STREAM-AQUIFER RELATIONS IN THE COASTAL AREA OF GEORGIA AND ADJACENT PARTS OF FLORIDA AND SOUTH CAROLINA

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Abstract. Stream-aquifer relations in a 31,835-square-mile area in parts of Georgia, Florida, and South Carolina were evaluated in support of ground-water modeling investigations using hydrograph-separation and a linear-regression analysis of streamflow duration curves. The study area consists of three major river systems—the Altamaha-Satilla-St Marys, Salkehatchie-Savannah-Ogeechee, and Suwannee—that interact with the underlying ground-water system to varying degrees largely based on the degree of incision of a river into an aquifer and on topography. Average mean-annual base-flow in the three basins ranged from about 42 to 69 percent of total mean-annual streamflow during 1981, 1997, and 2000. Baseflow provided a larger percentage of streamflow at sites in the Salkehatchie-Savannah-Ogeechee River Basin than in the other two basins, which probably results from their proximity to the upper Coastal Plain where there is greater topographic relief and interconnection between streams and aquifers. Linear-regression analysis of baseflow and streamflow duration indicate that the 65-percent flow duration is a reasonable estimate of mean-annual baseflow.

INTRODUCTION

The Georgia Coastal Sound Science Initiative is a study designed to better understand how to protect the Upper Floridan aquifer from salt-water intrusion. As part of the study, a regional model is being developed to evaluate ground-water flow and to better define stream-aquifer relations for the Upper Floridan aquifer. Estimates of ground-water discharge to selected streams in the study area are being used to help calibrate the model. This paper provides a conceptual model of stream-aquifer flow for coastal Georgia; presents a description of precipitation, streamflow, and ground-water level trends; and describes estimates of ground-water discharge to streams using hydrograph-separation and linear-regression techniques.

The 31,835-square-mile study area lies entirely in the Coastal Plain Physiographic Province and includes the 24-county coastal area and surrounding 42 counties extending into northeastern Florida and southwestern South Carolina (Fig. 1). Eight sites with 31 years of continuous record (Fig. 1, Table 1) in three major river basins were used to estimate baseflow using hydrograph-separation techniques and linear-regression analysis of streamflow duration. Ground-water level, streamflow, and precipitation data were used to describe fluctuations and trends in the Salkehatchie-Savannah-Ogeechee River Basin.

STREAM-AQUIFER RELATIONS

Surface water and ground water interact within a dynamic hydrologic system consisting of aquifers, streams, reservoirs, and floodplains. These systems are interconnected and form a single hydrologic entity that is stressed by natural hydrologic and climatic factors and by anthropogenic factors. A conceptual model of stream-aquifer flow is shown in Figure 2. In the study area, recharge to the hydrologic system is by precipitation that ranges from an average of about 47 inches per year (in/yr) near Tifton to about 53 in/yr near Homerville for the 30-year period 1971–2000 (National Oceanic and Atmospheric Administration, 2002). Most precipitation is lost as discharge into small streams, or as evapotranspiration, with only a small percentage recharging the ground-water system.

In the study area, major hydrogeologic units include, in order of descending depth, the surficial aquifer, the upper and lower Brunswick aquifers (Clarke and others, 1990), and the Floridan aquifer system consisting of the Upper and Lower Floridan aquifers (Miller 1986; Krause and Randolph, 1989). The Floridan aquifer system is the principal source of water supply in coastal Georgia, and the surficial and upper and lower Brunswick aquifers are secondary sources.

The study area includes three major river systems—Altamaha-Satilla-St Marys, Salkehatchie-Savannah-Ogeechee, and Suwannee (Fig. 1). These rivers interact with the underlying ground-water system to varying degrees largely based on the degree of incision of the river into an aquifer and on the surrounding topography. In general, there is greater interconnection between the surface- and ground-water systems in the upper Coastal Plain than in the lower Coastal Plain, due to greater incision of aquifers by streams and greater topographic relief (Fig. 2). This greater relief results in a steeper hydraulic gradient from the aquifer toward the stream and corresponding higher ground-water discharge.

Precipitation, Streamflow, and Ground-Water Level Fluctuations

Long-term fluctuations in ground-water levels and streamflow illustrate the effects of natural and anthropogenic stresses on the stream-aquifer flow system. Precipitation changes are reflected in streamflow and ground-water levels in aquifers that are semiconfined or unconfined. When ground-water levels are high from natural recharge (precipitation), ground-water contribution to streamflow is large. Conversely, when ground-water levels are low due to lack of recharge (drought) or increased pumping, ground-water contribution to streamflow is small.

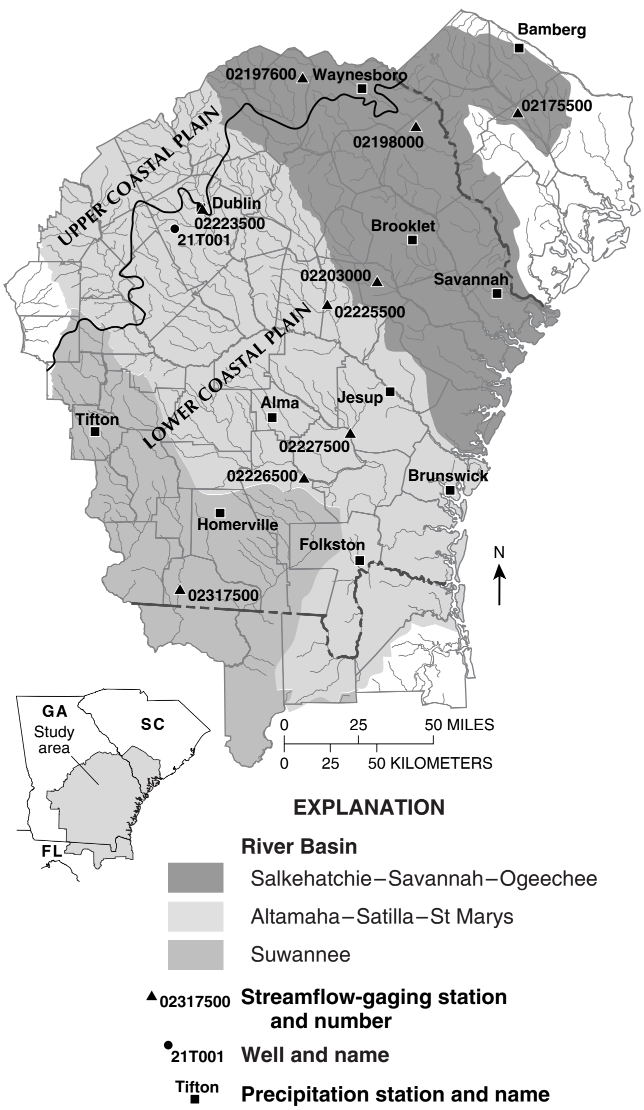

Figure 1. Study area, streamflow-gaging stations, wells, and precipitation monitoring stations.

Table 1. Percent of total mean-annual streamflow contributed from baseflow during 1981, 2000, 1997, and 1971–2001

[Baseflow estimated using HYSEP method.]

Site number	Baseflow (in percent of mean-annual streamflow): Drought year 1981	Drought year 2000	Average year 1997	Average year 1971–2001
Salkehatchie-Savannah-Ogeechee River Basin				
02175500	77	65	64	69
02197600	74	81	68	66
02198000	72	80	70	74
02203000	51	51	48	64
Basin average	68.5	69.2	62.5	65.8
Altamaha-Satilla-St Marys River Basin				
02225500	53	62	56	57
02226500	47	34	47	43
02227500	27	34	33	39
Basin average	42.3	43.3	45.3	46.3
Suwannee River Basin				
02317500	56	50	56	56
Three-basin average	57	57	55	57

Precipitation, streamflow, and ground-water level fluctuations and trends are illustrated on selected graphs in the upper part of the Altamaha-Satilla-St Marys River Basin for the period 1971–2001 (Fig. 3). The cumulative departure from normal precipitation describes the long-term surplus or deficit of precipitation over a designated period of time. Cumulative departure is derived by adding successive monthly departures from normal precipitation. For this investigation, normal precipitation is defined as the average monthly precipitation during the period 1971–2000. Precipitation at the Dublin, Ga., station was below normal during much of the 1970s and 1980s as indicated by a downward slope on the cumulative-departure graph (Fig. 3). This period of below-normal precipitation was followed by a period of above-normal precipitation during much of the 1990s, and the most recent period of below-normal precipitation during 1998–2001. Both streamflow and ground-water levels in this basin responded to variations in precipitation, but neither showed any evidence of long-term trends.

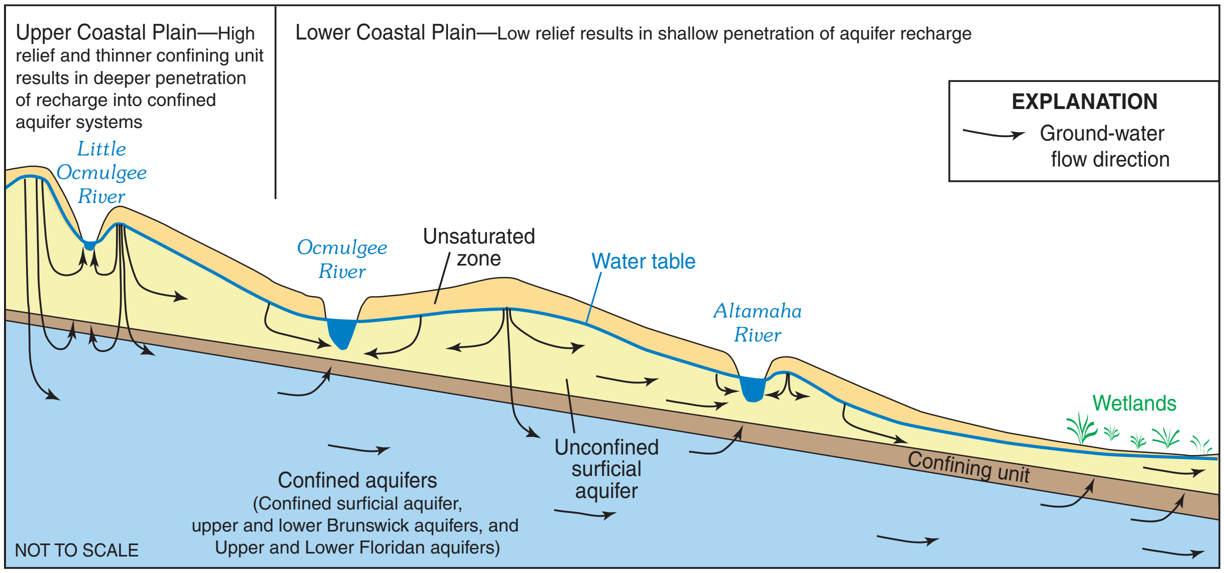

Figure 2. Schematic diagram of the conceptual hydrologic flow system in the upper and lower Coastal Plain of Georgia.

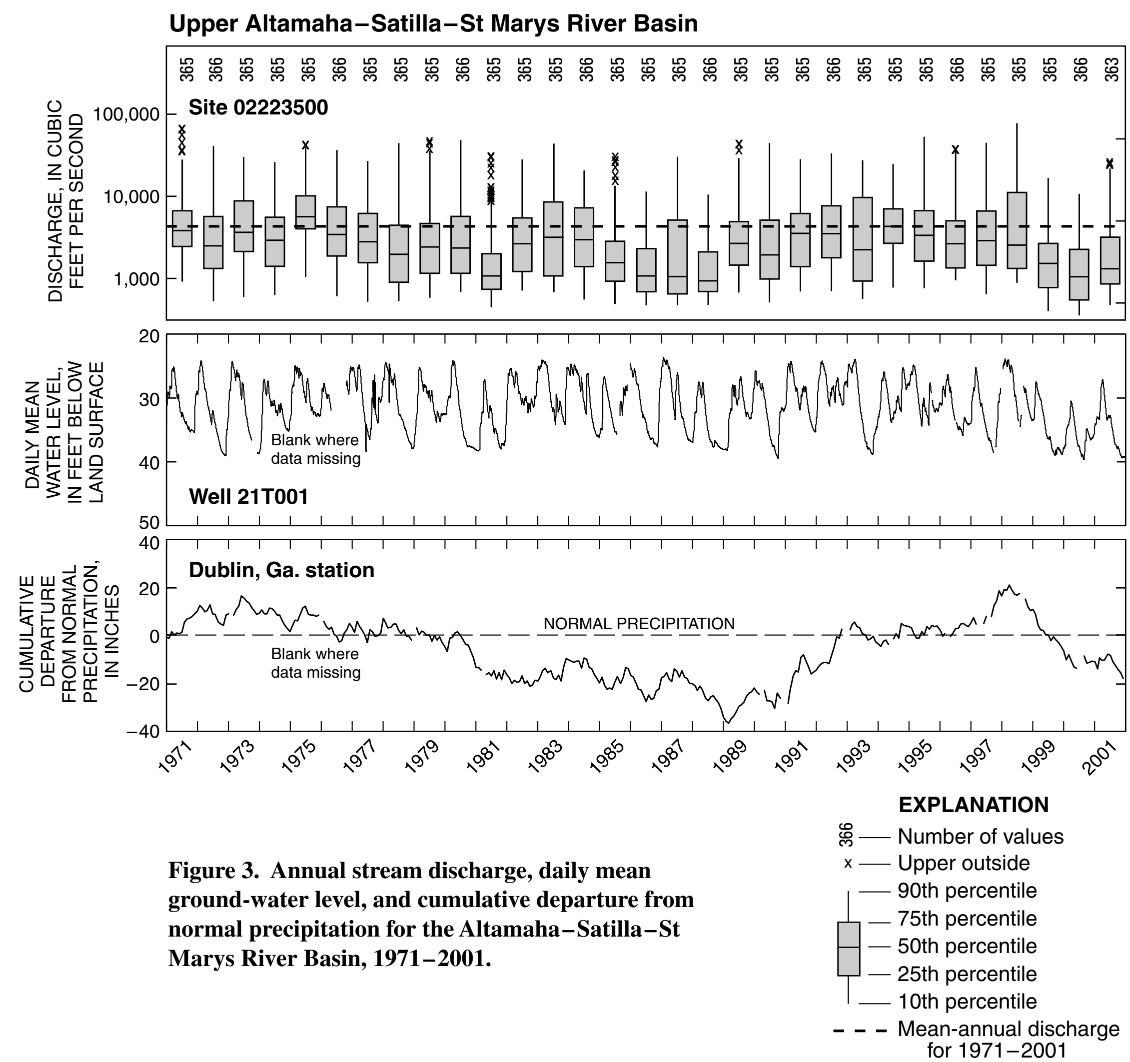

Figure 3. Annual stream discharge, daily mean ground-water level, and cumulative departure from normal precipitation for the Altamaha–Satilla–St Marys River Basin, 1971–2001.

GROUND-WATER CONTRIBUTION TO STREAMFLOW

Ground-water contribution to streamflow was estimated using hydrograph-separation and linear-regression analysis of streamflow-duration curves at eight continuous streamflow-gaging sites (Table 1). Hydrograph separation was conducted using the computer program HYSEP (Sloto and Crouse, 1996), which systematically separates the baseflow and surface runoff components of a stream hydrograph by connecting low points on the hydrograph. Each site selected for HYSEP analysis had negligible diversion or regulation, a drainage area less than 1,400 square miles, and at least 31 years of continuous record. Mean-annual baseflow, expressed as percent of total mean-annual streamflow, was estimated for 1981 and 2000 (drought conditions) and 1997 (year most representative of mean-annual precipitation for the period 1971–2001). Average mean-annual baseflow in the three basins ranged from about 42 to 69 percent of total mean-annual streamflow during the 3 years evaluated (Table 1).

Baseflow provided a larger percentage of streamflow in the Salkehatchie-Savannah-Ogeechee River Basin than in the other two basins. The average percentage contribution by baseflow was about 62 percent in 1997, and increased to 68–69 percent during the two drought years (1981 and 2000). In the Altamaha-Satilla-St Marys River Basin, the average contribution during the 3 years evaluated was about 42-45 percent, and in the Suwannee River Basin the average contribution was about 50–56 percent (Table 1). The higher percentage baseflow at sites in the Salkehatchie-Savannah-Ogeechee River Basin probably results from their proximity to the upper Coastal Plain where there is greater topographic relief and interconnection between streams and aquifers.

Linear-regression analysis was used to determine the streamflow duration that provides the best estimate of baseflow for streams in the study area. Mean-annual baseflows calculated using HYSEP were compared to streamflow durations at eight continuous streamflow sites using procedures similar to that performed by Stricker (1983) for streams in the northernmost Coastal Plain. The best fit between HYSEP estimates and flow duration was at the 65-percent flow duration (Fig. 4), comparable to findings reported by Stricker (1983).

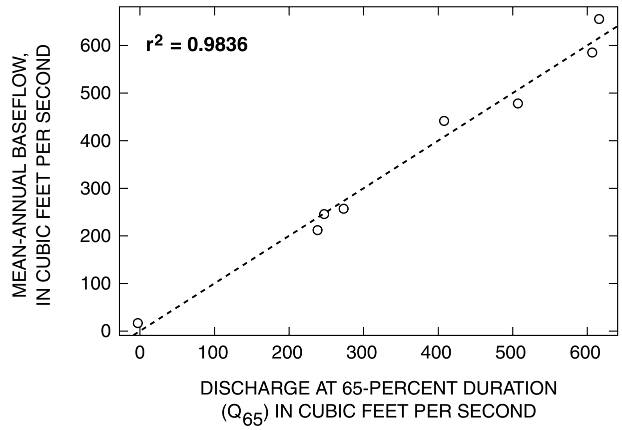

Figure 4. Regression of Q_{65} and mean-annual baseflow for the eight sites selected for hydrograph-separation technique.

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