STREAM FLOW CHANGES ASSOCIATED WITH WATER USE AND CLIMATIC VARIATION IN THE LOWER FLINT RIVER BASIN, SOUTHWEST GEORGIA

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Abstract. In the 1970's agricultural water use expanded rapidly in the lower Flint River Basin resulting from the introduction of center pivot irrigation technology. The rapid expansion has raised concerns about impacts on regional stream flows essential to support aquatic fauna. Using long-term stream gage records from the USGS and climate data, we analyzed trends in stream flow in two major sub-watersheds and regional patterns of rainfall from 1940 through 2004. We observed no change in annual rainfall but seasonality changed with winters being slightly wetter. Minimum flows showed substantial declines since the development of irrigation. We attribute altered stream flows to increased regional water demand however; the demand for water is also exacerbated by long-term variations in climate and rainfall distribution.

INTRODUCTION

Human water use affects regional hydrology through consumptive water withdrawals, resulting in reduced streamflow and depressed groundwater levels. In southwestern Georgia, practically all streams originate as groundwater seeps or springs. While stream flow is primarily sustained by precipitation for the much of the year, it is augmented by groundwater discharge, which during the low-flow periods (June-November) can account for a substantial part of the total stream flow. During late summer and fall, when rainfall historically is sparse, the baseflow of many streams in the lower Flint River Basin (FRB) is maintained almost solely by groundwater discharging directly into the streams through springs and seeps in the stream channels, or groundwater discharging from off-channel springs and flowing into the streams.

Between 1970 and 1980, southwestern Georgia saw an enormous increase in the agricultural use of water resources. Irrigated acres increased from 130,000 in 1976, to 261,000 in 1977 (Pollard et. al, 1978). By 1980, irrigated farmland had increased to more than 452,000 acres, and the combined surface water and groundwater annualized use was estimated to be more than 290 million gallons per day (Mgals/day) (Pierce et. al, 1984). By 1999, about 85% of the agricultural lands in the lower FRB were irrigated, mostly by withdrawals from the Upper Floridan aquifer (Litts et. al., 2001). Currently, agricultural irrigation is thought to be about 10 in/yr, or approximately 20% of long-term average annual precipitation of 50 in. (Harrison 2001). The large increases in irrigation drastically changed the pattern of water and land use throughout southwestern Georgia and have raised concerns of sustainability of streams and rivers.

Both surface-water and groundwater withdrawals are permitted by the GA EPD. It is likely that through regulatory oversight, permitted withdrawals may exceed sustainable capacities of the streams and aquifers of the lower FRB, particularly during periodic droughts. The effects of simulated groundwater pumping have been estimated and stream reaches classified based on their sensitivity to water withdrawal (Albertson and Torak, 2002). In addition, long-term declines in flow recession curves have been documented within selected tributaries (Stamey 1996; Torak and McDowell, 1996). It is important to estimate long-term trends in regional stream flow to determine impacts of water use and help determine sustainable stream flows. While some long-term records of stream flow exist, the impacts of water use and changing climate on regional hydrology have not been quantified. The purpose of this study was to examine the long term trends in climate and stream flow in selected streams of the lower FRB.

STUDY AREA

This study was conducted in two watersheds of the lower FRB: Spring Creek and Ichawaynochaway Creek. These streams flow through parts of Stewart, Webster, Randolph, Terrell, Clay, Early, Calhoun, Dougherty, Miller, Baker, Seminole, and Decatur Counties in southwestern Georgia (Figure 1).

METHODS

Long-term trends in rainfall and stream flow were assessed within the lower FRB. Rainfall data were obtained from the National Climate Data Center Drought Series Database (http://lwf.ncdc.noaa.gov/oa/climate/onlineprod/drought/xmgr.html#gr, last accessed December 2005). Rainfall data were obtained from Region 7 of southwest Georgia. Monthly rainfall data were obtained for the period 1940 through 2004. Annual total rainfall was determined and compared for the period of 1940 through 1974 (Pre-

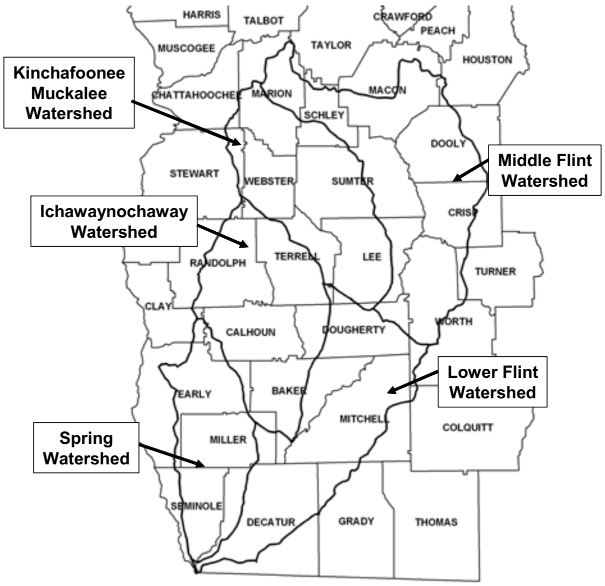

Figure 1. The lower Flint River Basin in southwestern Georgia.

irrigation development) and 1975-2004 (Post-irrigation development). Seasonal rainfall data were calculated from monthly data (winter, Jan-Mar; spring, Apr-Jun; summer, Jul-Sep; and fall, Oct-Dec). Seasonal mean rainfall and ranges were compared for the pre- and post-irrigation development period. In addition, long-term trends in seasonal rainfall were determined using 10-year running averages for the period of record (1940-2004).

Stream flow data were reviewed for 19 continuous monitoring stations that are operated by the U.S. Geological Survey (USGS) in the lower FRB. Of these 19 stations, continuous data adequate to assess long-term trends were only available for two stations: Spring Creek near Iron City (02357000) and Ichawaynochaway Creek at Milford (02353500). Many of the USGS gaging stations within the lower FRB were not in operation prior to the onset of intensive irrigation. Other stations were not usable for the statistical analyses because of back-water conditions, power generation regulation, or intermittent periods of record. Stream flow statistics used in the analyses contained within this paper were developed using the data obtained from the USGS.

REGIONAL HYDROLOGIC ALTERATION

Trends in rainfall

Average annual rainfall for Region 7 of southwestern Georgia is 51.8 inches (1940-2004). Lowest annual rainfall was recorded in 1954 (29.6 inches) and greatest rainfall was recorded in 1964 (77.2 inches). No differences were observed in annual rainfall in the pre- and post-irrigation development periods (Table 1). Slight differences in the seasonal distribution of rainfall were apparent. Winter rainfall tended to be greater in the post-irrigation development period while spring rainfall tended to be lower (Table 1). Summer and fall rainfall were similar across periods. Several long-term trends in rainfall were observed. Winter rainfall generally increased from the late 1950's through the mid 1990's. Spring rainfall generally declined throughout the period of record. Summer rainfall declined from 1950 through the early 1990's; summer rainfall recovered in the late 1990's largely due to the effect of very high rainfall in 1994-95. Fall rainfall did not show a long-term trend. Within the period of record the driest climate period appears to have been in the mid to late 1950's, a period when fall and winter rainfall were substantially below the long-term average.

Trends in stream flow in Ichawaynochaway Creek

Minimum daily stream flow has declined substantially in Ichawaynochaway Creek in the post-irrigation development period (Figure 2). One-day minimum stream flow has declined by 40% from 211 to 128 cubic feet per second (cfs) (Mann-Whitney Rank Sum Test, $p< 0.001$). Seven-day minimum stream flow has declined by about 31% from 219 to 151 cfs (Mann-Whitney Rank Sum Test, $p<0.001$). Thirty-day minimum stream flow has declined about 9% from 239 to 217 cfs (Mann-Whitney Rank Sum Test, $p<0.01$). No changes were observed in 1-day maximum daily stream flow (Mann-Whitney Rank Sum Test, $p=0.76$).

Declines in stream flow are also reflected in percentile flows. For 50- percentile stream flow, post-irrigation development flow equaled or exceeded pre-irrigation development flow for the months of January through March but was lower for late spring and summer. Irrigation season median monthly stream flow also showed a declining trend during May-August. Declines were weakly significant for May ($p=0.066$) and July ($p=0.085$) and highly significant for August ($p=0.002$). There was no significant

Table 1. Annual and seasonal rainfall totals for Region 7 in southwestern Georgia. Values are means and standard deviations.

	Annual (in.)	Winter (in.)	Spring (in.)	Summer (in.)	Fall (in.)
Pre-irrigation development (1940-1974)	51.6 (9.4)	14.6 (4.4)	13.2 (3.1)	14.8 (3.0)	9.3 (4.0)
Post-irrigation development (1975-2004)	52.0 (8.7)	15.4 (3.6)	11.7 (3.6)	14.3 (4.7)	10.1 (4.4)

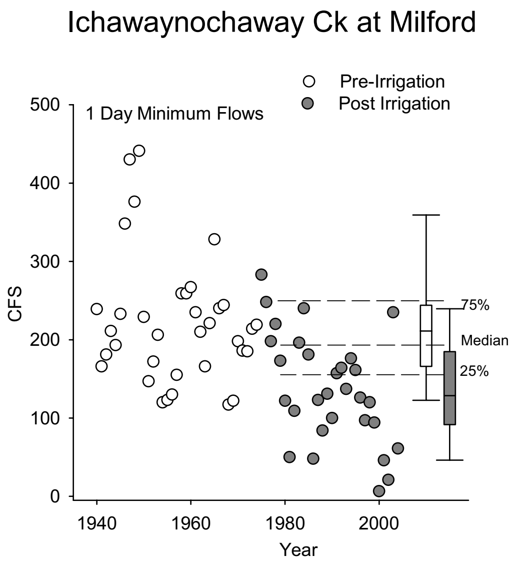

Figure 2. One-day minimum flows in Ichawaynochaway Ck.

difference in the pre-irrigation development and post-irrigation development June stream low in Ichawaynochaway Creek.

Trends in stream flow in Spring Creek

Minimum daily stream flow has also declined substantially in Spring Creek in comparisons of the pre- and post-irrigation development periods (Figure 4). One- day minimum daily stream flow has declined by about 46% from 43 to 23 cfs (Mann-Whitney Rank Sum Test, p=0.013). Seven-day minimum stream flow has declined by about 39% from 45 to 27 cfs (Mann-Whitney Rank Sum Test, p=0.016). Thirty-day minimum stream flow declined by about 42% from 58 to 33 cfs (Mann-Whitney Rank Sum Test, p=0.035). One-day maximum daily stream flow increased substantially in Spring Creek from 3,040 cfs in the pre-irrigation development period to 5,665 cfs in the post-irrigation development period (Mann-Whitney Rank Sum Test, p=0.05).

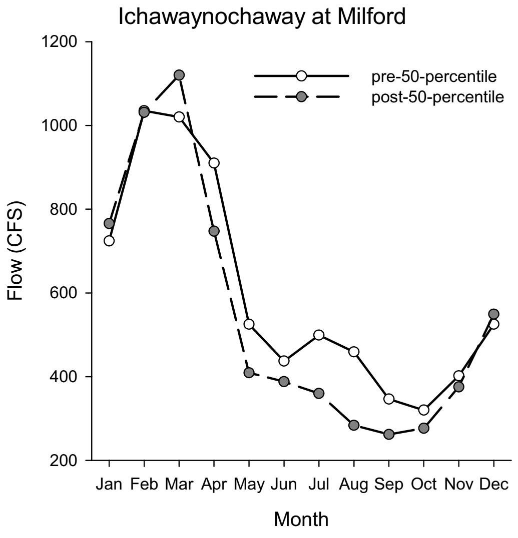

Figure 3. Fifty percentile flows in Ichawaynochaway Creek.

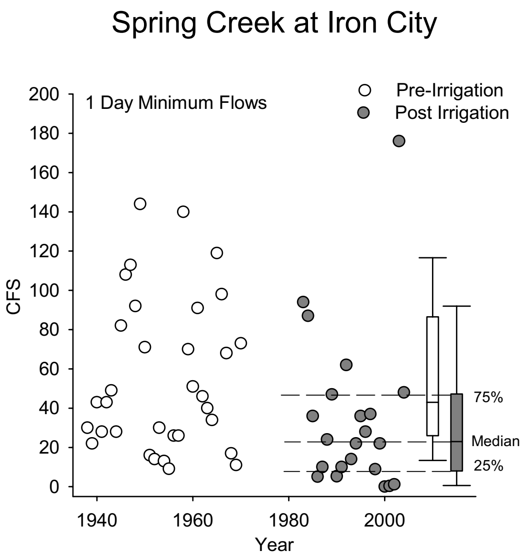

Figure 4. One day minimum flows for Spring Ck.

Trends in minimum and maximum stream flow are also reflected in percentile flows. Growing season stream flow tended to be lower for 50% percentiles in the post-irrigation development period (Figure 5). Interestingly, 50% percentiles of winter stream flow tended to be higher, in some cases substantially higher, in the post-irrigation development period. While some of this difference may be attributable to seasonal changes in precipitation, it also suggests that the hydrologic response of the watershed has quickened as landscape development has occurred. This could be explained by greater runoff from fallow fields during the winter or perhaps breaching of riparian buffers by field runoff (Stephen W. Golladay, J.W. Jones Center, personal observation, 2005). Declines in irrigation season mean monthly stream flow has also been observed in May (Mann-Whitney Rank Sum Test, p=0.09) and August (p=0.037). There were no differences between pre- and post-irrigation development stream flow for June and July.

DISCUSSION AND CONCLUSIONS

Annual rainfall in Georgia is influenced by a number of factors. Southwest Georgia generally receives abundant precipitation however, large annual variability occurs and most recording stations report two-fold differences between annual minimum and maximum rainfall during the 20th century (Golden and Hess, 1991). The region is also prone to extreme hydrologic events. Frontal or tropical weather systems circulate humid air from the Gulf of Mexico and can produce heavy rainfall and extended

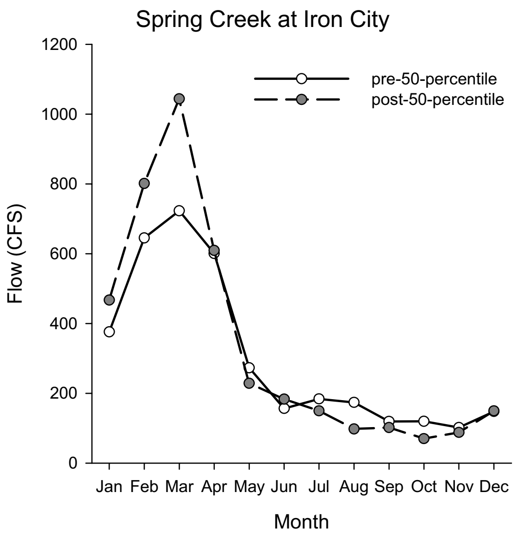

Figure 5. Fifty percentile flows for Spring Ck.

flooding throughout the year (Golden and Hess, 1991). Major floods in the southwest portion of the state occurred in 1925, 1948, 1994, and 1998. Extended droughts result from persistent high-pressure systems, which prevent influx of moisture from the Gulf of Mexico (Golden and Hess, 1991). Extended droughts occurred during the 1930's, 1950's, 1980's, and late 1990's through 2002.

Our analysis of climate data does not suggest long-term changes or trends in annual rainfall in southwestern Georgia. While seasonality of rainfall has shifted slightly there is no consistent change in annual total rainfall over the past 60 years. Our analysis of stream flow data show consistent and substantial declines in minimum and seasonal stream flow associated with the development and implementation of agricultural irrigation in the FRDP area of southwestern Georgia. This has resulted in some of the lowest flows on record during recent droughts. There is no climatologic indication that recent droughts were more severe or persistent than those in the past (i.e., 1930's or 1950's). Thus, we conclude that water use is the primary factor causing record low stream flow and other alterations in regional hydrology.

Record low stream flow raises concerns about the sustainability of stream health in the FRDP area. The region is noted for its diversity of freshwater mussels, stream fishes, and other aquatic life. Substantial declines in mussel diversity and abundance, including several rare and endangered species, were associated with stream drying during the most recent drought (1999-2002) (Golladay et al., 2003). Drying of major springs, a summer refuge for striped bass has caused concerns about the long-term viability of the Flint River population. Declining stream flow also reduces the assimilative capacity for waste discharges, an important ecological service provided by streams and rivers. In the development of water management plans, provisions for the maintenance of stream flows are clearly a critical priority.

LITERATURE CITED

Albertson, P.N., and L.J. Torak, 2002. Simulated effects of ground-water pumpage on stream-aquifer flow in the vicinity of federally protected species of freshwater mussels in the lower Appalachicola-Chattahoochee-Flint River basin (subarea 4), southeastern Alabama, Northwestern Florida, and southwestern Georgia. Water Resources Investigations Report 02-4016, U.S. Geological Survey, Atlanta.

Golladay, S.W., P. Gagnon, M. Kearns, J.M.Battle, and D.W. Hicks, 2004. Response of freshwater mussel assemblages (Bivalvia: Unionidae) to a record drought in the Gulf Coastal Plain of southwestern Georgia. Journal of the North American Benthological Society 23: 494-506.

Golden, H. G., and G.W. Hess, 1991. Georgia: Floods and Droughts. Pages 239-243 *in* National Water Summary 1988-1999. USGS Geological Survey Water-Supply Paper 2375, Doraville.

Harrison, K. M. 2001. Agricultural irrigation trends in Georgia. Pages 114–117 *in* K. J. Hatcher (editor). Proceedings of the 2001 Georgia Water Resources Conference. Institute of Ecology, University of Georgia, Athens, Georgia.

Pierce, R., R. Barber, and H. R.Stiles, 1984, Georgia Irrigation, 1970-80: A decade of growth, U.S. Geological Survey Water-Resources Investigations Report 83-4177, 29 p.

Litts, T., H. Russell, A. Thomas, and R. Welch. 2001. Mapping irrigated lands in the ACF riverbasin. Pages 79–83 *in* K. J. Hatcher (editor). Proceedings of the 2001 Georgia Water Resources Conference. Institute of Ecology, University of Georgia, Athens, Georgia.

Pollard, L.D., R.G. Grantham, and H.E. Blanchard, Jr., 1978, A preliminary appraisal of the impact of agriculture on ground-water availability in southwest Georgia: U.S. Geological Survey Water-Resources Investigations Report 79-7, 21 p.

Stamey, T.C., 1996. Streamflow Characteristics at Selected Sites in Southwestern Georgia, Southeastern Alabama, and Northwestern Florida, Near Lake Seminole. U.S. Geological Survey Open-File Report 95-455, Atlanta.

Torak, Lynn J., and McDowell R. J. 1996, Ground-water resources of the lower ACF river basin in parts of Alabama, Florida, and Georgia—Subarea 4 of the ACF and ACT river basins, U.S. Geological Survey Open-File Report 95-321, 145 p.