SEASONALITY AND TRENDS IN STREAM WATER QUALITY IN GWINNETT COUNTY, GEORGIA, 1996–2003

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Abstract. More than 400 water-quality samples collected during baseflow and stormflow conditions between 1996 and 2003 in six watersheds in Gwinnett County, Georgia, were analyzed for seasonality and long-term trends. Baseflow water quality did not have a statistically significant seasonal variation. Flow-adjusted stormflow concentrations of total suspended solids, total phosphorus, and total zinc showed a seasonal pattern between 1996 and 2003 in five of the six watersheds and typically peaked in late summer between July and August. The seasonal pattern may be related to seasonal land-disturbance activities and/or to seasonal rainfall intensity, both of which increased in summer. Graphical and statistical analyses do not indicate a time trend from 1996 to 2003 in flow- and seasonally adjusted stormflow concentrations of total suspended solids, total phosphorus, total zinc or total dissolved solids for the sampled streams in the six watersheds studied. The absence of a trend, when land use was changing rapidly, may reflect the time lag of impacts, natural variability and/or watershed management practices. The only long-term trend detected was a decline in baseflow concentrations of total zinc. The cause of this trend is currently unknown.

INTRODUCTION

The U.S. Geological Survey (USGS), in cooperation with the Gwinnett County Department of Public Utilities, is monitoring streamflow, water quality, and constituent loads in Gwinnett County watersheds (Fig. 1) (Landers and others, 2002). An important objective of the Gwinnett County monitoring program is to assess long-term trends in water quality that may relate to management and land-use practices. Seasonal trends also may indicate the effects of land-use and management practices. This paper evaluates seasonality and trends in six watersheds that have been monitored continuously since 1998, with sample collection beginning during 1996. This analysis is based on more than 400 water-quality samples collected during baseflow and stormflow conditions in the six watersheds described in the Table 1.

SEASONALITY IN WATER-QUALITY CHARACTERISTICS

Many physical, chemical, and biological stream characteristics can show strong seasonal patterns (Hem, 1985). Physical streamflow quantity varies directly with seasonal precipitation, temperature, and evapotranspiration. In response to seasonal streamflow quantity, concentration of some physical and chemical constituents and mass transport may follow seasonal patterns. Much of the seasonal variation in water quality may be explained by adjusting for changes in streamflow quantity; however, water quality may vary seasonally in response to seasonal patterns in rainfall intensity, biological activity, or land-use practices, such as construction and fertilizer application.

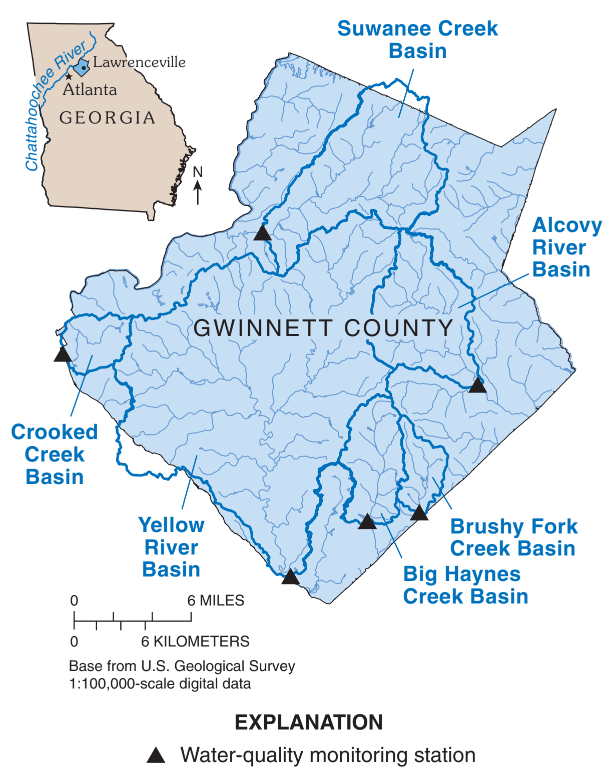

Figure 1. Location of basins in Gwinnett County, Georgia.

Table 1. Water-quality sample stations,Gwinnett County, Georgia.

[ID, identification; USGS, U.S. Geological Survey; mi^2, square mile]

Gwinnett County ID	USGS station number	Station name	Date established	Drainage area (mi^2)
GWLT-02	02207120	Yellow River at SR 124 near Lithonia, Ga.	Apr. 1996	162.00
GWLT-04	02207385	Big Haynes Creek at Lenora Road near Snellville, Ga.	June 1996	17.3
GWLT-05	02207400	Brushy Fork Creek at Beaver Road near Loganville, Ga.	June 1996	8.15
GWLT-07	02208150	Alcovy River at New Hope Road near Grayson, Ga.	June 1997	30.8
GWLT-12	02334885	Suwanee Creek at Buford Highway near Suwanee, Ga.	Sept. 1996	47.0
GWLT-01	02335350	Crooked Creek at Spalding Drive near Norcross, Ga	Mar. 1996	8.89

Methods to Evaluate Seasonality

For this study, seasonal changes in water quality were evaluated using the water-quality data collected at each site from 1996 through 2003. Within any season, stormflow and baseflow typically have unique water-quality characteristics and form statistically unique populations (Landers and others, 2002). Stormflow is most affected by nonpoint-source pollution, whereas baseflow is most affected by point-source pollution. Because they represent unique populations for many constituents, stormflow and baseflow samples were evaluated separately in this study. Streamflow at the time of sample collection (sample discharge) is the most significant factor affecting many sediment-associated constituent concentrations. The effect of streamflow will often mask the effect of less influential factors, such as seasonal or long-term trends. To adjust for streamflow effects, evaluation of seasonality and trends is performed on the residuals of a linear regression of concentration as a function of sample discharge (Hirsch and others, 1991). Linear regression analyses were made for each constituent, for each site, for stormflow and baseflow. Transformations of data also were evaluated, and natural logarithmic transformation of concentration and discharge was used to normalize the data and to improve the linear explanatory relations of these data. In the seasonal graphical analysis shown in Figure 2, log-residuals of a regression of log-concentration as a function of log-discharge are plotted with the month of the sample. Seasonality is indicated by nonrandom seasonal variation of the residuals. A locally weighted scatterplot smooth (LOWESS) through the residuals helps identify the seasonal trend.

In the statistical analysis, seasonality was evaluated using a periodic function (sine and cosine) of time, in addition to log-discharge, as an explanatory variable for log-concentration in linear regression models (Helsel and Hirsh, 1992). Seasonality was considered to be significant where the slope of the seasonal function in the linear regression was different from zero at a 0.1 level of significance (p-value) and where this conclusion was supported by the graphical analysis.

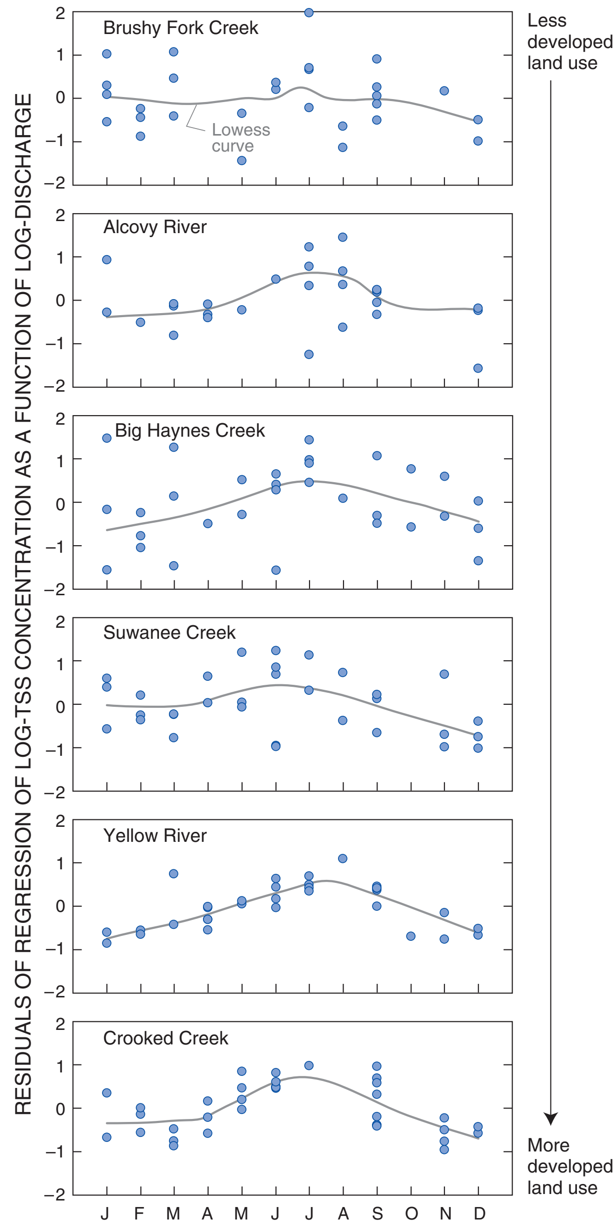

Figure 2. Seasonality in flow-adjusted residuals of logarithmic total suspended solids concentrations (TSS) for stormflow samples collected from 1996 to 2003. The six basins are in the order of increasing development from top to bottom.

Discussion of Seasonality

Baseflow water quality does not have a statistically significant seasonal variation, after adjusting for the effects of streamflow, for the analyzed parameters of total suspended solids (TSS), total phosphorus (PTOT), and total zinc (ZTOT). This result is expected in streams that are not strongly influenced by seasonally varying point-source pollution. This result also is reasonable because TSS, PTOT, and ZTOT are typically associated with suspended-phase pollutants. Seasonality in total dissolved solids (TDS) was also evaluated and found to be insignificant in baseflow and in stormflow samples.

Stormflow water quality varies seasonally for five of the six streams, after adjusting for the effects of streamflow, as shown in Figure 2 for flow-adjusted residuals of logarithmic TSS concentration for samples collected from 1996 to 2003.

Seasonality was statistically significant for TSS, ZTOT, and, to a lesser extent, PTOT for five of the six watersheds. Seasonal effects on stormflow TSS are stronger for more developed watersheds, as indicated in Figure 2 (the six basins are in the order of increasing development from top to bottom). Seasonal effects are not significant in the Brushy Fork Creek watershed, possibly because of an upstream reservoir and a less-developed watershed. Seasonal patterns in flow-adjusted PTOT, and total metals concentrations are similar to those for TSS. The seasonal pattern is lower in winter months and typically peaks in later summer, between July and August. The seasonal pattern of TSS, PTOT, and ZTOT may be related to seasonal land-use patterns, including land-disturbance activities that generally increase in the spring and summer; and to seasonal variations in rainfall intensity. More intense rainfall events can cause greater erosion and wash load than more gradual winter rainfall patterns. Typical rainfall patterns in the Georgia Piedmont in late summer are intense afternoon thunderstorms. The probability of intense 1-hour rainfall events is highest in summer and peaks during the month of July for the southeastern United States (National Weather Service, 1961).

Seasonality is important in the computation of constituent loads for watershed characterization. Seasonality was accounted for using a periodic function of time in the rating curve models used to compute watershed load in each of the watersheds, except Brushy Fork Creek. After adjusting for seasonality, model results for summer TSS loads increased by an average of 45 percent, and winter TSS loads decreased by an average of 40 percent; whereas changes in the spring and fall load rates were negligible. Total annual loads changed by less than 5 percent on average, with some sites showing an increase and others a decrease in total load. Adjusting for seasonality in the load model caused the standard error of computed annual TSS load to improve by an average of 11 percent in the five watersheds adjusted for seasonality.

LONG-TERM TRENDS IN WATER-QUALITY CHARACTERISTICS

Long-term trends are a critical indicator of the overall effectiveness of watershed-management strategies and practices. Reliable, continuous water-quality data are essential to assess and improve watershed-management efforts, which can represent a substantial investment for public and private entities. Evaluation of water-quality trends, however, often requires a decade or more of monitoring because of factors including large natural variability from year to year; lag-time between watershed changes and water-quality effects; and cumulative, offsetting effects from multiple activities in the watershed. When watershed land use is changing rapidly, the lag-time between effects may be shortened. Population in Gwinnett County increased by more than 250 percent from 1980 to 2000 and by more than 40 percent from 1996 to 2003 (accessed December 2004 at *www.census.gov*). Land use has changed to varying extents in the study watersheds as well, with more than 10,000 acres changing from undeveloped to developed land-use classifications within the boundaries of the six watersheds between about 1998 and 2002 (Gwinnett County, Department of Public Utilities, land-use data, 1998 and 2002).

Methods to Evaluate Long-Term Water-Quality Trends

Methods to evaluate long-term water-quality trends, as for seasonal trends, include separate analysis of baseflow and stormflow, adjusting for sample discharge, and natural logarithmic transformation. Stormflow constituent concentrations were adjusted for seasonality in addition to discharge for the long-term trend analysis. The graphical analysis in Figure 3, for stormflow samples, uses residuals from a linear regression of log-concentration as a function of log-discharge and a seasonal periodic function. The graphical analysis in Figure 3, for baseflow, uses residuals from a linear regression of log-concentration as a function of log-discharge only. Long-term trends were considered to be significant where the slope of the time function in the linear regression was different from zero at a 0.1 level of significance (p-value) and where this conclusion was supported by the graphical analysis. The statistical analysis used elapsed time (days since January 1, 1996) in the regression model, along with discharge, and for stormflow, seasonality.

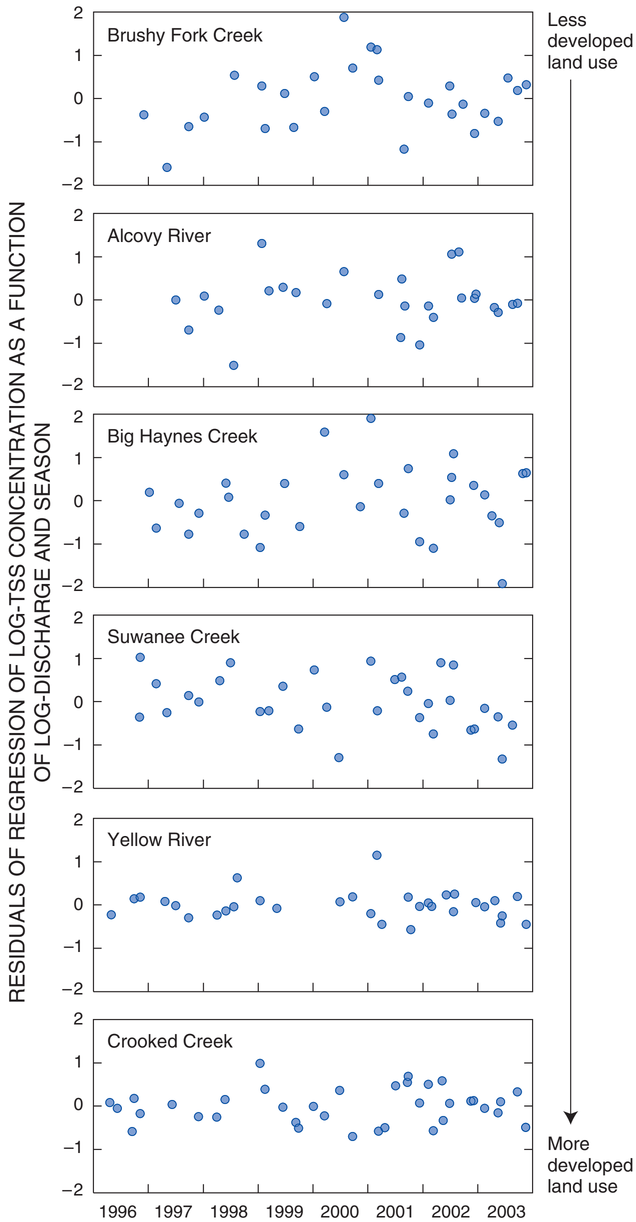

Figure 3. Long-term trend analysis of seasonal- and flow-adjusted residuals of logarithmic total suspended solids (TSS) stormflow concentration from 1996 to 2003.

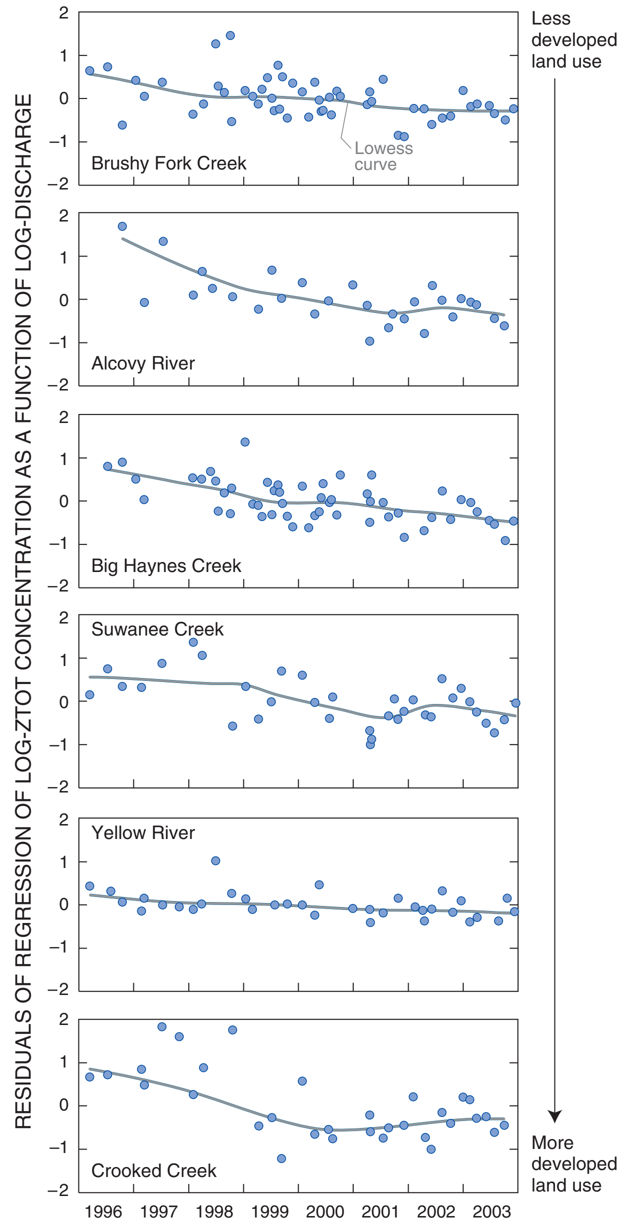

Figure 4. Long-term trend in flow-adjusted residuals of logarithmic total zinc (ZTOT) baseflow concentration from 1996 to 2003.

Discussion of Long-Term Trends

Figure 2 shows the seasonal- and flow-adjusted residuals of logarithmic TSS stormflow concentrations for the six study watersheds from early 1996 to late 2003. Graphical and statistical analyses, as shown for TSS in Figure 3, do not indicate a long-term trend in adjusted stormflow concentrations of TSS, PTOT, ZTOT, or TDS for the sampled streams in the six watersheds studied. The absence of a trend in nonpoint source-driven stormflow concentrations from 1996 to 2003, when land use was changing rapidly, may reflect ongoing implementation of watershed-management practices, in addition to the effects of natural variability and the time lag of impacts.

Baseflow water quality also did not show trends for TSS, PTOT, and TDS, after adjusting for streamflow. Trends are present, however, in flow-adjusted total zinc trace metal concentrations during baseflow.

Flow-adjusted total zinc trace metal concentrations during baseflow have been decreasing since 1996, as indicated in Figure 4. Zinc concentrations in baseflow do not have a seasonal variation and are marginally related to sample discharge; thus, sample concentrations were flow-adjusted. Flow-adjusted zinc concentrations have a strong significant time trend (p-value less than 0.01 for five sites, and less than 0.04 for all sites).

Baseflow concentrations of trace metals other than zinc were almost always below analytical detection limits, so evaluation of trends was not possible. Trace metals concentrations; however, typically are highly correlated.

The cause of decreasing baseflow zinc concentrations is uncertain. In five of the six sites, the pH has an increasing time trend (p-value less than 0.01 for four sites and equal to 0.05 for the fifth site). More alkaline (higher pH) water may mobilize less zinc in the dissolved phase; but this may not be the cause of decreasing zinc concentrations.

SUMMARY

Flow-adjusted TSS, PTOT, and ZTOT stormflow concentrations between 1996 and 2003 have a seasonal pattern in five of the six watersheds. Flow-adjusted concentrations typically peak in late summer, between July and August. The seasonal pattern may be related to seasonal land-disturbance activities and/or to seasonal rainfall intensity, both of which increase in summer. Adjusting for seasonality in the computation of constituent load caused the standard error of annual TSS load to improve by an average of 11 percent, and increased computed summer TSS loads by an average of 45 percent and decreased winter TSS loads by an average of 40 percent. Total annual loads changed by less than 5 percent on the average.

Graphical and statistical analyses do not indicate a time trend from 1996 to 2003 in flow- and seasonally adjusted stormflow concentrations of TSS, PTOT, ZTOT, or TDS for the sampled streams in the six watersheds studied. The absence of a trend, when land use was changing rapidly, may reflect the time lag of impacts, natural variability and/or watershed-management practices. The only long-term trend detected was in baseflow concentrations of ZTOT. The cause of this trend is currently unknown.

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