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Delineating groundwater/surface water interaction in a karst watershed: Lower Flint River Basin, southwestern Georgia, USA

Kathleen Rugel[a,b,*], Stephen W. Golladay[b], C. Rhett Jackson[c], Todd C. Rasmussen[c]

[a] Odum School of Ecology, University of Georgia, Athens, GA, USA
[b] Joseph W. Jones Ecological Research Center at Ichauway, Newton, GA, USA
[c] Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA, USA

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ABSTRACT

Study region: Karst watershed in Lower Flint River Basin (LFRB), southwestern Georgia, USA.
Study focus: Baseflow discharges in the LFRB have declined for three decades as regional irrigation has increased; yet, the location and nature of connectivity between groundwater and surface water in this karstic region are poorly understood. Because growing water demands will likely be met by further development of regional aquifers, an important management concern is the nature of interactions between groundwater and surface water components under natural and anthropogenic perturbations. We conducted coarse and fine-scale stream sampling on a major tributary of the Lower Flint River (Ichawaynochaway Creek) in southwestern Georgia, USA, to identify locations and patterns of enhanced hydrologic connectivity between this stream and the Upper Floridan Aquifer.
New hydrological insights for the region: Prior water resource studies in the LFRB were based on regional modeling that neglected local heterogeneities in groundwater/surface water connectivity. Our results demonstrated groundwater inputs were concentrated around five of fifty sampled reaches, evidenced by increases in multiple groundwater indicators at these sites. These five reaches contributed up to 42% of the groundwater detected along the entire 50-km sampling section, with ~24% entering through one groundwater-dominated tributary, Chickasawhatchee Creek. Intermittent flows occurred in two of these upstream reaches during extreme drought and heavy groundwater pumping, suggesting reach-scale behaviors should be considered in resource management and policy.

1. Introduction

Groundwater is being increasingly utilized to serve a growing worldwide demand for freshwater (Shah et al., 2000; Gleick et al., 2009). Approximately 60% of all global groundwater use is for agricultural irrigation, which is mainly consumptive (Postel, 1999; WWAP, 2012). Intensive groundwater extraction has been shown to reduce stream baseflows, resulting in increased water temperatures, lowered dissolved oxygen, diminished assimilative capacity, reduced habitat complexity,

* Corresponding author at: Joseph W. Jones Ecological Research Center at Ichauway, Newton, GA, USA. Fax: +1 2297344707.
E-mail addresses: krugel@uga.edu, keen55@hotmail.com (K. Rugel).

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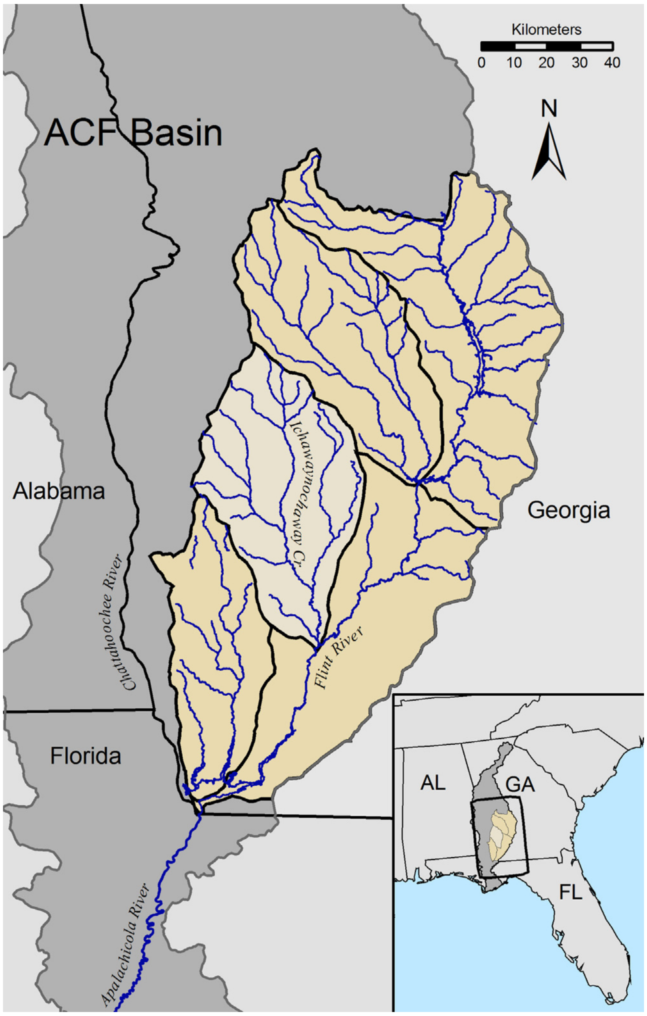

Fig. 1. Map of Lower Flint River Basin and Ichawaynochaway Basin within the larger Apalachicola-Chattahoochee-Flint River Basin in the southeastern United States.

and negative impacts on stream, riparian and upland biota (Stromberg et al., 1996; Bunn and Arthington, 2002; Golladay et al., 2004; Light et al., 2005; Zektser et al., 2005; Torak and Painter, 2006; Rugel et al., 2012).

It has become increasingly apparent that groundwater and surface water should be managed as a single resource (Woessner, 2000; Winter, 2001; Sophocleous, 2002); however, hydrologic connectivity in karst watersheds is poorly understood compared to alluvial, glacial and volcanic systems. High transmissivity in karst aquifers makes them ideal for the development of groundwater (Driscoll, 1986); however, this also exposes both groundwater and streams to over-extraction and degradation (Seitzinger et al., 2006). Because future freshwater demands will likely escalate the development of karst aquifers, the susceptibility of these systems will continue to increase, making it essential to discern the complexity of flow paths between surface and subsurface components.

The Apalachicola-Chattahoochee-Flint (ACF) River basin is a 50,000 km^2 watershed in the southeastern US. The ACF has its headwaters in northern Georgia and occupies portions of Georgia, Alabama and Florida, discharging into the Gulf of Mexico at Apalachicola Bay. Upper reaches of the ACF support fast-growing urban populations while water in the lower portion sustains agricultural irrigation, recreation, power generation, tourism, shrimping and oyster industries, in addition to populations of threatened and endangered aquatic biota. The Lower Flint River Basin (LFRB) is an economically important agricultural sector within the lower ACF (Fig. 1) generating $1.9 billion in farm gate revenues for the state (McKissick, 2004). Intensive irrigation in this region is mostly maintained using groundwater from the Upper Floridan Aquifer (UFA). This prolific carbonate aquifer underlies most of the southeastern US Coastal Plain and supplies over 15×10^9 m^3 d^{-1} (15 GL/d) of water to more than ten million people in the southeastern US corridor (Marcella and Berndt, 2005). Between 1970 and 2000, irrigated acreage in the LFRB increased more than ten-fold, from 59,000 to 607,000 ha (590–6070 km^2), accounting for over half of statewide (Georgia) totals (Torak and Painter, 2006). Agricultural pumping in the LFRB has been correlated with seasonal declines in groundwater and surface water levels (Stamey, 1996; Couch and McDowell, 2006; Jones and Torak,