DESCRIPTION OF A HYDROLOGIC METHOD FOR SEPARATING STREAM FLOW FROM GROUNDWATER AND BACKWATER BY MEANS OF OXYGEN-18, SAVANNAH RIVER PLANT, SOUTH CAROLINA

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INTRODUCTION

The wetland ecology of Upper Three Runs Creek (UTR), located within the Savannah River Plant (SRP), South Carolina, has been intensively studied by researchers from the Savannah River Ecology Laboratory (SREL). Their studies have revealed the importance of understanding the wetland hydrology of this riverine wetlands system of UTR and the Savannah River. The study's method described here, initiated in October, 1988, is designed to answer some of these hydrologic questions. Specifically, the study will 1) evaluate the relationship between stream flow in UTR and subsurface flow in the adjacent wetland, 2) evaluate the extent of recycling of UTR water in the wetland during overbank flood events, 3) evaluate the oxygen isotope value of UTR baseflow, and 4) evaluate the extent of Savannah River backwater flow into UTR during large flood events.

The study will be accomplished by measuring stable oxygen contents ($\delta^{18}O$) for ground and surface waters in a number of settings and locations in and around UTR's basin, and by measuring stream flow and water table elevations in the lower reaches of UTR's basin. $\delta^{18}O$ denotes oxygen-18 content in per mille relative to a standard.

LOCATION AND SURFACE DRAINAGE

Upper Three Runs, located in the Aiken Plateau, is the area's longest tributary and drains most of SRP in Aiken County. The creek flows southwesterly, roughly at a right angle to it's discharge point, the Savannah River. The surface of the Plateau is highly dissected and is characterized by a broad interfluvial area and relatively narrow steep sided slopes. Eocene and possibly Miocene deposits underlie the plateau. The plateau represents a constructional landform formed during the later stages of this period (Siple, 1967).

SAMPLING AND INSTRUMENTATION

Figure 1 shows the sample and instrumentation locations for the study. Six surface water samples, one composite rain sample, and three groundwater samples are taken bimonthly. The groundwater samples are collected from lysimeters. Surface water samples are collected as grab samples. The composite two week rain samples are taken from a raingage designed to eliminate evaporation. All samples are kept in full, tightly sealed 12 ml polyurethane bottles. Mass spectrometry is used to analyze these water samples for their $\delta^{18}O$ content. Several USGS stream gages are located along the study site. Where automatic gages are not present, staff gages have been installed. A transect of piezometers roughly perpendicular to Upper Three Runs was established to measure the water table fluctuations in the wetland (inset of Figure 1). The water table is measured daily by resin encased transducers and the data automatically recorded on a data logger. Stream storm samples are collected every hour by a Manning sampler when the stream stage exceeds a preset stage. At the margin of the wetland, two tensiometer clusters were installed three meters apart. At each site, the tensiometers were installed at depths of 30, 60, 90, and 120 cm. Their information is recorded on the data logger every 15 minutes.

DISCUSSION

As in any surface water body, there exists a relationship between the visible flowing stream and the less easily observed subsurface component. In order to gain an understanding of the groundwater component in the wetland, piezometers and tensiometers were installed to measure the hydraulic gradient. During non-flood events, the wetland is an area of discharge.

Usually in winter, there occur several rain storms that cause overbank events in the wetland. During such an event, the water level in the lower wetland basin (inset on Figure 1), can reach 4 or 5 feet above normal bank level. The lateral extent from the stream channel can be from 150 to 300 feet on either side of the creek. With the influx of this standing water, the hydraulic gradient will reverse. This reversal will be monitored by the piezometers and tensiometers and the data automatically recorded.

An important aspect of flooding is the change in nutrients delivered to the wetland. Normally, groundwater delivers nutrients; during flooding, surface water becomes the nutrient source. This surface source's influence does not immediately diminish with the receding flood water. With the reversal in gradient during flooding, substantial amounts of surface water and their nutrients infiltrate. With this gradient measured automatically in the piezometers and wells by transducers and the hydraulic conductivity established by slug tests, the flux of infiltration can be determined by the manipulation of Darcy's Law. Thus with flooding and subsequent infiltration, the isotopic character of the groundwater component has changed to a mixture of ground and infiltrated flood water. This change exists for an unknown amount of time. The length and degree of change will be handled through the use of stable oxygen as a tracer.

Stream storm flow originates from two isotopic reservoirs, precipitation and groundwater, with isotope contents δp and δg respectively. A steady-state mass balance for isotope and water flow gives the groundwater fraction, X, in stream flow

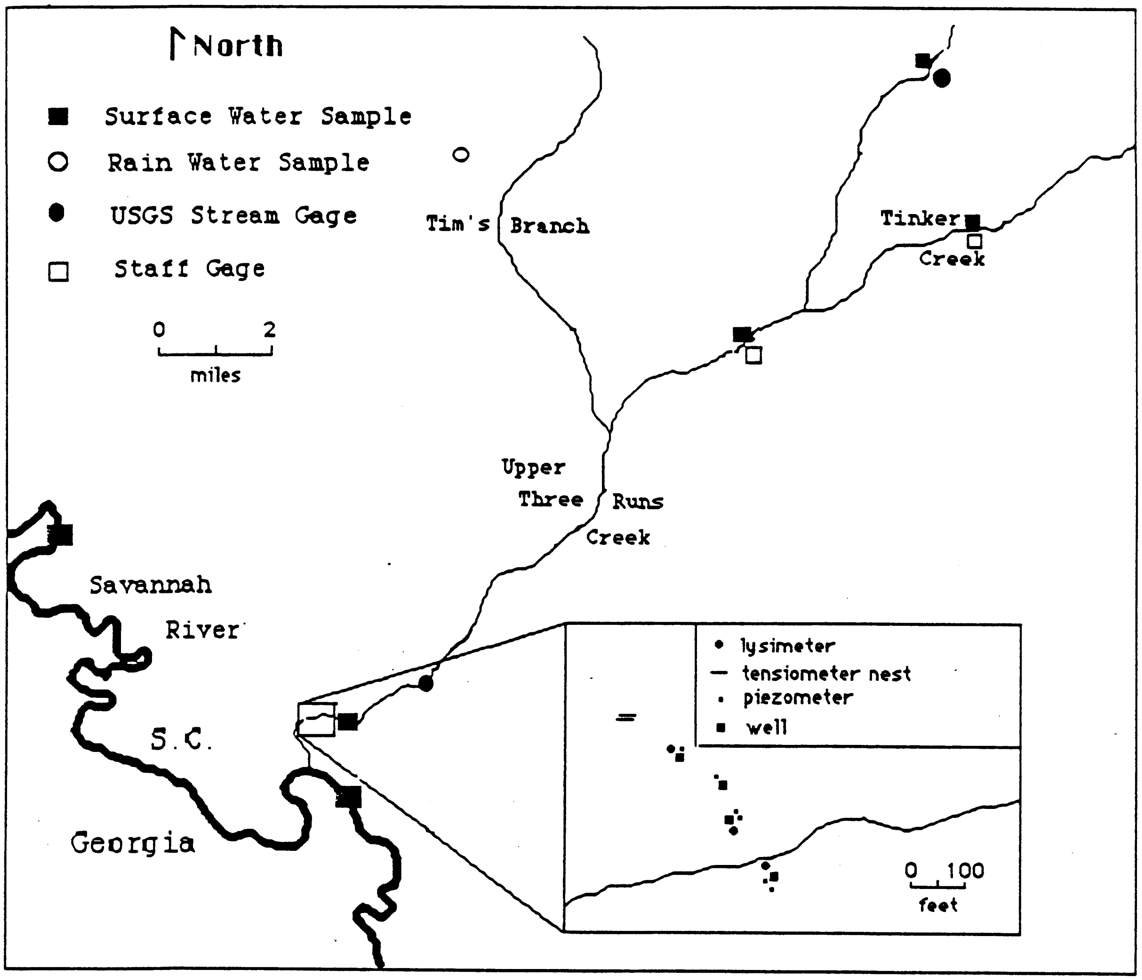

Figure 1. Study area at the Savannah River Plant, South Carolina.

as

Eq. 1
$$X = \frac{\delta p - \delta s}{\delta p - \delta g}$$

where δs is the isotope content of stream water (Rodhe, 1983). This equation is widely used for two component hydrograph separation by isotopes. Because the stream storm water isotopic content (a mix of δp and δg) differs from that of the pre-flood groundwater (δg), groundwater sampling after the flood makes it is possible to establish the degree of subsurface mixing. The mixed oxygen-18 value should be between the two comprising waters. If the infiltrated water is assumed to mix completely in a groundwater reservoir of constant volume, V, then the rate of isotopic change of groundwater with respect to time is given by

Eq. 2
$$\frac{d\delta g}{dt} = \frac{q * X}{V} (\delta p - \delta g)$$

where q is the specific discharge (Rodhe, 1983). Through continued post-flood groundwater sampling, it may be possible to determine the amount of time required for the subsurface component to return to pre-flood character.

It is not fully known to what degree UTR's base flow is influenced by the subsurface component. Use of the area's naturally unique ground and surface waters' oxygen isotope concentrations allows for this determination in the lower, instrumented wetland (inset of Figure 1). The bimonthly surface sampling of UTR, without the experience of a recent rain event, will give the isotopic signature of UTR base flow. Comparing the isotopic signature of the groundwater samples to the isotopic signature of a UTR surface sample taken near to the groundwater samples, will result in the identification of the base flow fraction from groundwater in the instrumented area. Expanding this theme to the evaluation between the groundwater's isotopic content and the isotopic content of the other bimonthly basin wide surface samples, will allow the determination of whether oxygen isotopes can be used as a basin wide tracer in future hydrologic studies.

Maybe once a year, the lower wetland basin is inundated by a major flood (flood elevation greater than 5 feet above normal bank level). The extent Savannah River backwater plays in such a flood is not known, but can be evaluated isotopically. Because Savannah River water has gone through several reservoirs before it's contact with UTR, it's oxygen-18 content will be imparted with a more positive isotopic value as compared to UTR. The more positive value is the result of evaporation taking place in the reservoirs, thus increasing the amount of the heavier, less abundant oxygen isotope, ^{18}O. Evaluation of this isotopic difference will enable the determination of the role played by Savannah River water backing up into the lower reaches of UTR's basin.

CLOSING REMARKS

To truly understand the hydrology of a wetland one must manipulate and incorporate as many useful instrument techniques as possible. The early results of this study have shown that one tracer tool, stable oxygen isotopes, has the potential to add light to several hydrologic questions in a Savannah River wetland. Because each wetland reservoir, ground, UTR surface and Savannah River waters all have unique isotopic signatures, it is hoped that this will led to determining the interaction between ground and UTR's water, as well as determining the interaction between these components during floods. In addition, it is hoped that the extent of Savannah River backwater up UTR can be evaluated.

ACKNOWLEDGMENTS

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