ABSTRACT

In 2002, the leadership of the City of Atlanta kicked off a comprehensive program to have the cleanest urban streams and rivers in the country within a decade, recognizing that the City’s future economic growth, jobs, affordability, and quality of life all depend on clean water. Atlanta is faced with many obstacles on the way to meeting this challenge; a few of these include:

- Ongoing implementation of court-mandated activities to improve the City’s unique mix of aging combined and separated wastewater infrastructure
- Significant costs and an ambitious schedule associated with this infrastructure upgrade and maintenance
- A dense urban environment which is experiencing major redevelopment activities; from 2000 to 2005 the City increased its population by 6 percent to approximately 445,000 residents and its total housing stock by 11 percent while less than 15 percent of the total City area remained undeveloped in 2003 (Atlanta Regional Commission [ARC], 2003)
- The fact that all of the primary tributaries in the City are currently on the Georgia 303(d) list of impaired streams as partially supporting or not supporting their designated uses of “fishing” (Georgia Environmental Protection Division [GA EPD], 2006)
- The small size/drainage area of the City’s primary waterways, relative to other urban areas in the United States, making them particularly difficult to manage for watershed integrity

The City initiated its Long-Term Water Quality Monitoring Program (LTWMP) in 2003 working with the United States Geological Survey (USGS), a Technical Advisory Committee (TAC), and others to develop an approach that meets the specifications of multiple regulatory programs as well as infrastructure-related Consent Decrees. Specifically, the LTWMP was designed to meet:
• GA EPD guidance for Watershed Assessment and Protection Planning, a National Pollutant Discharge Elimination System (NPDES) wastewater permit requirement in Georgia
• GA EPD’s NPDES Phase I Municipal Separate Storm Sewer System (MS4) monitoring requirements
• Metropolitan North Georgia Water Planning District Watershed Management Plan (District WMP) monitoring requirements (District, 2004)

The City has been collecting water quality data since the fall of 2003 as part of the LTWMP and biological data since 2001 in anticipation of the LTWMP. This information has already proven useful for reporting, site-specific analysis, and identification of hotspots in the City. In anticipation of final NPDES permits being issued for the City’s three Water Reclamation Centers (WRCs), the City recently submitted a Watershed Monitoring Plan to GA EPD to illustrate that the LTWMP meets their Phase I Monitoring requirements for Watershed Assessment and Protection Planning. Upon approval of the Monitoring Plan by GA EPD, the City will proceed with sequential development of the remaining two phases – the Watershed Assessment (Phase II) and the Watershed Protection Plan (Phase III). This manuscript describes the City’s ongoing efforts to implement an adaptive management approach to monitor and manage its watersheds in the challenging environment described above.

KEYWORDS
Water Quality Monitoring, Urban Watershed Management, Combined Sewer Overflows (CSOs), Sanitary Sewer Overflows (SSOs), National Pollutant Discharge Elimination System (NPDES), and Urban Stormwater Management.

INTRODUCTION
Clean Water Atlanta (CWA) is the City’s comprehensive, long-term program to ensure clean drinking water and streams for Atlanta and its downstream neighbors. On October 16, 2002, Mayor Shirley Franklin announced the new CWA initiative and unveiled a Five Point Plan for improving the City of Atlanta’s wastewater system (see Figure 1).

To do this, the City initiated its Long Term Water Quality Monitoring Program (LTWMP) in 2003 working with the United States Geological Survey (USGS), a Technical Advisory Committee (TAC), and others to develop an approach that meets the

Figure 1 - Point Three of the Mayor’s Five Point Plan directs Clean Water Atlanta to “Monitor Water Quality of Atlanta’s Stream and Rivers to Ensure Programs Are Effective.”
specifications of multiple regulatory programs as well as the Consent Decree and First Amended Consent Decree. The LTWMP integrates infrastructure improvement programs such as the Combined Sewer Overflow (CSO) Consent Decree and Sanitary Sewer Overflow (SSO) First Amended Consent Decree with the monitoring required by the City’s wastewater and stormwater permits. This paper describes the City’s ongoing efforts to implement an adaptive management approach to monitor and manage its watersheds.

BACKGROUND

The City of Atlanta is located in north Georgia on the sub-continental ridgeline dividing two of the state’s major drainage basins: the Chattahoochee River Basin to the west and the Ocmulgee River Basin to the southeast (see Figure 2). The Chattahoochee is part of the larger Apalachicola-Chattahoochee-Flint (ACF) River Basin system, which drains south to the Gulf of Mexico through portions of Alabama and Florida. The Ocmulgee drains southeast to the Altamaha River, which flows to the Atlantic Ocean on the Georgia coast. Much of the City drains to the Chattahoochee River via seven small tributaries including Long Island Creek, Nancy Creek, Peachtree Creek, Proctor Creek, Sandy Creek, Utoy Creek, and Camp Creek. The southeast section of Atlanta eventually drains to the Ocmulgee River via the South River and two of its tributaries: Poole Creek and Intrenchment Creek.
The City operates three Water Reclamation Centers (WRCs), all of which discharge to the Chattahoochee River Basin, though one of the WRCs is located in the Ocmulgee (South River) Basin. The SSO program includes the development and implementation of maintenance, operations, and management (MOM) programs, completion of the City’s Capital Improvement Program (CIP) for the sewer system, an aggressive grease management program, the evaluation and rehabilitation of existing sewers, and the planning and implementation of necessary capacity relief projects. The City also currently operates six CSO facilities, including four locations in the Chattahoochee River Basin and two in the Ocmulgee (South River) Basin. The CSO program includes elimination of noncompliant CSO discharges through partial separation of sewers (separation of Greensferry and McDaniel, leaving just four CSO facilities), upgrading WRCs, consolidated storage and treatment, and other measures outlined in the City’s authorized CSO Control Plan. The CSO improvements are scheduled to be completed in November 2007 and the SSO capital improvements are scheduled to be completed by July 2014.

In 1996, the City of Atlanta established the Metro Atlanta Urban Watersheds Initiative (MAUWI) to guide the development of a holistic approach to improving Atlanta’s water quality. Using watershed management principles espoused by the US Environmental Protection Agency (EPA) and environmental groups around the country as a framework, the MAUWI effort was designed primarily to understand what factors influence the watersheds in metro Atlanta and to assist governments, environmentalists, regulators, businesses, schools, and others in protecting and enhancing the watersheds. As part of MAUWI, and prior to the Georgia Environmental Protection Division (GA EPD) releasing its phased watershed planning guidance, the City conducted assessments of the water quality, aquatic habitat, biological communities, and pollutant loadings in the streams. The data analysis concluded that four key elements needed to be addressed if improvements in water quality were to be achieved: minimizing CSOs, improving the wastewater collection system, stormwater management, and stream restoration, including streambank stabilization (CH2M HILL, 1996).

**LONG-TERM WATER QUALITY MONITORING PROGRAM**

The City initiated its LTWMP in 2003 working with the USGS, a TAC, and others to develop an approach that meets the specifications of multiple regulatory programs as well as the Consent Decree and First Amended Consent Decree. Specifically, the LTWMP was designed to meet:

- GA EPD guidance for Watershed Assessment and Protection Planning, an NPDES wastewater permit requirement in Georgia
- GA EPD’s NPDES Phase I Municipal Separate Storm Sewer System (MS4) monitoring requirements
- Metropolitan North Georgia Water Planning District Watershed Management Plan (District WMP) monitoring requirements

The LTWMP 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. Developed and implemented with oversight from a diverse TAC, the LTWMP includes the following main objectives:
• **Assess Baseline Conditions**—The City conducted a comprehensive watershed assessment documenting biotic integrity, habitat conditions, and estimated pollutant loads for all of the major watersheds within the City during 1996 and 1997. The assessment provided information on baseline conditions within the watersheds; however, limited in-stream water quality data were collected and new guidelines have been published by GA EPD. The data collected by the LTWMP will be used to develop a Phase II Watershed Assessment that follows GA EPD’s guidance.

• **Identify Sources of Impairment**—Identifying a specific source of impairment is one of the most difficult aspects of urban watershed management. The LTWMP is useful in identifying sources of impairment by (1) providing real-time flow and water quality data for the current status of all major streams within the City limits, (2) providing a network of data collected that can be used to isolate the location of the impairment(s) within the watershed network, and (3) providing long-term data to evaluate natural fluctuations in water quality conditions over time with respect to seasonal and other natural factors that can influence water quality conditions as compared to actual episodic events contributing to water quality and biotic integrity impairment.

• **Comply with SSO Consent Decree Requirements**—The monitoring network will also be used to track and evaluate the effect that SSOs and other point and nonpoint sources may have on receiving streams within the City. The City is currently under a federal Consent Decree which requires action for expeditious public notice, limited public access to impaired areas, and timely notice to state and federal agencies in response to an SSO event. In addition, the City must administer an Emergency Response Program (ERP) to ensure rapid dispatch of personnel and equipment to SSOs, to ensure preparedness, and to maintain a monitoring, sampling, analysis, and reporting program to address water quality standards.

• **Document Stream Improvement**— Currently, the main stems of most streams within the City on the state 303(d) list as partially supporting or not supporting their designated use. Data from the LTWMP will be used to provide additional information on the status of these streams for meeting their designated uses and current water quality standards. The City is implementing several programs to improve stream water quality conditions, including the CSO Remedial Action Program and the SSO Remedial Action Program. These initiatives should result in measurable enhancements in water quality and the biotic integrity of streams. The LTWMP is designed to collect the data needed to document stream improvements and any pollutant reduction that can be attributed to program implementation.

• **Consolidate Water Quality Program Sampling Requirements** - The City is required to conduct various stream monitoring activities as part of its NPDES stormwater program, and the SSO Consent Decree requirements. The LTWMP integrates and consolidates these program needs by providing more comprehensive, consistent, and long-term data for area streams.

• **Identify New Programs to Address Streams Requiring Further Action**— Watershed management requires a flexible, adaptive approach and the monitoring network is gathering the data necessary to make informed decisions about the direction of the City’s watershed management program.
• **Provide Public Education on Water Quality** – Information from the LTWMP is being made available to the public via the City’s web site (http://www.atlantawatershed.org/bureaus/storm/storm.htm) and the USGS web site (http://ga2.er.usgs.gov/urban/atlanta/). The development of the Phase II Watershed Assessment and Phase III Watershed Protection Plan will provide additional public education opportunities.

**PROGRAM DEVELOPMENT**

For the City of Atlanta LTWMP, sample locations (see Figure 3) were established to capture a large variety of land uses, land use changes, and potential and known sources of water quality degradation. From the results and analysis of historic water quality sampling, a network of monitoring stations was created to make best use of limited resources while establishing the most consistent data set possible. An iterative process involving City staff, USGS, CH2M HILL, and members of the City’s TAC was used to select the original 20 LTWMP stations and develop the sampling plan in 2002. Preliminary results led to the addition of the 21st LTWMP station on Woodall Creek. As illustrated by Figure 3 and Table 1, the LTWMP involves the following components:

- 11 “real-time” water quality and discharge stations
- 2 “real-time” discharge stations
- 8 “intermittent” water quality and discharge stations
- 40 synoptic stations sampled during high- and low-flow conditions
- 21 biological (fish and macroinvertebrate community) stations
Table 1: Summary of Monitoring and Sample Types and Analysis

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Number of Stations</th>
<th>In Situ</th>
<th>Nutrients/Carbon Major Ions</th>
<th>Dissolved Trace Elements</th>
<th>Bacteria</th>
<th>Suspended Trace Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real-time/continuous sampling</td>
<td>11</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Storm event sampling:</td>
<td>11</td>
<td>X X X c</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 storms</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6 storms</td>
<td>X a</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monthly grab sampling</td>
<td>21</td>
<td>X X X X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biweekly ERP sampling</td>
<td>7</td>
<td>X c</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Low-flow synoptic :</td>
<td>43</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X c</td>
<td>X</td>
</tr>
<tr>
<td>Water column</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bed sediments</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-flow synoptic :</td>
<td>43</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X c</td>
<td>X</td>
</tr>
<tr>
<td>Water column</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:

a – Total suspended solids (TSS) as subset of sediment trace elements is analyzed for all storms.
b – A subset of Nutrients & Major Ions, including Conductivity, pH, and nutrients is analyzed for all storms.
c – Fecal coliform and E. coli are sampled, and a geometric mean will be calculated for seven stations from the biweekly ERP samples and the monthly grab samples.

Table 2 lists all of the parameters that are measured by the LTWMP, based on the categories in Table 1. There are multiple water quality parameters that are known to increase and decrease in similar patterns as a result of specific types of watershed influences. The LTWMP was designed to include a suite of parameters that can indicate the same water quality influences as most other parameters that are not included in the program.

Table 2: Summary of Monitored Parameters

<table>
<thead>
<tr>
<th>In Situ</th>
<th>– Temperature</th>
<th>– pH</th>
<th>– dissolved oxygen</th>
<th>– conductivity</th>
<th>– turbidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nutrients/Carbon Compounds/Major Ions</td>
<td>– biochemical oxygen demand (BOD)</td>
<td>– phosphorus (total)</td>
<td>– nitrogen (total Kjeldahl nitrogen [TKN], ammonia, nitrate/nitrite)</td>
<td>– ions: calcium, magnesium, sodium, potassium, fluoride, chloride, bromide, sulfate, bicarbonate</td>
<td></td>
</tr>
<tr>
<td>Dissolved Trace Elements</td>
<td>– metals (Cd, Cu, Pb, Zn)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 2: Summary of Monitored Parameters

<table>
<thead>
<tr>
<th>Bacteria</th>
<th>fecal coliform</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>E. coli</td>
</tr>
<tr>
<td>Suspended Trace Elements</td>
<td>suspended sediment concentration (SSC)</td>
</tr>
<tr>
<td></td>
<td>total metals (Cd, Cu, Pb, Zn)</td>
</tr>
<tr>
<td></td>
<td>arsenic, aluminum, antimony, beryllium, barium, chromium, cobalt, iron, lithium, manganese, mercury, nickel, molybdenum, selenium, silver, strontium, titanium, vanadium</td>
</tr>
</tbody>
</table>

RESULTS

As discussed previously, the LTWMP was designed to meet multiple objectives and to adapt to changing regulatory conditions. Installation of the monitoring network was completed in June 2003, and routine water quality sampling was initiated in August 2003. The two synoptic sampling events were conducted in 2003: high flow synoptic samples were collected between March and June and low flow synoptic samples were collected at the same sites in July. Three biological monitoring events were completed in December 2001, October 2003, and November 2005. Upon approval of the Phase I Watershed Monitoring Plan by GA EPD, the City will move forward with formal analysis of the LTWMP data collected to date during the development of the Phase II Watershed Assessment. However, to date, the LTWMP data have been used for four activities, which are discussed in the following sections.

- Create Web-based Watershed Data Management System (WDMS)
- Conduct NPDES MS4 Stormwater Management Program and Annual Reporting
- Perform Investigative Activities and Adaptive Monitoring and ERP Revisions
- Develop Calibrated Water Quality Model

WDMS:
The City’s WDMS was developed to provide staff with a tool to easily access the results of the LTWMP. The first year of in-situ, event, and biological data collected as part of the LTWMP was input into WDMS after an extensive Quality Assurance/Quality Control process. Using a web interface (see Figure 4), WDMS provides basic maps and information such as the vision, objectives, and approaches of the WDMS. A menu at the left of the screen provides the user with frequently used Web sites for easy access. With appropriate access rights, users can gain access to three major components – Data
Management, Data Analysis, and Data Reporting. Four types of reports are available: station summaries, parameter summaries, date summaries (data export), and outlier reports (CH2M HILL, 2005a).

**NPDES MS4 Stormwater Management Program and Annual Reporting:** WDMS has already been used to provide baseline information for the development of the TMDL portion of the City’s NPDES MS4 Stormwater Management Program. The City was also granted a minor modification to the SWMP related to the City’s two Water Quality Trend monitoring stations. The objective of this specific monitoring task is to “establish the extent of the progress towards the goal of reducing pollutant loads to the receiving waters to the ‘Maximum Extent Practicable’” as specified by the MS4 permit. The original Phase I MS4 Water Quality Trend stations were selected in 1991 based on guidance provided by the Atlanta Regional Commission (ARC) specifying a minimum drainage area of 5 square miles. The modification allowed the City to relocate its two MS4 Water Quality Trend monitoring sites to the nearby USGS-maintained LTWMP monitoring locations. The justification for relocating the MS4 Water Quality Trend monitoring stations is that the information collected at the LTWMP monitoring stations is directly applicable to the assessment of water quality trends in these two watersheds and provides a much more robust data set for evaluation.

**Investigative Activities, including Adaptive Monitoring and ERP Revisions:** Data collected as part of the LTWMP have already been used to identify areas of high pollution potential, or “hot spots,” enabling the City to investigate and address the source. Preliminary results from synoptic sampling triggered further investigation of Woodall Creek, a tributary to Peachtree Creek and the Chattahoochee River, with the City proactively adding one more real-time station to characterize this watershed, which is dominated by industrial land uses.

One of the requirements of the City’s First Amended Consent Decree is the implementation of an ERP to identify and respond to SSOs. Historically, the City was required to sample all SSOs, which generated a significant workload for City staff. As a result of data collected by the LTWMP, the City was able to revise the “Area-wide Monitoring Program and Investigative Approach” of the ERP in 2006 with an investigative methodology custom-tailored to site-specific conditions. ERP sampling now occurs biweekly at 8 of the 21 long-term monitoring stations, representing 75 percent of the total City area, to identify stream segments needing further investigation. The ERP revision included changing the SSO sampling requirements to require the City to sample only “major” SSOs, which are defined as those spills that are over 25,000 gallons or that create water quality violations.

**Figure 5:** Identification of Fecal Coliform Spikes,
The purpose of the “Area-wide Monitoring Program and Investigative Approach” is to provide a routine monitoring program for identification of fecal coliform spikes (see Figure 5 in receiving waters possibly triggering the need for further investigation while avoiding investigations resulting from wet weather nonpoint sources or background conditions. The site-specific threshold, or trigger, levels for fecal coliform bacteria were developed from LTWMP data with a frequency of sampling to ensure that spikes indicative of a wastewater discharge from the City’s collection system are detected. The 90th percentile distribution of historical fecal coliform data for the 8 ERP LTWMP stations is provided in Table 3 as well as the number of sample events represented.

<table>
<thead>
<tr>
<th>LTWMP Station</th>
<th>NAN-1</th>
<th>NAN-3</th>
<th>PEA-2</th>
<th>PRO-1</th>
<th>WOO-1</th>
<th>SAN-1</th>
<th>UTO-1</th>
<th>SOU-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Events Sampled</td>
<td>37</td>
<td>32</td>
<td>33</td>
<td>35</td>
<td>26</td>
<td>36</td>
<td>42</td>
<td>42</td>
</tr>
<tr>
<td>90th percentile (col/100 mL)</td>
<td>48,000</td>
<td>11,000</td>
<td>42,000</td>
<td>21,000</td>
<td>53,000</td>
<td>10,000</td>
<td>27,000</td>
<td>96,000</td>
</tr>
<tr>
<td>Events Exceeding the 90th percentile</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>

The trigger levels will be re-evaluated every 2 years based on LTWMP data with results reported to EPA and GA EPD. As improvements are made to the City’s combined and sanitary sewer systems resulting in decreased volumes and frequencies of treated and untreated wastewater discharges to waterways, the trigger levels may require adjustment to ensure proper sensitivity and effectiveness of investigations.

Water Quality Modeling

As required by GA EPD as part of the Phase II Watershed Assessment, the initial LTWMP data are also being used to develop a water quality model for the City (EPA, 2001). A Technical Memorandum (TM) was developed describing the data inputs and approach for the model and how it can best be used to answer specific questions related to:

- The effects of CSO/SSO infrastructure improvements
- How best to meet Total Maximum Daily Loads (TMDLs)
- The effects of ongoing redevelopment in the City as it relates to improving stormwater runoff through new stormwater management requirements
- The realistic potential for the City to fully meet water quality standards and criteria (CH2M HILL, 2005b)

An HSPF water quality model developed for the District-wide watershed management planning process (Hummel et al., 2003) was used as the base for the development of the more detailed and watershed-specific model for the City of Atlanta watersheds. The data collection phase for the water quality model is now complete and the City has started the process of calibrating and validating the model. Model calibration will proceed in two stages, with hydrological process calibration preceding calibration for water quality. It is critical to have all necessary input and calibration (i.e., observational) data related to a particular process or processes finalized by the
start of calibration, to avoid time-consuming re-calibration. Data collected through the LTWMP provided a robust source of information for validation of this model. The final calibrated and validated model will be used to evaluate future watershed management alternatives.

CONCLUSION

As the results above illustrate, the City of Atlanta continues to diligently work towards having the cleanest urban streams and rivers in the country within a decade, recognizing that the City’s future economic growth, jobs, affordability, and quality of life all depend on clean water. The City recently submitted its Phase I Watershed Monitoring Plan to GA EPD as part of the State’s required watershed planning process. Upon approval of the Watershed Monitoring Plan, the City will complete the Phase II Watershed Assessment within 3.5 years and submit an approvable Watershed Protection Plan within 4 years as indicated by the City’s 3 draft NPDES permits. When used in concert with other City programs such as the Greenway Acquisition Project and initiation of a stormwater funding mechanism, the Watershed Assessment and Protection Plan will provide the City with significant tools to help it meet recently developed TMDLs or to support the development of Use Attainability Analysis(s), if necessary. Initial results of the LTWMP have already proven to be valuable in supporting the City’s adaptive monitoring approach to watershed management. Continued data collection and analysis will help the City to evaluate the effectiveness of its watershed management efforts and to direct future efforts to ensure timely and long-term improvements in water quality conditions within the City’s streams.

REFERENCES


GADNR Environmental Protection Division (GA EPD). (2006). Draft State 305(b)/303(d) List.


