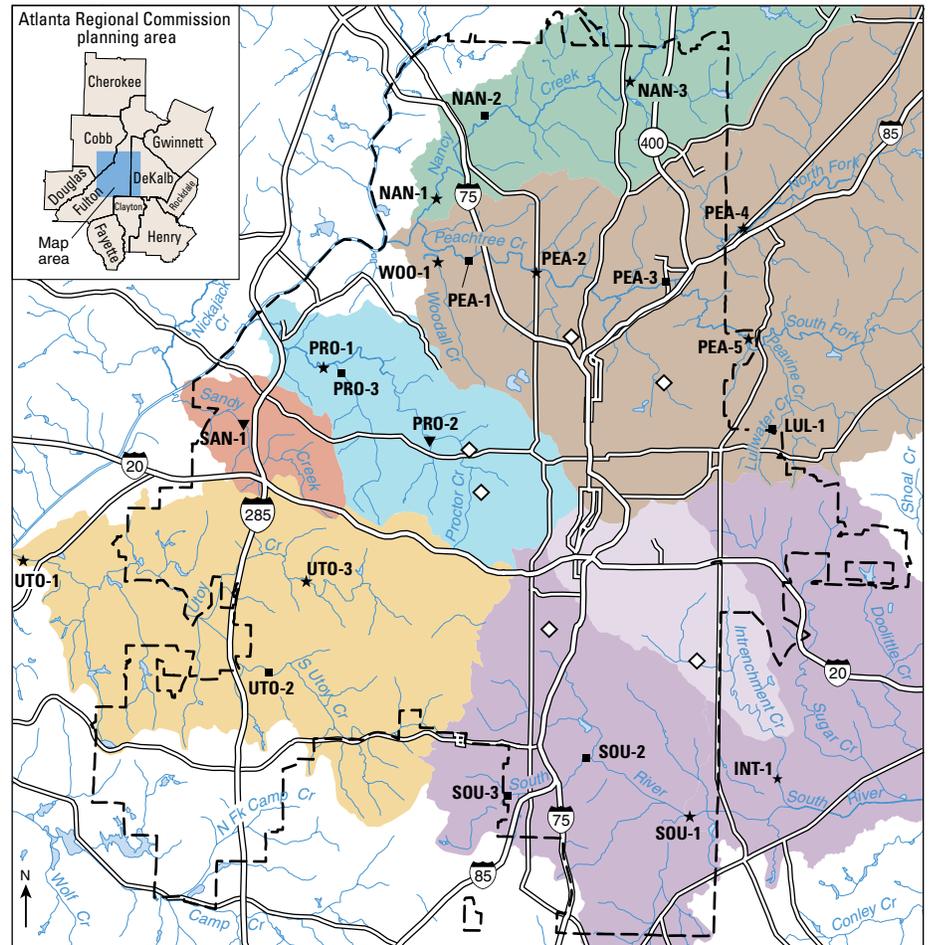


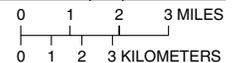
The U.S. Geological Survey and City of Atlanta Water-Quality and Water-Quantity Monitoring Network

Population growth and urbanization affect the landscape, and the quality and quantity of water in nearby rivers and streams, as well as downstream receiving waters (Ellis, 1999). Typical impacts include: (1) disruption of the hydrologic cycle through increases in the extent of impervious surfaces (e.g., roads, roofs, sidewalks) that increase the velocity and volume of surface-water runoff; (2) increased chemical loads to local and downstream receiving waters from industrial sources, nonpoint-source runoff, leaking sewer systems, and sewer overflows; (3) direct or indirect soil contamination from industrial sources, power-generating facilities, and landfills; and (4) reduction in the quantity and quality of aquatic habitats (Driver and Troutman, 1989; Ellis, 1999; Rose and Peters, 2001).

Atlanta, Georgia, is one of the fastest-growing urban areas in the United States. Between the early 1970s and 2000, the population of Metropolitan Atlanta increased by about 125 percent; at the same time, urbanization increased up to 210 percent (Peters and Kandell, 1999; Atlanta Regional Commission, 2004; Elizabeth Kramer, University of Georgia, oral commun., 2004). As a result, the City of Atlanta's (COA) storm, sanitary, and combined sewers have been unable to meet current demands. About 15 percent of the current COA sewer system is combined (stormwater and sanitary waste in the same pipe). During dry periods, all sewer flows are discharged to wastewater treatment plants; whereas under wet conditions, some of these flows are sent to combined treatment facilities (see map). When this occurs, the combined flow is screened to remove solids, and disinfected, prior to being discharged to local streams. On average, there are more than 300 combined sewer overflows (CSOs) per year from Atlanta's six existing CSO facilities (Clean Water Atlanta, 2004).



Base from U.S. Geological Survey 1:100,000-scale digital data



EXPLANATION

Watershed		Sampling site and identification	
Nancy Creek	Utoy Creek	W00-1 ★ Continuous water quality and quantity, periodic water quality	
Peachtree Creek	South River	SAN-1 ▼ Continuous water quality, periodic water quality	
Proctor Creek	Intrenchment Creek	SOU-3 ■ Periodic water quality	
Sandy Creek		Combined sewer overflow facility	
-- City of Atlanta boundary			

During 1998, the COA entered into a consent decree to reduce the incidence of CSOs, and other discharges, to permitted limits (U.S. District Court, 1998). Compliance with the consent decree is scheduled during 2007 for CSOs and 2014 for sanitary sewer overflows (SSOs), and is based on an improved infrastructure that includes the construction of two large tunnels (about 360-million-

gallon combined capacity) for the storage and conveyance of combined stormwater and sanitary waste to two new treatment facilities. Further, the COA plans to reduce the relative size of the existing combined system from 15 to 10 percent of the total. Lastly, the COA is required to monitor all SSOs, as well as the impact of stormwater, on downstream water quality (Clean Water Atlanta, 2004).

During 2001, the COA asked the U.S. Geological Survey (USGS), in conjunction with CH2M Hill, to design a water-quality and water-quantity monitoring network that would fulfill the requirements of the consent decree, provide an evaluation of the planned infrastructural improvements, and monitor the ongoing state of the COA's water quality (see Sampling Design). The monitoring program provides real-time measurements of water quantity and precipitation, as well as water quality (e.g., pH, turbidity), combined with manual and automated sampling, and subsequent chemical and biological analyses. Constituents include major ions (e.g., sodium, sulfate), metals (e.g., zinc, lead), nutrients (e.g., nitrogen, phosphorus), bacteria (e.g., fecal coliform), and wastewater tracers. The current COA monitoring program is one of the largest in the United States.

PROGRAM OBJECTIVES AND SAMPLING DESIGN

The design criteria for the COA monitoring program include: (1) consolidating all water-quality monitoring (storm-water and sanitary sewer) into a single consistent program; (2) determining current water-quality conditions for evaluating the impact of infrastructural improvements; (3) locating sources of water-quality impairments throughout the city; (4) documenting water-quality changes in response to infrastructural improvements; (5) providing an assessment of long-term water-quality trends; and (6) over time, as monitoring data accrue, altering the network to improve effectiveness and limit costs.

The COA monitoring network consists of 21 long-term sites. Eleven of these are "fully instrumented" to provide real-time data on water temperature, pH, specific conductance, dissolved oxygen, turbidity (intended as a surrogate for suspended sediment concentration), water level (gauge height, intended as a surrogate for discharge), and precipitation. Data are transmitted hourly and are available on a public Web site (<http://ga.water.usgs.gov>). Two sites only measure water level and rainfall as an aid to stormwater monitoring. The eight remaining sites are used to assess water quality.

SAMPLING AND ANALYSES

All the fully instrumented sites (11) are equipped to collect stormflow samples

Continuous measurements recorded and available in real time (hourly) on the Web at <http://ga.water.usgs.gov>

Measurement	Explanation
Stage	The water level in a stream; indicates the flow conditions (baseflow, flooding).
Discharge	The volume of water flowing past a point; can be used to determine loads—the amount of sediment or a particular chemical transported by the stream.
Water temperature	Measured to show the daily and seasonal changes in stream temperature; can be elevated in urban streams by runoff from sun-heated pavement and roofs, and sewage discharges.
pH	A measure of the acidity of stream water; typical streams have nearly neutral pH (7.0) but can become elevated (basic) or lowered (acidic) due to the presence of contaminants.
Specific conductance	A measure of the water's ability to conduct electricity; the conductivity of stream water increases as the quantity of dissolved ions increases.
Turbidity	A measure of the ability of light to penetrate the water column in the stream; this is affected by the presence of some dissolved chemicals, but high turbidity usually results from increased suspended sediment in streams.
Dissolved oxygen	Measured to show the daily and seasonal changes in the level of oxygen in a stream—low oxygen levels can have severe ecological impacts and may be indicative of sewage or wastewater.

Laboratory analyses for the City of Atlanta monitoring program

Analysis	Sample medium ¹	Examples
Major ions	Filtered water	Ions such as sodium, potassium, iron, and chloride.
Nutrients	Filtered water and suspended sediment	Compounds containing nitrogen, phosphorus, and carbon.
Trace metals	Filtered water and suspended sediment	Metals that occur in small quantities such as lead, copper, and zinc.
Bacteria	Filtered water	Microorganisms that are indicators of contaminated water such as fecal coliform and <i>Escherichia coli</i> .
Wastewater tracers ²	Filtered water	A variety of chemicals that provide an indication of wastewater contamination such as food additives, fragrances, antioxidants, flame retardants, plasticizers, industrial solvents, disinfectants, fecal sterols, polycyclic aromatic hydrocarbons, and high-use domestic pesticides.

¹Dissolved constituents are transported in the water; suspended constituents typically are associated with the sediment that is transported in the water.

²Analysis completed during 2005.

using programmable autosamplers. These samples are important because much of the suspended sediment, sediment-associated and dissolved chemical transport occurs during storms (Horowitz, 1995; Peters and Kandell, 1999; Rose and Peters, 2001). Further, local rainfall tends to be convective; that is, it occurs in the late afternoon and evenings when manual sampling is logistically difficult. Lastly, even though the USGS office is physically close to most sampling sites, heavy traffic, combined with the rapid response of COA

streams to rainfall, makes it likely that relying solely on manual sampling could lead to the loss of information about the initial "flush" from numerous nonpoint sources. Collecting samples from the first "flush" is important because it may contain substantial amounts of suspended sediment, as well as chemical and biological constituents (e.g., Larsen and others, 1999).

This real-time data-collection effort is complemented with a two-part manual sampling program. Part one is a pair of



Samples are collected during all weather conditions for the City of Atlanta monitoring program. USGS personnel are shown collecting water samples at Nancy Creek during floods caused by Hurricane Ivan (2004). Collecting samples during high stream flows is important because as much as 90 percent of the material carried by a stream may be transported during floods and high flows. This is readily apparent in most Atlanta area streams and rivers because of the increased turbidity (muddiness) of the streams during higher flows. Photographs by Andrew C. Hickey, USGS.

intensive synoptic (temporal snapshots) surveys; one conducted during high flow and one conducted during baseflow. The synoptic surveys encompass 43 sites beyond those in the long-term network. They were selected to: (1) increase the resolution of the network; (2) identify additional sources of water-quality impairment that may require monitoring; (3) provide a broader context for evaluating and interpreting long-term water-quality monitoring data; and (4) provide additional benchmark data to evaluate the impact of infrastructural improvements. The paired high-flow/baseflow approach also is indicative of the relative impact of point (baseflow) and non-point sources (high flow) on water quality.

Part two of the manual sampling program is the collection of nonconvective storm and scheduled samples. Standard USGS procedures ensure the collection of representative samples (e.g., Edwards and Glysson, 1999). Each site is sampled 12 times per year and is intended to cover at least 80 percent of the annual range of water discharges at each long-term site.

The manual sampling program provides chemical and biological data that cannot be obtained with real-time measuring equipment (e.g., trace elements, nutrients, bacteria). It also is used to calibrate/validate the real-time data probes and the samples collected by the autosamplers. This is necessary because the sondes and autosamplers are at fixed positions in each stream cross section; thus, they collect point measurements/samples that may not be representative. To evaluate this, and to develop

appropriate correction factors if needed, a series of concurrent (simultaneous) measurements/samples must be collected over a range of flows. Both samples are measured/analyzed for the same constituents and compared. When necessary, appropriate correction factors are developed so that data from the sondes and autosamplers are representative (e.g., Horowitz, 1995). Past studies indicate that it may take from 20- to 30-paired measurements/samples to evaluate the need for, and to develop, correction factors; often, these factors are site specific, and differ within the same stream (Horowitz, 1995; Christensen, 2001).

Most of the sampling and analytical procedures are standard. The exceptions relate to suspended-sediment sampling and analyses for the entire program, the low-flow synoptic survey, and the measurement of wastewater tracers in both the manual and automatic sampling phases of the program. The COA monitoring program determines sediment-associated constituents directly on dewatered material. This method tends to provide more representative chemical data than the standard approach (Horowitz and others, 2001).

During the low-flow synoptic survey, suspended sediment was not collected for chemical analyses; instead, representative bed-sediment samples were used as a surrogate. However, to better represent suspended sediment, only the less than 63-micrometer fractions were analyzed (e.g., Horowitz and others, 1999; Meybeck and others, 2004).

The COA monitoring program makes extensive use of data that fall into a class of compounds titled sewage tracers, or organic wastewater contaminants. This class represents various chemical types (fungicides, pharmaceuticals, fire retardants, household chemicals, etc.) that have been found in streams near to, as well as downstream from, wastewater sources (Kolpin and others, 2004). These analyses are intended to identify wastewater, especially leaking sewer or septic systems.

SCHEDULING

The monitoring program began during early 2002. The high- and low-flow synoptic surveys were completed by the end of June and August 2003, respectively. Manual sampling at the long-term monitoring sites began in July–August 2003; the first instrumentally collected storm-water samples also were collected during the same period. Currently (2006), both types of sample collections are ongoing. Based on the synoptic surveys, a fully instrumented site was added on Woodall Creek in January 2005.

Calibration and validation of the real-time data sondes and autosamplers began with the manual sampling program. Based on 12 samples per site, per year, and the need for 20–30 paired samples/measurements over a range of flow conditions, calibration/validation, and the development of correction factors, if required, could take from 2 to 4 years. Once completed, manual sampling will decline to a level commensurate with

ensuring continued data validity. The monitoring program is scheduled to continue at least through 2007, when the infrastructural improvements are scheduled for completion.

The City of Atlanta monitoring program is overseen by a Technical Advisory Committee (TAC) that meets quarterly to review project plans and progress. The TAC includes representatives from the following organizations:

Upper Chattahoochee Riverkeeper—
Chair, Sally Bethea
U.S. Environmental Protection Agency
Georgia Environmental Protection Division
Cobb County—Marietta Water Authority
Gwinnett County Department of
Public Utilities
Georgia Institute of Technology
The University of Georgia
Georgia State University

REFERENCES CITED

- Atlanta Regional Commission, 2004, accessed July 22, 2004, at <http://www.atlantaregional.com>
- Christensen, V.G., 2001, Characterization of surface-water quality based on real-time monitoring and regression analysis, Quivira National Wildlife Refuge, south-central Kansas, December 1998 through June 2001: U.S. Geological Survey Water-Resources Investigations Report 01-4248, 28 p.
- Clean Water Atlanta, 2004, accessed August 17, 2004, at <http://www.cleanwateratlanta.org>
- Driver, N.E., and Troutman, B.M., 1989, Regression models for estimating urban storm-runoff quality and quantity in the United States: *Journal of Hydrology* 109, p. 221–236.
- Edwards, T.K., and Glysson, G.D., 1999, Field methods for measurement of fluvial sediment: U. S. Geological Survey Techniques of Water-Resources Investigations, book 3, chap. C2: 118 p.
- Ellis, J.B. (ed.), 1999, Impacts of urban growth on surface water and groundwater quality: International Association of Hydrological Sciences (IAHS) Publication No. 259, 437 p.
- Horowitz, A.J., 1995, The use of suspended sediment and associated trace elements in water quality studies: Wallingford, United Kingdom, IAHS Special Publication No. 4, IAHS Press, 58 p.
- Horowitz, A.J., Elrick, K.A., and Smith, J.J., 2001, Estimating suspended sediment and trace element fluxes in large river basins: methodological considerations as applied to the NASQAN program: *Hydrological Processes* 15, p. 1,107–1,132.
- Horowitz, A.J., Meybeck, Michel, Idlafkih, Zayed, and Biger, Erwan, 1999, Variations in trace element geochemistry in the Seine River Basin based on floodplain deposits and bed sediments: *Hydrological Processes* 13, p. 1,329–1,340.
- Kolpin, D.W., Skopec, M.P., Meyer, M.T., Furlong, E.T., and Zaugg, S.D., 2004, Urban contribution of pharmaceuticals and other organic wastewater contaminants to streams during differing flow conditions: *The Science of the Total Environment* 328, p. 119–130.
- Larsen, Torben, Broch, Kristen, and Andersen, M.R., 1999, First flush effects in urban catchment area in Aalborg, *Water Science and Technology* 37, p. 251–257.

- Meybeck, Michel, Horowitz, A.J., and Grosbois, C.A., 2004, The geochemistry of Seine River Basin particulate matter: distribution of an integrated metal pollution index: *The Science of the Total Environment* 328, p. 219–236.
- Peters, N.E., and Kandell, S.J., 1999, Evaluation of stream water quality in Atlanta, Georgia and the surrounding region, in Ellis, J.B. (ed.), *Impacts of urban growth on surface water and groundwater quality*: IAHS Publication No. 259, p. 279–290.
- Rose, Seth, and Peters, N.E., 2001, Effects of urbanization on streamflow in the Atlanta area (Georgia, USA): a comparative hydrological approach: *Hydrological Processes* 15, p. 1,441–1,457.
- U.S. District Court, Northern District of Georgia, Atlanta Division, 1998, Civil Action File No. 1:95-CV-2550-TWT.

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<http://ga.water.usgs.gov>
<http://www.usgs.gov>
<http://www.cleanwateratlanta.org>
<http://www.atlantaga.gov>



U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
P. Patrick Leahy, Acting Director



Eleven of the 21 sites for the City of Atlanta monitoring program, such as this one at Woodall Creek, are equipped with streamflow and water-quality instruments that collect and transmit data via a satellite linkup. These data are updated several times a day and displayed on the USGS Web site at <http://ga.water.usgs.gov>. Photograph by Andrew C. Hickey, USGS.



State-of-the-art equipment, such as this acoustic Doppler profiler, is used to measure streamflows. These instruments use sophisticated electronics to determine the speed of the water and to measure the cross section of the stream channel. Photograph by Andrew C. Hickey, USGS.