IDENTIFYING GROUNDWATER/STREAM INTERACTION IN THE LOWER FLINT RIVER BASIN USING MULTIPLE STREAM PARAMETERS AND REMOTE SENSING DATA SETS

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Abstract. Many streams in the lower Flint River Basin are hydraulically connected to the underlying Upper Floridan Aquifer which supplies millions of gallons of water per day to irrigated agriculture throughout the Coastal Plain province of Georgia. Extensive pumping of surface and groundwater within the lower Flint River Basin has resulted in significant streamflow declines, threatening aquatic species which are listed as endangered and threatened in this region. Our research focuses on detecting fracture and dissolution paths between Ichawaynochaway Creek and the underlying Upper Floridan Aquifer. We collected and analyzed stream samples for NO_3^-, Ca^+, $\delta^{18}O$, and δD, as well as specific conductivity, temperature and pH, at 1 km intervals along a 53 km reach of the Ichawaynochaway Creek in southwestern Georgia, USA. We hypothesized that stream reaches within close proximity to fractures and joints would reflect the chemical signature of inputs from the underlying aquifer. We compared stream chemistry with proximity to various surface features visible on remote sensing data sets in order to identify geomorphological characteristics which might be associated with and predictive of stream-aquifer exchange.

INTRODUCTION

The lower Flint River Basin (FRB) is located within the Coastal Plain province of southwestern Georgia, USA (Figure 1). This region is underlain by a highly productive karstic aquifer, the Upper Floridan, which is heavily exploited for irrigation of row crop agriculture. Many streams in the lower FRB are incised into underlying bedrock formations resulting in heterogeneous hydrologic connectivity between groundwater and surface waters.

Groundwater/stream dynamics are highly complex in this and other karstic basins. Data is needed to help identify locations where increased interactions between streams and the underlying aquifer are occurring in this watershed in order to adequately allocate limited water resources. We used multi-parameter physiochemical testing to delineate complex hydrological pathways between the Ichawaynochaway Creek and the Upper Floridan with the assumption that certain physiochemical changes are the result of flux between stream and groundwater reservoirs. Finally, we identified correlations between physiochemical differences and geomorphological attributes of stream reaches which are visible by remote sensing.

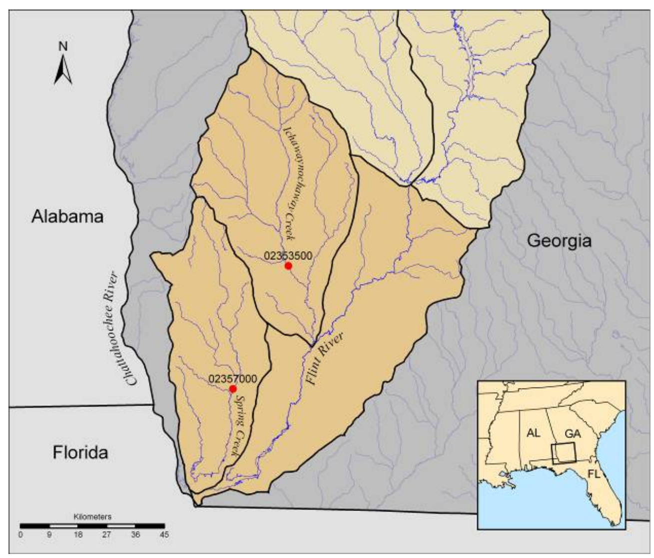


Figure 1. Map of the lower Flint River Basin in southwestern Georgia showing location of USGS gaging stations

BACKGROUND AND STUDY SITE

The Ichawaynochaway sub-basin is located within the Dougherty Plain district in the Coastal Plain province of SW Georgia, USA. Limestone bedrock formations of late to middle Eocene age are overlain in this region by undifferentiated Oligocene and Miocene sediments (Hicks *et al.*, 1987). Mature karstic development has resulted from percolation of regional precipitation through slightly acidic soils into the underlying Ocala Formation. Streams in this region begin as seeps and springs around the Fall Line Hills, flowing onto the Dougherty Plain in a southeasterly direction. Tributaries of the lower Flint have eroded through overlying residuum and are hydrologically connected to varying degrees with the underlying Upper Floridan aquifer (Mosner, 2002; Opsahl *et al.*, 2007). Land use in lower FRB is approximately 50% agricultural, with the remaining acreage in managed forest and depressional wetlands (Couch and McDowell, 2006). All sampling of precipitation and groundwater was conducted within the Ichawaynochaway sub-basin. Stream monitoring and sampling were performed within a 53 km reach of the Ichawaynochaway Creek, a 5^{th} order tributary of the lower Flint River.

METHODS

Precipitation samples (n=11) were collected during rainfall events extending over a two hour period or until a sufficient quantity could be collected. Rainfall samples were acquired periodically before and during stream collection (early summer to early fall). Samples for nitrate and calcium analysis were vacuum-filtered through 45μ filters into 20 mL plastic scintillation vials and frozen for later analysis. Samples for isotope analysis were collected in 20 mL glass scintillation vials and sealed with tape to prevent atmospheric contamination. Groundwater samples (n=26) were collected from wells (accessing the Upper Floridan Aquifer) within a 1 km distance of the Ichawaynochaway Creek during late fall 2009. Well heads or spigots were flushed for 10 minutes and samples were collected and prepared for analysis as above.

A 53 km reach of the Ichawaynochaway Creek was monitored (downstream to upstream) for specific conductivity, pH and temperature. Measurements and collections were taken at 6/10 depth in mid-channel at 1 km intervals. Stream samples (n= 191) were obtained for calcium, nitrate and isotopic analysis and processed as above. Coordinates were entered into a Garmin Oregon 550 handheld GPS at each sampling site. Three complete sampling runs were performed under baseflow conditions between late June and late October, 2010.

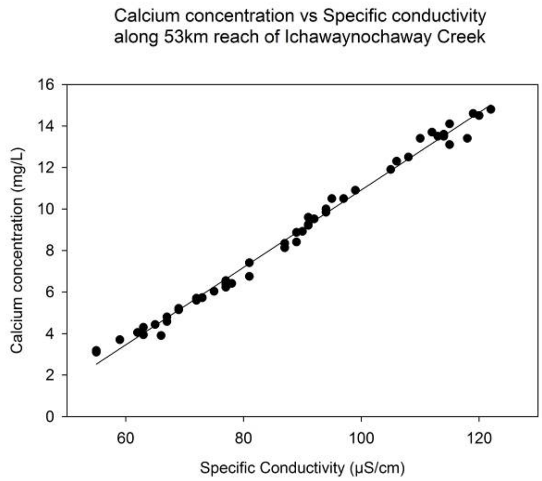
National Wetland Inventory (NWI), 1999 USGS Digital Ortho Quarter Quads, Digital Elevation Models (DEMs), and 2007 National Agricultural Imagery Program (NAIP) data sets of the lower FRB were examined to identify geophysical trends within this basin. Lineament maps were created by overlaying shapefiles on NWI, NAIP and DOQQ images in ArcGIS 9.1. A modified Boundary Convexity Tool (BCT) was used to generate a series of "nodes" at 50 meter intervals along the 53 km study reach (overlain on NAIP imagery). Creek deflection (angle), bearing and direction were determined for each node.

Coordinates from all sampling events were downloaded as ArcGIS shapefiles from Garmin GPS using DNRGarmin application software (Minnesota Department of Natural Resources, http://www.dnr.state.mn.us). All site coordinates were associated with the nearest node (at point of deflection), generating geophysical attributes for each sampling site. Lineament maps and site attributes were compared with changes detected in stream reach chemistry to determine if these differences were associated with any geomorphic or landscape characteristics.

RESULTS

Specific conductivity decreased from downstream to upstream, with an average overall decrease of 68.7 ± 2.3 μS/cm, per sampling run.

Changes in conductivity between 1 km intervals ranged from 0-15 µS/cm (median =1 µS/cm). Calcium concentrations in precipitation samples ranged from 0.01 to 0.14 mg/L (median = 0.10 mg/L). Concentration of calcium in groundwater was 35.00 mg/L - 72.05 mg/L (median = 53.88 mg/L). Calcium decreased going downstream to



upstream from 14.8 mg/L (downstream) to 3.18 mg/L (upstream). Decreasing calcium concentration was almost perfectly correlated with decreasing specific conductivity in stream samples (R^2= 0.992, p<0.0001, α=0.05, n=55) (Figure 2).

Figure 2. Calcium concentration vs specific conductivity in stream samples collected within the Ichawaynochaway Creek, October 2010

Values for $\delta^{18}O$/ $\delta^{16}O$ in end members and stream samples are reported below in Table 1. End members showed distinctive signatures within the Ichawaynochaway sub-basin when $\delta^{18}O$/ $\delta^{16}O$ values were compared with calcium concentrations (Figure 3).

Table 1. $\delta^{18}O$/ $\delta^{16}O$ values of end members and stream samples collected within the Ichawaynochaway sub-basin, southwest GA

Values for $\delta^{18}O$/ $\delta^{16}O$ $^0/_{00}$				
Source	**Range (min/max)**	**Median**	**Mean**	**Std. Dev.**
Precipitation	-9.09/ -3.50	-4.37	-4.78	1.72
Groundwater	-5.93/ -2.71	-3.77	-4.05	0.89
Stream				
Run 1	-6.55/ -0.49	-3.72	-3.66	0.88
Run 2	-4.72/ -3.27	-4.34	-4.28	0.25
Run 3	-5.07/ -2.71	-4.38	-4.36	0.42

Stream reaches in Ichawaynochaway Creek which exhibited significantly higher changes in specific conductivity (4-15 µS/cm between 1 km collection points) trended in a NW direction when compared with geomorphic attributes generated at 50 meter intervals by the Boundary Convexity Tool. (Figure 4).

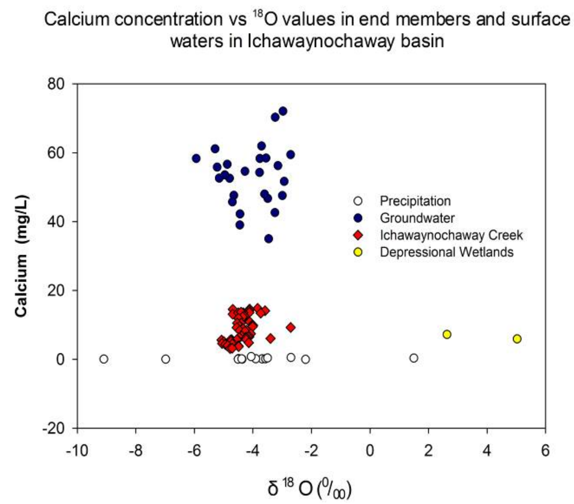
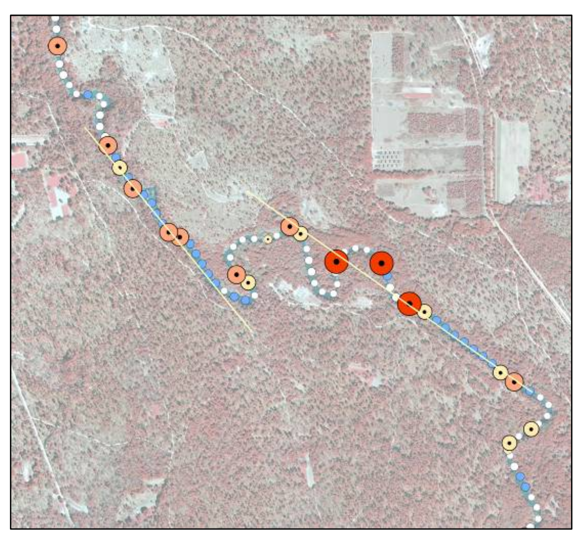


Figure 3. Comparison of calcium concentration and $^{18}O/^{16}O$ values in groundwater, precipitation and stream samples collected within the



Ichawaynochaway sub-basin

Figure 4. NAIP image of collection reach on Ichawaynochaway Creek. Dots, with center dot inside, indicate sites where significantly different changes in conductivity were detected (increasing size = greater difference).

DISCUSSION

Overall upstream decreases in specific conductivity in stream samples remained extremely consistent over the entire collection period with a minimum of 67 μS/cm and maximum of 72 μS/cm. Median change in specific conductivity between 1 km intervals for the entire collection period was 1 μS/cm. Collection sites with differences >4 μS/cm showed little or no deflection in creek angle and trended in a NW direction when compared with directional attributes of associated nodes (generated by BCT). This directional trend follows the down dip of the underlying Upper Floridan and runs parallel to bedrock fracturing trends in this region (Hicks *et al.*, 1987).

Calcium concentrations decreased going upstream in stepwise increments and showed a very strong correlation with decreasing specific conductivity. We assume that sites with higher calcium concentrations represent reaches receiving greater inputs of groundwater which have been exposed to underlying carbonate formations. Depletion of ^{18}O in stream samples compared to end members (which is an indicator of biogeochemical interactions within the aquifer) further confirms increased groundwater interaction at these sites.

CONCLUSION

Our preliminary results show that some reaches of the Ichawaynochaway Creek exhibit significantly different physiochemical characteristics which suggest the presence of fracture flow through joints or dissolution paths within the streambed. Reach chemistry at these sites showed strong correlations with multiple geomorphological attributes which are visible on remote sensing data sets. Continued data collection and testing of these methods at multiple scales may help to more fully develop tools for predicting groundwater-stream interaction which are transferrable across this and other basins. This information would be useful for updating regional hydrological models and informing important policy and water resource decisions in this watershed.

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