

RECONNAISSANCE OF BASEFLOW WATER QUALITY IN GEORGIA

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Abstract. During 1995, the Georgia Department of Natural Resources, Georgia Environmental Protection Division (GaEPD) adopted and implemented significant changes to the strategy for water-quality trend monitoring in Georgia. The changes were made to implement a rotating basin monitoring approach in support of the River Basin Management Planning (RBMP) program. Important environmental water-quality indicator parameters that support RBMP objectives are total suspended solids, turbidity, fecal coliform, total nitrogen, total phosphorus, and pH. Through many U.S. Geological Survey water-quality projects, including cooperative projects with GaEPD, a large database of water-quality analyses exists; samples have been collected since the late 1960s, with many analyses representing baseflow conditions. However, the spatial variability of baseflow water quality in Georgia has received little documentation. A statewide reconnaissance-level study of baseflow water quality provides information that may be valuable in assessing background water quality, minimally affected by anthropogenic pollutant sources. Regionalized unit-area streamflow percentiles provide a basis for selecting water-quality sample discharges that likely represent baseflow. Samples taken during baseflow must be screened to remove those with apparent point-source influences. The reconnaissance-level approach has several assumptions that are probably violated to some extent. However, the resulting maps of screened, baseflow water-quality characteristics provide a reconnaissance-level indicator of background concentrations of constituents during baseflow.

INTRODUCTION

The Georgia Environmental Protection Division (GaEPD), in cooperation with the U.S. Geological Survey (USGS), initiated long-term water-quality monitoring of streams at strategic locations throughout Georgia during the late 1960s. During 1995, GaEPD adopted and implemented significant changes to the strategy for trend monitoring in Georgia. The changes were made to implement a rotating basin monitoring approach in support of the River Basin Management Planning (RBMP) program. Through many USGS water-quality projects, including the RBMP program, a large database of water-quality analyses have been collected since the late 1960s, with many analyses

representing baseflow conditions. However, the spatial variability of baseflow water quality in Georgia has received little documentation.

Important environmental water-quality indicator parameters that support RBMP objectives include total suspended solids (TSS), turbidity, fecal coliform, total nitrogen, total phosphorus, and alkalinity (pH). These parameters each have natural sources and are present at background levels in streams unaffected by human activities. Knowledge of these background levels is valuable to determine when a stream may be affected by human or other influences. The background level is not the same as a threshold of stream impairment, because a stream may have the capacity to assimilate various water-quality stressors without impact to its beneficial characteristics.

A statewide reconnaissance-level study of baseflow water quality provides information that may be valuable in assessing background water quality, minimally affected by anthropogenic pollutant sources. The resulting maps of screened, baseflow water-quality characteristics provide a reconnaissance-level indicator of background concentrations of constituents during baseflow. Knowledge of spatial variation in background levels of a constituent could lead to a better understanding of watershed effects and to more informed watershed management.

ASSUMPTIONS OF RECONNAISSANCE-LEVEL METHODOLOGY

The reconnaissance-level methodology described herein was used to map regional baseflow concentrations for selected constituents. The reconnaissance-level approach has several assumptions that are probably violated to some extent. Interpretation of these maps must be strongly qualified by the assumptions made in this reconnaissance-level analysis. The extensive water-quality data evaluated in this study were collected over 35 years by the USGS, in cooperation with GaEPD and other cooperating agencies, to address diverse objectives. One primary assumption of this reconnaissance-level method is that long-term trends are negligible in background levels of the analyzed parameters during baseflow conditions. This assumption is necessary where nonconcurrent periods are used in a common regional study. Real trends may affect the baseflow data and results shown herein, but were not strongly

evident in the baseflow sample data. A second assumption is that baseflow samples affected by human activities (typically point sources) have been eliminated by the screening procedure described below. This assumption is probably valid for strongly influenced samples (high outliers) and samples collected below known point sources. However, the screening process probably did not remove all samples influenced by human activities. A third assumption is that screened baseflow samples are not affected by groundwater constituent sources. This assumption is probably violated, particularly for nutrients in some streams. A fourth assumption is that the method of separating baseflow from nonbaseflow samples is valid. This method was evaluated for several long-term record sites and is regarded as sound for identifying sample discharges unaffected by storm runoff. However, many excluded samples with discharges higher than the 20th-percentile threshold were likely representative of actual baseflow conditions. Finally, as with any regionalization method, this approach does not represent background characteristics affected by localized factors that are not represented by the scale of this study.

METHODOLOGY

Water-quality samples were extracted from the USGS National Water Information System (NWIS) for the period 1966–2001. This sampling period includes most of the programmatic water-quality data collected in Georgia by USGS, GaEPD, and other agencies. In this reconnaissance analysis, sample discharge was used to select samples that likely represent baseflow conditions. The baseflow data were then screened in an attempt to remove those that were likely affected by surface runoff or point sources.

Selection of Baseflow Samples

To determine which samples were collected during baseflow, analyses were performed on all streamflow gage data having a minimum of 20 years of daily flow record (146 sites). For each month of the year, the 80-percent flow exceedences were calculated. This is the flow that was exceeded 80 percent of the time of measured flow. The 80-percent flow exceedence was selected based on analyses of selected long-term gages in the State. A more thorough analysis in the future may indicate different baseflow thresholds for different areas of the State; but such analysis was beyond the scope of the current study. The flow-exceedence discharge values were normalized by drainage area in preparation for regional mapping. Monthly unit flow exceedences were mapped using an inverse distance weighting method based on 12 near neighbor points and a squared distance term. Figure 1 shows a surface of the 80-percent flow exceedence per unit area (in cubic feet per second per square mile) for the months of April and October.

Mean-monthly values of the 80-percent flow exceedence were derived from the map for each water-quality sample site. Values for ungauged sites were multiplied by their respective drainage areas to produce estimated monthly exceedence values. This method was used to estimate monthly percent exceedence discharge values for 548 sampled sites. Baseflow samples were identified by comparing sample discharge with 80-percent exceedence discharge values for the sample month. Samples for which discharge was less than or equal to the monthly 80-percent flow exceedence for the sample month were retained in the analysis data set. For this reconnaissance-level analysis, no relations were established for the runoff

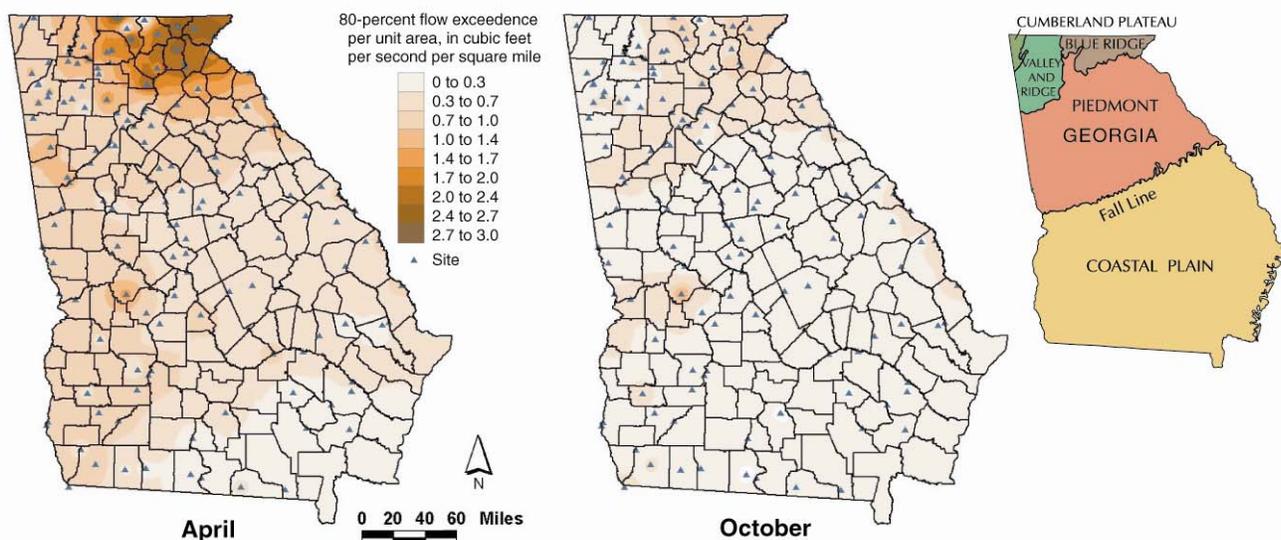


Figure 1. Eighty-percent flow exceedence per unit area, in cubic feet per second per square mile, for the months of April and October, respectively, and physiographic provinces of Georgia.

flow regime, which typically has much higher variance and is affected by factors other than baseflow.

Screening for Point-Source Affected Samples

An outlier analysis of the sample data indicated that many baseflow sample concentrations were affected by point sources. Further analysis indicated that these outliers usually occurred prior to the 1980s and were most often at sites with known upstream point sources. To further identify point sources, wastewater treatment facility maps and experienced hydrologists (with careers spanning the 35-year period of data collection) were consulted. Outlier thresholds were based on the data sets and available water-quality criteria (Georgia Department of Natural Resources, 2004). Samples probably affected by point sources were screened from the data by removing these measurements. Screening criteria and the number of watersheds and samples remaining after screening are shown in Table 1.

Mapping Baseflow Background Levels

After screening to remove samples that may be affected by runoff or point sources, samples representing from 87 to 498 watersheds remained in the data set. At each site, for each parameter, the median value for the sample data set was computed. For each parameter, these median values were plotted on a statewide map. Map surfaces were computed for each parameter using an inverse distance weighting method based on 12 near neighbor points and a squared distance term. The resulting maps are shown in Figure 2.

DISCUSSION

Figure 2 depicts characteristics of the screened baseflow water-quality data set for the parameters TSS, turbidity, fecal coliform, total nitrogen, total phosphorus, and pH, respectively. Figure 2A and B indicates baseflow levels of less than four for TSS in milligrams per liter (mg/L) and turbidity in nephelometric turbidity units (NTUs) in the lower Coastal Plain Province, and also low values typical in the Blue Ridge Province. Higher TSS and turbidity are evident in the Valley and Ridge Province, and roughly along the Fall Line. Higher TSS values in the middle Coastal Plain and Valley and Ridge Provinces may be due to point-source effects that were below the threshold of the screening process. Higher TSS and turbidity values that very roughly follow Georgia's Fall Line in the Piedmont Province and in northern Georgia may be related to surficial soil type, land cover, watershed slope, precipitation characteristics, and past erosion and sedimentation affecting stored fine sediments. Figure 2C shows

Table 1. Count of sites and measurements after screening for runoff and potential point-source effects

[TSS, total suspended solids; <=, less than or equal to; mg/L, milligrams per liter; NTU, nephelometric turbidity unit; MPN, most probable number; NS, not screened]

Water-quality parameter	Site before screening	Sites after screening	Measurements after screening	Screening criteria
TSS	548	362	5,174	<= 40 mg/L
Turbidity	548	456	6,560	<= 40 NTU
Fecal coliform	548	465	8,285	<= 4,000 MPN
Total nitrogen	102	87	1,092	<= 1.0 mg/L
Total phosphorus	498	473	8,492	<= 0.5 mg/L
pH	498	498	12,317	NS

that background levels of fecal coliform range from low values, under 200 most probable number (MPN), in much of the State, to higher values, from about 600–4,000 MPN which are more localized and tend to lie near major interstate corridors. Natural nonpoint sources for fecal coliform from all warm-blooded animals make high readings possible during baseflow in any part of the State, and may not represent elevated background levels of fecal coliform. Figure 2D shows that background levels of total nitrogen range from low values, less than 0.3 mg/L, in about five small areas of the State to more than 0.75 mg/L. Average total nitrogen values of 0.4–0.75 mg/L occur throughout most of the State. Nitrogen is present in much of the organic detritus characteristic of Georgia streams and may also be elevated due to human factors. Figure 2E shows that background levels of total phosphorus average 0.01–0.1 mg/L throughout much of the State. An area of higher values, 0.2–0.45 mg/L, occurs in five counties near the Georgia–Florida State line. Figure 2F shows that background values of nearly neutral pH (approximately seven standard units) for much of the State. PH values from about 7.25 to greater than 8 standard units occur in areas where the stream are incised into limestone, mostly in the Valley and Ridge Province and southwest areas of the State. PH values range from about six to less than four standard units occur in streams that are naturally affected by tannic acid in the lower Coastal Plain. More detailed analysis of these parameters by basin, land use, land-use change, slope, soil types, seasonality, time-trends, more specific flow conditions, and upstream point sources are needed to evaluate cause-and-effect relations.

LITERATURE CITED

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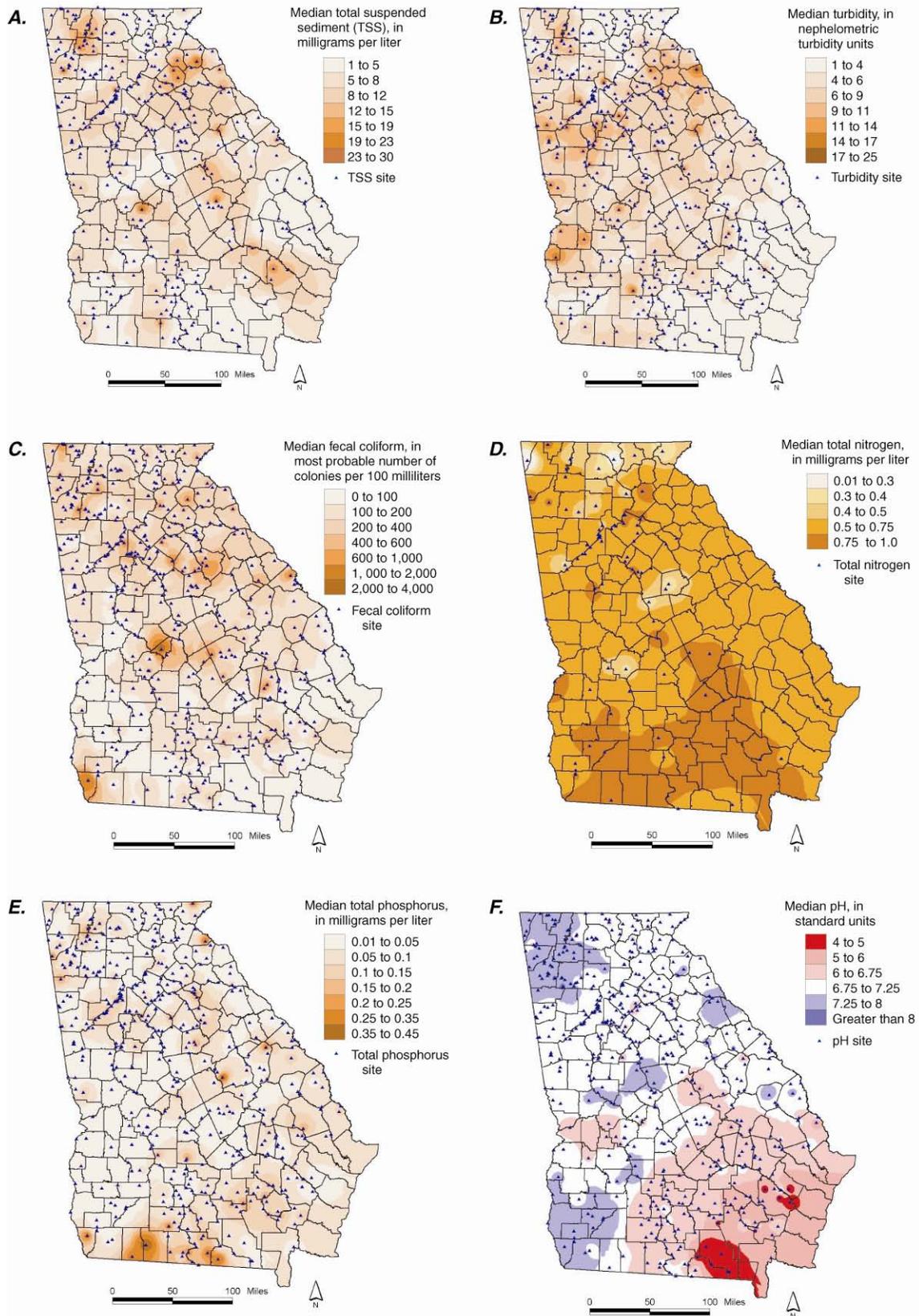


Figure 2. Surface representations of median concentrations for 1966–2001 for (A) total suspended sediment, (B) turbidity, (C) fecal coliform, (D) total nitrogen, (E) total phosphorus, and (F) pH.