River Plan) (Georgia Environmental Protection Division, 2006a).

To guide development of the Flint River Plan, staff from the GaEPD modified the calibrated model of Jones and Torak (2006) to simulate detailed water budgets in the Ichawaynochaway Creek, Spring Creek, and lower Flint River Basins for both normal- and drought-year climatic and pumping conditions, and for projected increases in pumping caused by a "backlog" of pending permit applications (Georgia Environmental Protection Division, 2006a). From these simulations, the reduction in the amount of ground-water flow to streams was computed for Hydrologic Unit Code level-12 (HUC-12) subbasins for each of the climatic and pumping conditions. Three water-management categories were designated by GaEPD on the basis of the simulated reduction in stream baseflow (ground-water discharge) in the HUC-12 subbasins during drought years (Fig. 6): (1) "Conservation Use" areas, (2) "Restricted Use" areas, and (3) "Capacity Use" areas. These water-management categories are used by the State to guide ground-water withdrawal permitting in the area.

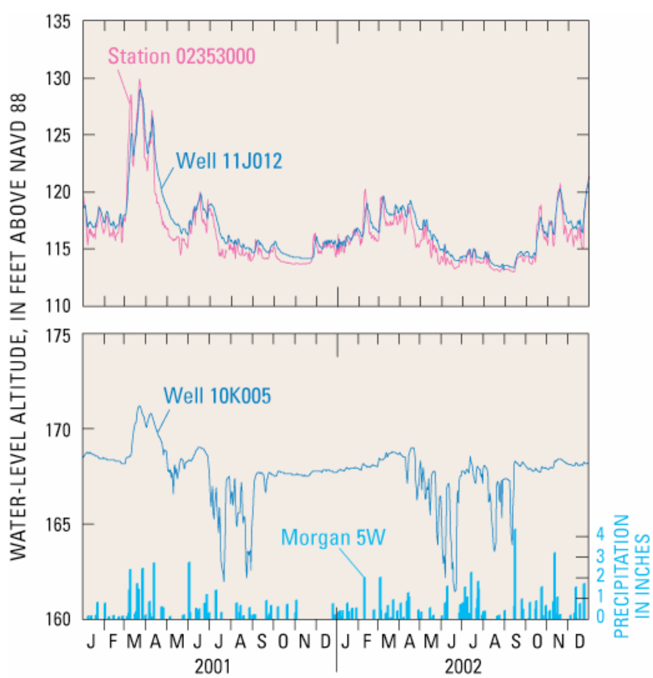

Figure 5. Ground-water levels, stream stage, and precipitation at selected sites in the lower Apalachicola–Chattahoochee–Flint River Basin, 2001–2002. See figure 6 for site locations. (Modified from Torak and Painter, 2006, vertical coordinate information is referenced to the North American Vertical Datum of 1988—NAVD 88).

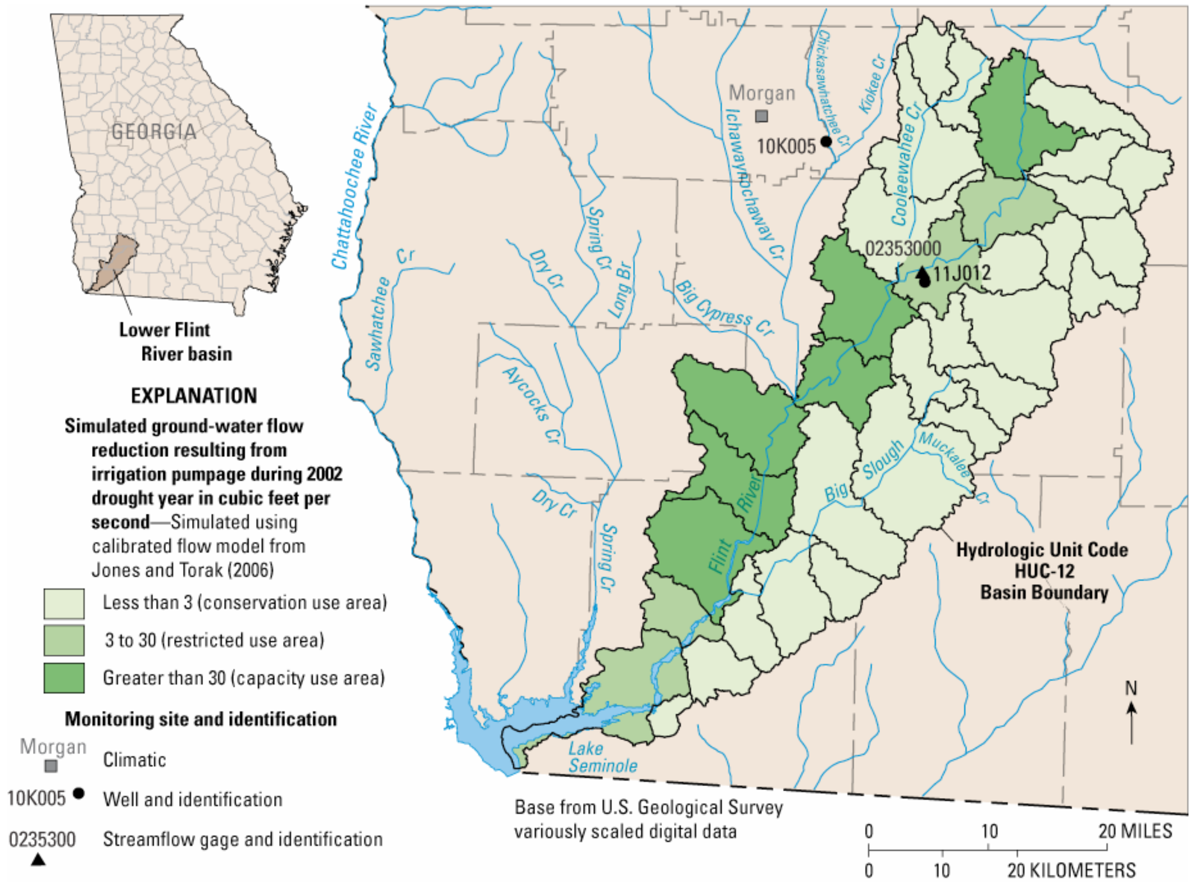

Figure 6. Simulated ground-water flow reduction for lower Flint River Basin during a drought year (2002), and locations of selected monitoring wells, climatic stations, and streamflow gages. (Modified from Georgia Environmental Protection Division, 2006a.)

OUTLOOK

As Georgia's comprehensive statewide water plan is implemented, there will be an increased need for water-use data and ground- and surface-water monitoring to support development and implementation of new regulatory requirements. Expanded monitoring to fill data gaps in northern Georgia and in the ASO River Basin will enable determination of the impact of ground-water development on surface-water resources. Real-time monitoring of ground-water levels, streamflow, and pumpage can provide valuable information to assess the effect of drought on water resources throughout the State. In coastal Georgia, real-time monitoring of ground-water levels and specific conductance can provide valuable information on the effect of water-management practices on ground-water levels and saltwater contamination.

Ground- and surface-water modeling can provide a basis for predictive simulation of the effects of future water demand on ground- and surface-water resources. Some areas of the State facing ground-water issues—such as the ASO Basin and the northernmost Coastal Plain—have not been studied in sufficient detail to develop ground-water models, which could be used to provide insight into the effects of water-management options on stream-aquifer conditions. Long-term monitoring data can provide a basis to evaluate the effectiveness of water-management practices, and provide vital information for the development of new, and update of existing, ground-water models.

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