EFFECTS OF URBANIZATION ON STREAM ECOSYSTEMS IN THE PIEDMONT ECOREGION OF GEORGIA AND ALABAMA — A STUDY DESIGN

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Abstract. As part of the U.S. Geological Survey's National Water-Quality Assessment program, the effects of urbanization on the water quality and ecology of streams throughout the United States are being studied. These studies are examining a range of physical, chemical, and biological changes that occur in streams as human populations increase in watersheds and land uses are converted from rural to urban. As part of one of these investigations, thirty streams were selected along a gradient of increasing urban intensity in the Piedmont Ecoregion of Georgia and Alabama, specifically in the vicinity of Metropolitan Atlanta, Georgia. Fixed interval and synoptic sampling of stream water will be conducted for a period of 1 year and will include measurement of *Escherichia coli* (*E. coli*) bacteria levels, pesticides, major ions, alkalinity, pH, dissolved oxygen, and specific conductance. Water temperature and stream stage will be monitored continuously using data loggers. Stream geomorphic and habitat features, as well as stream biological communities, will be characterized during spring and summer 2003. Data collection for this project began during October 2002 and will continue through October 2003.

INTRODUCTION

During the 1990s, the Metropolitan Atlanta region underwent a prolonged period of unprecedented population growth and rapid urban and suburban development. Similar to recent growth patterns of many other large U.S. cities, much of this growth and development has occurred in outlying areas, which until recently were not considered part of Metropolitan Atlanta. Currently, the Atlanta metropolitan statistical area includes 20 counties and encompasses an area of approximately 6,100 square miles—an area larger than the combined land areas of the states of Connecticut and Rhode Island. During 2000, the population of this region was more than 4.1 million people, which was approximately 50 percent of the population of Georgia (Atlanta Regional Commission, 2002).

Urbanization and sprawling metropolitan development have been linked to serious environmental problems, especially those related to the degradation of water quality, habitat conditions, and biological communities in streams. The U.S. Environmental Protection Agency (USEPA) has estimated that nationally urban runoff accounts for 43 percent of impaired estuary acres, 24 percent of impaired lake acres, and 11 percent of impaired river miles (U.S. Environmental Protection Agency, 1992). More recent estimates implicate urban runoff for impairing as many as 34,871 stream miles or 13 percent of assessed stream miles in the United States (U.S. Environmental Protection Agency, 2000).

During 1999, scientists from the U.S. Geological Survey (USGS) National Water-Quality Assessment (NAWQA) program began investigating the effects of urbanization on stream ecosystems in metropolitan areas of Anchorage, Alaska; Birmingham, Alabama; Boston, Massachusetts; Chicago, Illinois; Cincinnati-Dayton, Ohio; Los Angeles, California; Philadelphia, Pennsylvania; Trenton, New Jersey; and Salt Lake City, Utah (Fig. 1*A*). The successful implementation and findings from these pilot studies resulted in the implementation of a national project designed to increase our understanding of the linkages between watershed urbanization and stream ecosystems. During 2001, personnel at six NAWQA study units began planning intensive 1-year field studies designed to investigate the effects of urbanization on stream ecosystems. During 2002, personnel at three study units began collecting data at three 28- to 30-site networks located in Atlanta, Georgia; Raleigh-Durham-Chapel Hill, North Carolina; and Denver, Colorado (Fig. 1*A*, *B*). During 2004, three additional studies will be implemented using the same design in Portland-Salem-Eugene, Oregon; Dallas–Fort Worth, Texas; and Milwaukee, Wisconsin. This paper summarizes the study design and site network for the investigation currently under way in the vicinity of Metropolitan Atlanta.

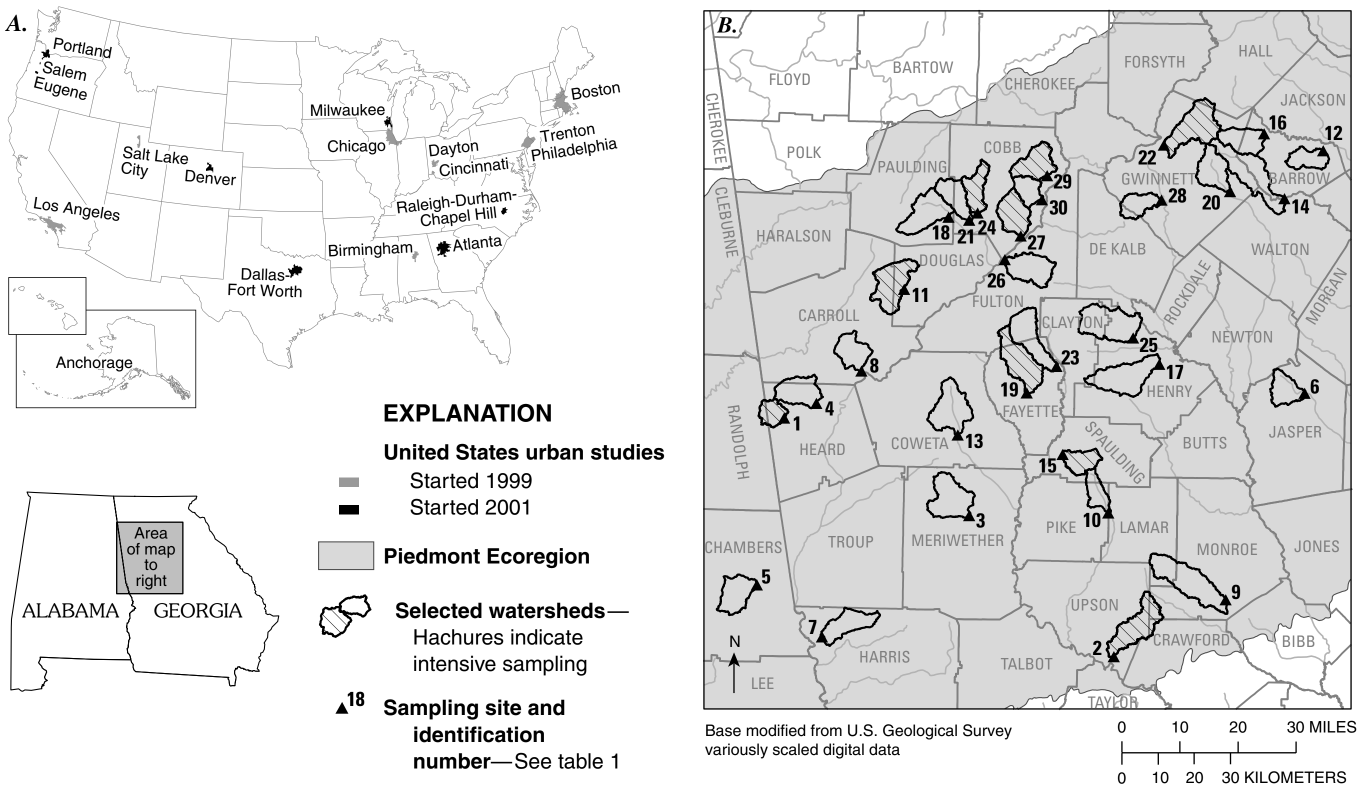

Figure 1. *(A)* **Urban areas in the United States being investigated by the National Water-Quality Assessment (NAWQA) program (Couch and Hamilton, 2002), and** *(B)* **watersheds to be sampled as part of the study under way on the Piedmont Ecoregion in the vicinity of Atlanta, Georgia.**

STUDY DESIGN

Thirty stream monitoring sites were selected in the Chattahoochee, Flint, Ocmulgee, and Oconee River Basins within the Piedmont Ecoregion of Georgia and Alabama (Fig. 1*B*). Candidate basins were selected using a Geographic Information System to select watersheds ranging in size from 15 to 60 square miles. The urban character of each candidate basin was estimated using an index that quantifies the multiple dimensions of human influence on the landscape at the basin scale and included factors such as land use, infrastructure, population, socioeconomic characteristics, and estimates of impervious surface (McMahon and Cuffney, 2000). An environmental framework that considered natural factors—such as soil texture and drainage characteristics, bedrock litho-chemical zones, watershed elevations, and slopes—was developed using multivariate analysis. As a result of this analysis, candidate basins were assigned to relatively homogeneous clusters based on natural landscape features that might affect water quality (Hopkins, 2003). Sites were selected within similar clusters to represent the gradient of urban land uses throughout the region. The simultaneous use of the urban index and environmental framework allowed selection of study sites in which the influence of natural factors on the water-quality response should be minimized, while the effects of urbanization on water quality should be maximized.

The study design consists of a 10-site, bimonthly sampling network nested within a 30-site synoptic network (Fig. 1, Table 1). Sampling at the 10-site intensive network will be fixed frequency and consist of six sampling events during various flow conditions throughout the year. Sampling frequency at the 30-site synoptic network will consist of two sampling events, once during early spring at high baseflow conditions and once during mid- to late summer at low baseflow conditions. The assumption is that the water-quality conditions at the more frequently sampled 10-site network will be representative of water-quality conditions in the entire 30-site network. This monitoring network also includes two sites that are part of the NAWQA's 4-site trend network that will be sampled monthly for a similar set of constituents during 2002–2005. These trend sites are located at endpoints on the gradient of urbanization (Fig. 1*B* and Table 1) and will allow long-term analysis of water-quality trends at urban and reference streams in the Piedmont Ecoregion of Georgia and Alabama.

Table 1. Urban gradient sites located in the Piedmont Ecoregion of Georgia and Alabama

[Bold sites are sites part of NAWQA trend network; ID, identification]

Map ID (Figure 1*B*)	USGS station ID	Station Name	Intensive site	Urban index	Watershed area (square miles)
1	02338523	**Hillabahatchee Creek at Thaxton Road near Franklin, Georgia**	x	5	17
2	02347748	Auchumpkee Creek at Allen Road near Roberta, Georgia	x	9	43
3	02344887	Red Oak Creek near Greenville, Georgia		10	36
4	02338375	Centralhatchee Creek at Notnomis Road near Centralhatchee, Georgia		11	34
5	02339480	Oseligee Creek at county Road 92 near Fredonia, Alabama		12	30
6	02221000	Murder Creek near Monticello, Georgia		14	24
7	02340282	House Creek at Georgia 103 near Whitesville, Georgia		14	30
8	02338280	Whooping Creek at State Route 5 near Whitesburg, Georgia		18	27
9	02213450	Little Tobesofkee Creek near Bolingbroke, Georgia		21	54
10	02346358	Turnpike Creek near Milner, Georgia		35	19
11	02337395	Dog River at North Helton Road near Winston, Georgia	x	30	44
12	02217471	Beech Creek at Georgia 211 near Statham, Georgia		31	24
13	02344797	White Oak Creek at Cannon Road near Raymond, Georgia		35	54
14	02218700	Apalachee River near Bethlehem, Georgia		36	54
15	02344480	Shoal Creek near Griffin, Georgia	x	37	22
16	02217293	Little Mulberry River at State Route 211 near Hoschton, Georgia		40	30
17	02204468	Walnut Creek at Airline Road near McDonough, Georgia		41	49
18	02336822	Mill Creek at Morning Side Drive near Hiram, Georgia		43	35
19	02344737	Whitewater Creek at Willow Pond Road near Fayetteville, Georgia	x	46	43
20	02208150	Alcovy River at New Hope Road near Grayson, Georgia		50	28
21	02336876	Powder Springs Creek at Oglesby Road, Powder Springs, Georgia		52	25
22	02334885	Suwanee Creek near Suwanee, Georgia	x	53	47
23	02344340	Morning Creek at State Route 54 near Fayetteville, Georgia		59	39
24	02336968	Noses Creek at Powder Springs Road, Powder Springs, Georgia	x	64	44
25	02204230	Big Cotton Indian Creek at State Route 138 near Stockbridge, Georgia		71	46
26	02336728	Utoy Creek at Great Southwest Parkway near Atlanta, Georgia		73	34
27	02336635	Nickajack Creek at US 78/278 near Mabelton, Georgia	x	77	36
28	02206314	Jackson Creek near Lilburn, Georgia		85	22
29	02335870	**Sope Creek near Marietta, Georgia**	x	91	31
30	02335910	Rottenwood Creek at Interstate Parkway near Smyrna, Georgia		96	19

DATA COLLECTION

All data collection will follow previously published USGS protocols (Wilde and Radtke, 1998) to ensure consistency throughout the study and among participating study units. Field parameters to be measured include water temperature, dissolved oxygen, specific conductance, pH, and turbidity. Water-chemistry parameters including chloride, sulfate, nutrients, pesticides, organic carbon, suspended sediment, and *E. coli* levels will also be measured during each sampling event. All laboratory analyses for chemical constituents will be done at the USGS National Water-Quality Laboratory. Indicator bacteria will be analyzed in the Georgia District laboratory in Atlanta. All sampling sites within the network will be instrumented with pressure transducers and temperature probes for continuous measurement of stage and temperature.

Status of stream ecological communities will be evaluated by assessing stream geomorphic and habitat conditions, algae, benthic invertebrates, and fish communities from representative stream reaches at each of the 30 sites once during summer 2003. Instream habitat will be evaluated by using standard USGS protocols (Fitzpatrick and others, 1998), which include various geomorphic measurements such as channel gradient, cross sections, and pebble counts. Quantitative analysis of benthic algae communities and algal chlorophyll *a* levels will be determined at all sites. The Philadelphia Academy of Sciences will conduct algal enumeration and identifications. Benthic invertebrates will be collected qualitatively from the entire stream reach, and semiquantitatively from the richest habitat types, which typically are riffles or snags in Piedmont streams. The USGS National Water Quality Laboratory Biological Group in Denver, Colorado, will conduct invertebrate sample identification and enumeration. Fish communities will be assessed and biomass estimates made using a two-pass electrofishing technique. All biological data will be collected using nationally consistent USGS techniques documented by Moulton and others (2002).

ADDITIONAL WORK ELEMENTS

The design of a site network along an *a priori* gradient of urban intensity is ideal for allowing additional studies to be added onto to the original design. These work elements take advantage of the existing network design and concurrent data-collection activities to amass large amounts of data that can provide an increased understanding of urbanization effects on stream ecosystems. Several additional work elements will be completed as part of this study including investigations of urbanization effects on hydrophobic contaminant transport, sources of nutrients, and food-web structure. These additional work elements are described briefly below.

Semipermeable membrane devices (SPMDs) are polyethylene membrane tubes containing a purified synthetic lipid found in fish tissue (triolein). SPMDs have been used successfully during the past decade to determine the presence and concentration of organic pollutants in a wide variety of settings (Lebo and others 1995; Huggins and others 1996). The permeability of the membrane is similar to fish gills in terms of size selectivity and mimic bioaccumulation of organic compounds. SPMDs will be deployed in all 30 streams for a period of approximately 1 month immediately prior to biological sampling. After retrieval, hydrophobic compounds will be extracted and a subsample of the extracts from each SPMD will be used for micro-toxicity testing.

Stable isotope analyses offer a potential tool for estimating the relative contributions of terrestrial and instream sources of riverine particulate organic matter and nutrient sources because these various sources often have distinctive isotopic compositions. Carbon and nitrogen stable isotopes will be used to evaluate energy sources in urban streams and to compare changes in isotopic signatures of nutrients across the gradient of urban land use.

SUMMARY

Urbanization continues to be a dominant trend in many regions of the United States, and problems associated with urbanization make a large contribution to the overall degradation of the nation's water. The objectives of NAWQA's urban studies are to link physical, chemical, and biological responses to indicators of urban land-use intensity. By utilizing the gradient approach, these studies substitute space along the gradient for time and have the potential to predict stages of degradation that streams undergo as watershed development increases. This information will be of value to watershed managers who are faced with investing public resources to mitigate or restore beneficial uses to streams affected by development, but who often have no scientific information with which to understand the ecological consequences of their choices. The national and regional comparison among areas participating in these studies will highlight similarities/differences in the ways that watershed development affects different stream types in various environmental settings throughout the United States.

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