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

The Suwannee River Basin Pilot Study: Issues for Watershed Management in Florida

USGS

Introduction

In most watersheds (river basins) in Florida the interactions between ground water and surface water typically result in a single dynamic flow system. This direct hydraulic linkage results from numerous karst features (such as sinkholes, conduit systems in the underlying limestone, and springs) that facilitate the exchange of water between the surface and subsurface (fig. 1). Unique problems can arise in protecting water quality in karst areas because of the direct and rapid transport of recharge through conduits to the subsurface and through resurgence by springs. In some areas, recharge from unknown drainage pathways to areas of discharge may contribute to chemical and biological contamination of water supplies. Such contamination in karst areas has been documented by many studies.

Legislation enacted in 1993 mandated the Florida Department of Environmental Protection (FDEP) to develop and implement measures to protect the functions of the State's ecosystems. Watershed management is one of the main components of a program designed to protect and manage Florida's ecosystems. The FDEP has identified several key objectives to effectively address watershed management issues: (1) more coordinated management of ground- and surface-water resources, (2) more effective partnerships with local, regional, State, and Federal government agencies, (3) coordination of ground- and surface-water monitoring efforts to assess the quality and quantity of the water resources and delineate the boundaries of three-dimensional watersheds, and (4) the development and maintenance of comprehensive statewide data bases for water resource information and monitoring networks oriented toward targeted watersheds.

The Suwannee River basin in Florida is one of several watersheds in the U.S. that was chosen for a pilot study by the Intergovernmental Task Force on Monitoring Water Quality (ITFM) to evaluate the effectiveness of current monitoring programs that are coordinated among Federal, State, and local agencies in addressing the key issues related to monitoring water resources. The ITFM previously found that information gaps existed in State and Federal monitoring programs and recommended that these gaps be addressed by developing an integrated, voluntary, nationwide strategy for water-quality monitoring. The ITFM recommended the watershed approach as a highly effective way to manage water resources because this approach integrates ground-water and surface-water systems.

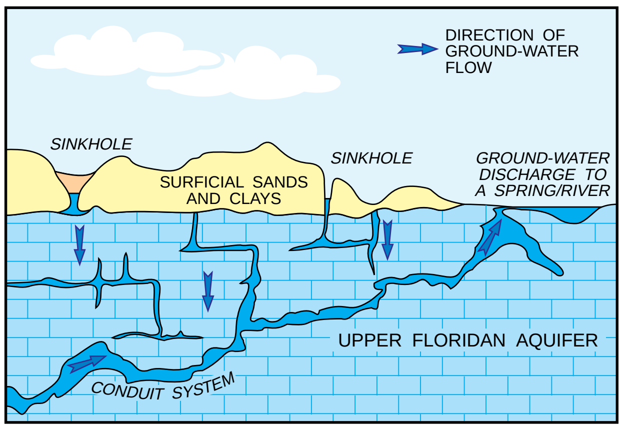

Figure 1. Generalized cross section in the Suwannee River basin showing karst features that facilitate the exchange of water between the surface and subsurface.

The Suwannee River basin pilot study is attempting to provide answers to critical watershed-management questions such as: (1) Can boundaries be delineated for ground-water and surface-water basins and do these boundaries change depending upon hydrologic conditions? (2) What does existing information tell about the hydrochemical interaction between ground water and surface water in the basin? (3) Can natural processes provide a remediation of elevated concentrations of nitrate in the Upper Floridan aquifer (UFA) during high or low flow conditions and or mixing of surface and ground water? and (4) Can a framework be developed in this study for evaluating the interactions between ground water and surface water and for delineating watershed boundaries that can be extrapolated to other watersheds within Florida and nationwide that have similar hydrogeologic conditions?

Monitoring Programs in the Basin

The Suwannee River basin in Florida comprises an area of 4,230 mi^2 (fig. 2). The basin is characterized by karstic wetland and lowland topography, a small number of tributary streams, and an abundance of discharge as springs from the UFA. Historically, ground-water and surface-water systems in the Suwannee River basin have been monitored as separate media under specific programs, with the exception of a small number of local studies. During the past 30 years, a considerable amount of hydrologic data (such as river stage and ground-water level) was collected as part of extensive surface-water and ground-water networks.

The Suwannee River Water Management District (SRWMD) in cooperation with the FDEP and U.S. Geological Survey (USGS), maintains extensive monitoring networks for surface water and ground water in the Suwannee River basin. As part of a surface-water network, water levels are being measured regularly at 17 lakes, river stage and discharge are monitored at 18 sites, and daily rainfall is recorded at 34 stations. Surface-water quality samples are collected monthly or bimonthly at 52 sites by the SRWMD as part of the Surface Water Improvement and Management Program. Currently, ground-water levels are being measured at 328 sites in the basin, which includes monthly measurements at 43 wells and continuous measurements (using water-level recorders) at 32 wells. Since 1987, extensive information on ground-water quality is being collected as part of the Florida Ground Water Quality Monitoring Program (FGWQMNP), which contains 107 wells designed to monitor background water quality of the principal aquifers. Water from these wells is sampled every three years for major ions, nutrients, trace elements, and selected organic compounds (Maddox and others, 1992). Also as part of the FGWQMNP, the effects of various land-use practices on ground-water quality are being investigated at a mixed urban-industrial site and at an agri-

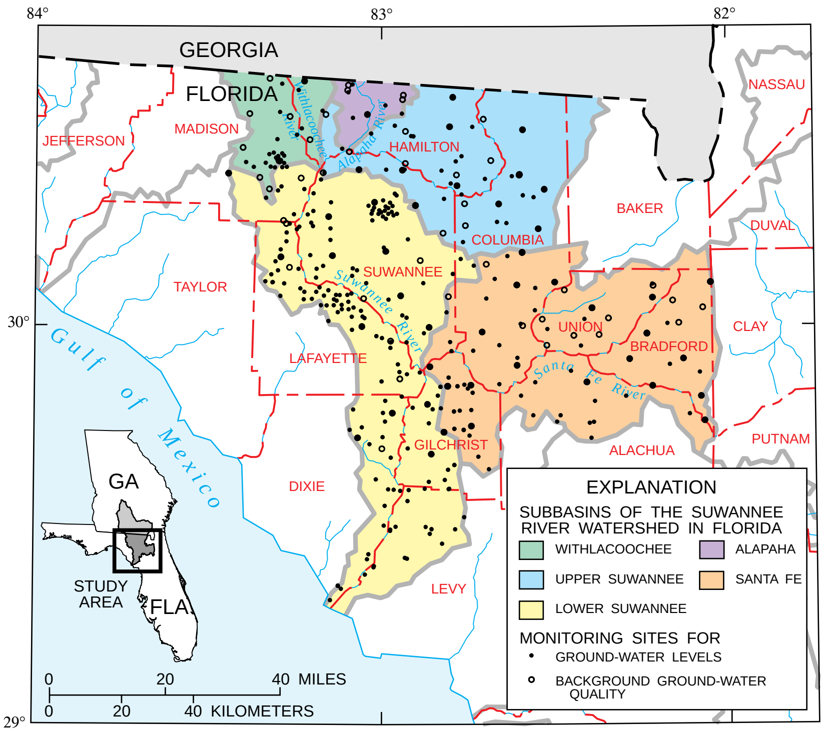

Figure 2. Location of monitoring sites and subbasins in Suwannee River watershed, Florida.

cultural area in the Suwannee River basin. As part of the National Water Quality Assessment Program (NAWQA), the USGS has sampled water from six wells in its regional background network for the surficial aquifer system. Seven sites on the Suwannee River in Florida and one site on the Santa Fe River are being sampled by NAWQA for bed material, water quality, and biological species.

Comparison of ground-water and surface-water basin boundaries

The accurate delineation of karst drainage basins represents a considerable challenge because of complex patterns of surface-water and ground-water flow. In studies of karst areas in other parts of the world it was determined that surface water basins typically do not coincide with corresponding ground-water basins. For example, streams that sink within one surface drainage basin can reappear in a different basin. Ground-water divides are controlled by aquifer properties as well as by topographic conditions.

Two-dimensional boundaries for surface-water and ground-water subbasins in the Suwannee River basin were compared for two different hydrologic conditions: low-flow conditions during December 1990 to January 1991 and high-flow conditions during April to May 1984. Patterns of ground-water flow were derived from potentiometric-surface maps of the UFA constructed for low flow and high flow conditions. These patterns were superimposed on surface water drainage areas for the major subbasins in the Suwannee River basin. Generally, the regional flow patterns indicate that boundaries for ground-water basins do not coincide with surface-water drainage subbasins except in some parts of the lower Suwannee River basin and the Santa Fe River subbasin. There are several areas in the basin where ground water that originates outside of the Suwannee River basin crosses surface-water basin boundaries during both low flow and high flow conditions. However, the measured ground-water levels were part of a network whose objective is to delineate the regional potentiometric surface of the UFA. The wells in this network are open to different depths in the aquifer and probably intercept more localized ground-water flow systems. Therefore, the wells in the present network (approximately 250 wells in the basin) are not adequately distributed to accurately define two-dimensional ground-water basin boundaries in most areas of the Suwannee River basin.

To more accurately define drainage areas, the connection between discharge areas (such as springs) for the UFA and surface water must be determined for different flow conditions using tracer techniques involving dyes and naturally occuring isotopes and, in some cases, human exploration (cave diving). In one such study in the Santa Fe River basin, the degree of interconnection among springs that discharge from Ginnie Springs Park to the Santa Fe River was investigated using rhodamine dye tracing experiments. Based on the dispersion of dye to more than one spring, Wilson and Skiles (1988) concluded that there is an extensive network of three-dimensional braided conduits in the aquifer system and unique ground-water drainage divides do not exist within a few hundred meters of the spring discharge points.

Interactions Between Ground Water and Surface Water in the Basin

In some cases, the linkage between ground water and surface water can be obvious, as when water levels in the UFA respond directly to changes in stage of a nearby river. One such example is a monitoring well located near the Alapaha River (fig. 3). There is a high correlation between stage of the river and water levels in the aquifer. As the stage increases in the Alapaha River, ground water sampled at the Alapaha Tower well sometimes represents a mixture of river water and ground water. However, additional geochemical evidence is needed to determine the extent of mixing of river water with water from the UFA.

In other cases, the interaction between ground water and surface water can be subtle and tracers have been used to establish the relation. For example, several local studies have effectively used naturally occurring radionuclides, such as uranium (^{238}U and ^{234}U), radium (^{226}Ra), and radon (^{222}Rn), to trace the amount of ground water influx to rivers and amount of streamflow losses to ground water. These studies rely on the fact that the mobility of U, Ra, and Rn is controlled by different geochemical and physical processes that lead to their separation or fractionation in ground-water and surface-water systems. For example, ^{222}Rn is a gas and, hence, its concentration in ground water is about 1,000 times that in surface water. Based on measurements of ^{222}Rn in ground water and in a 2-kilometer reach of the Santa Fe River, a tributary to the Suwannee River, Kincaid (1994) reported that as the river discharge increased, corresponding increases were observed for ground-water discharge to springs, streamflow losses to ground water, and input to springs from resurgent streamflow. One particularly noteworthy finding was that even though the regional potentiometric-surface map of the UFA indicates that the Santa Fe River is a gaining stream, streamflow is actually being lost to the UFA in many places along the river. Siphons that are visible at the surface also provide direct evidence of stream water being diverted to the subsurface. As much as 55 percent of spring discharge at the Devil's Ear basin was supplied by resurgent surface water that originated in the the overlying Santa Fe River and not water from the UFA.

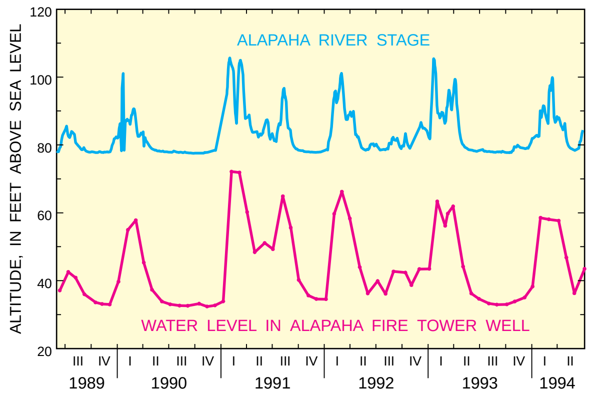

Figure 3. Comparison of Alapaha River stage and water level in Alapaha Fire Tower well.

Crane (1986) used differences in the $^{234}U/^{238}U$ activity ratio (UAR) and uranium (U) concentrations in ground water and surface water to determine the source and amount of recharge for different parts of the aquifer and ground-water contributions to the Suwannee River. Most sampled sites produced waters with low activity ratios and high U concentrations, which are typically associated with areas of the UFA that are unconfined and where recent and intense dissolution of aquifer minerals is occurring, such as in places where material overlying the UFA has been breached by sinkholes. For example, three water samples (the Little River springs and wells upgradient) from the Little River basin (in which material overlying the UFA has undergone recent and fairly intense dissolution) had very low activity ratios (0.57) and high U concentrations (1.76 micrograms per liter). Many springs had activity ratios greater than 0.75, which Crane attributed to a mixture of waters from areas of high recharge with those from areas of little or no recharge. The Suwannee River has UAR values and U concentrations that are anomalous when compared to those of other river systems of the world (Crane, 1986). The anomalous values result from mixing of some surface runoff (high UAR, low U concentration) with large amounts of ground-water flow from springs and seeps (generally low UAR and high U concentrations).

The input of water to the Suwannee River from large springs south of Branford, Fla., was traced using ^{226}Ra (Burnett and others, 1990). They found that stream stations north of Branford, Fla., tended to have a lower mean concentration of ^{226}Ra (0.189 disintegrations per minute per liter) compared to the mean concentration for stations south of Branford (0.270 disintegrations per minute per liter). Even though ^{226}Ra has a strong affinity for adsorption on aquifer minerals, the concentration of ^{226}Ra in ground water is generally several times to several orders of magnitude higher than in surface waters. Several of the first-order magnitude springs have relatively high ^{226}Ra concentrations (0.155 to 0.917 disintegrations per minute per liter) and the concentration of ^{226}Ra in these springs progressively increased in a downstream direction. This trend was attributed to the increasing contribution of water from deeper parts of the UFA that supply spring water to the lower reaches of the river.

An ongoing study that began in 1994 is investigating the connection between the Suwannee River and the unconfined UFA along a 75-kilometer reach from Ellaville to Branford, as part of the NAWQA study, in collaboration with the SRWMD and the University of Florida. Based on existing data from ten wells, sampled as part of the FGWQMNP during 1991 to 1994 for water levels and water-quality constituents, Hirten (1995) found that water-level data indicate that the direction of the hydraulic gradient is away from the river during high-flow conditions, in contrast to low flow conditions when the direction of the hydraulic gradient is toward the river. The effect of elevated river stage on the potentiometric surface may extend as much as 8 kilometers away from the river.

Natural Remediation of Contaminants in Ground Water

High nitrogen loading from wastes generated by poultry and dairy farms, and fertilizers applied to cropland along the Suwannee River in Lafayette and Suwannee Counties has resulted in elevated nitrate levels in the river and in parts of the UFA. Changes in water quality and flow patterns in the UFA are being evaluated in a 73-square kilometer study area in Lafayette County, which is located near the Suwannee River and consists mainly of agricultural land use, such as dairy and poultry farms, cropland, and silvaculture. In 1990, 1991, and 1994, 18 wells tapping the UFA and 7 springs that discharge into the Suwannee River were sampled for major dissolved inorganic constituents, trace elements, nutrients, and volatile and nonvolatile organic compounds as part of the FGWQMNP. In the study area, ground-water flow patterns remained relatively unchanged during 1990, 1991, and 1994, even though large fluctuations in ground-water levels were observed. For example, measured ground-water levels in 1991 increased by as much as 20 feet at some wells following three months of above normal rainfall, compared to water levels in 1990.

Nitrate concentrations in ground water had large fluctuations from one sampling period to the next and were associated with fluctuations in water levels in the UFA. For instance, the median and range (in parentheses) of nitrate concentrations in water samples from the UFA, in milligrams per liter as nitrogen, were: April-May 1990, 1.52 (<0.02-17); March 1991, 0.20 (<0.05-9.5); and June 1994, 2.0 (<0.02-22.). Substantially lower concentrations of nitrate were measured in water from 76 percent of wells sampled in 1991 compared to 1990, and probably resulted from denitrification reactions. The process of denitrification involves the transformation of nitrate by bacteria (present in the soil and aquifer) to nitrogen gases, resulting in lower amounts of nitrogen. Based on extensive analysis of chemical and hydrologic data, evidence for denitrification in water from the UFA was indicated by increased concentrations of dissolved organic carbon, a decrease in measured redox potential, and an increase in pH and dissolved iron concentrations. Dilution of nitrate concentrations in ground water was unlikely because concentrations of chloride and other major ions did not show a corresponding decrease from 1990 to 1991. In fact, chloride concentrations increased in water samples from 75 percent of the wells in which nitrate concentrations decreased from 1990 to 1991. Thus, the combination of higher ground-water levels in 1991 with increased amounts of organic carbon and decreased amounts of dissolved oxygen in ground water created conditions favorable for the natural reduction of nitrate in ground water. As a result, less nitrate was discharged by ground water to the Suwannee River.

Lessons Learned

The vast amount of information that has been gathered on ground-water and surface-water systems in the Suwannee River basin provides an extensive data base from which water-resource managers can begin to understand the importance of the hydraulic and hydrochemical linkage between ground water and surface water in the basin. However, to address specific management issues, several gaps have been identified where more information is critically needed:

- *It is difficult to use existing data to evaluate basin boundaries and the extent of interaction between ground water and surface water because these data were collected by different agencies for programs with different monitoring objectives. Existing information indicates that ground-water basin divides, as delineated from potentiometric-surface maps, do not always coincide with boundaries for surface water basins; that is, there is flow of ground water across surface-water basin divides. However, to more precisely define ground-water basin boundaries, additional wells are needed to refine the map of the potentiometric surface for the UFA and obtain data to determine more detailed flow patterns.*
- *Complex ground-water flow patterns can be revealed only through consistent monitoring over time and during varying hydrologic conditions. Sampling of ground water and surface-water should be coordinated and performed during changing hydrologic conditions, such as periods of high and low flow.*
- *Reduction in nitrate concentrations in ground water by denitrification processes is likely to occur naturally during periods of high flow conditions (high water levels in the UFA and high stages in the river and its tributaries). More detailed investigations, however, are needed to confirm and document this preliminary finding.*
- *Insufficient information exists at present to determine the lateral extent of mixing of river water with water in the UFA during periods of high flow conditons.*
- *The Suwannee River is both a gaining and losing stream depending on the stage of the river. However, the existing spatial distribution of wells in the UFA is not sufficient to delineate areas of ground water flow to the river and areas where the river recharges the aquifer.*
- *A combination of naturally occurring tracers (isotopes, chemical constituents), artificially introduced tracers (dyes), and detailed water-level data could provide much needed information on hydaulic interactions between ground water and surface water, such as the amount of recharge to the aquifer from surface-water inflow, the amount of resurgent surface water in spring flow to the river, and the amount of ground-water flow to the river during low and high stages.*
- *It is unlikely that adequate State and Federal funding will be available, in the foreseeable future, to conduct statewide delineation and mapping of zones of interaction between ground water and surface water. One solution to this problem would involve the establishment of watershed coalitions, involving the private sector stakeholders, that could be responsible for generating the necessary resources for proper watershed assessments. The watershed coalitions will benefit their communities by participitating in, not only identifying, the threats to watersheds health and function, but also by being a part of the solution to existing problems.*

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Ongoing Studies in the Little River Basin

Two studies are currently gathering detailed information on the hydrochemical interaction between ground water and surface water in the Little River basin, a tributary basin to the Suwannee River. One study, which is part of the NAWQA Program, is investigating the extent of the mixing zone between the Suwannee River and ground water during various flow conditions. Another study, which is a cooperative effort among the FDEP, the SRWMD, and the USGS, is investigating the hydrochemical linkage between the UFA and the Little River where the river disappears underground through a series of sinkholes. Results from these studies are expected to provide important information on ground-water basin boundaries, the hydrochemical effect of surface water migration into the aquifer during various hydrologic conditions, and natural processes that could remediate contaminants in the aquifer and surface water.

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