Evaluation of Leaf Collection Programs as a Means to Reduce Nutrient Loads from Urban Basins in Wisconsin

History of the U.S. Geological Survey - Water Resources Division

The Water Resources Division is one of six science mission areas of the U.S. Geological Survey (USGS). Water's mission is to collect and disseminate reliable, impartial, and timely information that is needed to understand the Nation's water resources. The USGS Water Mission Area actively promotes the use of this information by decision makers to --

- Minimize loss of life and property as a result of water-related natural hazards, such as floods, droughts, and land movement.
- Effectively manage groundwater and surface-water resources for domestic, agricultural, commercial, industrial, recreational, and ecological uses.
- Protect and enhance water resources for human health, aquatic health, and environmental quality.
- Contribute to the wise physical and economic development of our Nation's resources for the benefit of present and future generations.

Project Overview

Eutrophication is a common problem for lakes in urban areas. Nutrients entrained in runoff, such as phosphorus and nitrogen, can be contributing factors that lead to eutrophication. The city of Madison, as well as many other regulated municipal separate storm sewer systems (MS4s) around the country, will soon be required to control the amount of nutrients, specifically phosphorus (P), entering surrounding water bodies as part of a Total Maximum Daily Load (TMDL). The TMDL quantifies the amount of P that can be assimilated in a waterbody, identifies the source(s) of P, and recommends regulatory or other actions to be taken to achieve compliance with applicable water quality standards based on the relationship between pollution sources and in-stream water quality conditions.

Numerous studies have identified a variety of potential sources of P and nitrogen (N) in urban settings. Most agree that organic detritus and particulate matter can act as a major source of P and N, especially in urban areas with dense overhead tree canopy (Waschbusch et. al. 1999). Particulate matter can be both a source and sink of nutrients that result from the interaction and imposition of anthropogenic/biogenic activities and urban infrastructure design practices and materials on the hydrologic cycle (Berretta and others, 2011).

In order to meet impending regulation to reduce P loads, MS4s will require information on structural and non-structural Best Management Practices (BMPs) that target organic detritus and particulate matter. Although data on sources of P and N is extensive, few studies have quantified the water-quality benefits of their removal. For example, one way to remove organic detritus and particulate matter before it becomes entrained in runoff is to implement a city-wide leaf collection, terracing or bagging of leaves, and street cleaning program. This option may be preferable to structural BMPs since most cities already conduct some level of leaf collection and street sweeping program and may receive the benefit of phosphorus removal requirements with minor changes to existing practices.

Objectives

The primary objective of this project is to quantify changes in P and N concentrations and load as a result of existing or improved leaf collection practices compared to no practices. Water-quality samples will be collected from four study sites to determine if water-quality benefits are realized by a leaf collection and street cleaning program, and to what extent.

Secondary objectives are:

1. Estimate P and N load that is available for wash-off at each site
2. Characterize seasonal differences in P and N load (if any)
3. Characterize P and N load in suspended and gross solids entrained in runoff

Methods

This study will use a paired basin approach, meaning that data will be collected from four basins for direct comparison. Two basins will serve as the control and will have minimal to no leaf collection program. At this level, the intent is to show what would happen if the city of Madison did next to nothing. No street cleaning would be done so any leaves that fell in the street would stay there. During leaf collection residents would be told they can put leaves in the street if they wished. Data from the two test basins will measure the response of implementing existing and escalated leaf collection and street cleaning programs.

The basis of the paired basin approach is that there is a quantifiable relationship between paired water quality data between the test and control basins, and that this relationship is valid until a major change is made at one of the basins. At that time, a new relationship will exist. This basis does not require that the quality of runoff be statistically the same for the two basins, but rather that the relationship between paired observations of water quality remains the same over time except for the influence of the BMP. Often, in fact, the analysis of paired observations indicates that the water quality is different between the paired basins. This difference further substantiates the need to use a paired basin approach because the technique does not assume that the two basins are the same; it does assume that the two basins respond in a predictable manner together.

The four basins will be defined as follows:

1. Two will have no leaf collection or street cleaning programs except at the start of the equilibration period, or as necessary to appease citizen complaints. These will be the *control* basins.
2. Two will first have a leaf collection and street cleaning program that is currently done throughout the city, and then will add the element of bagging leaves. These will be referred to as the *Existing* and *Escalated* test basins.

Each basin will be monitored for a period of 4 years (table 1). The first year will serve as a calibration period to develop a quantifiable relationship between the control and test basins. All basins will have no leaf control during the calibration period. After the first year, the control basins will maintain no leaf control while the test basins will resume the existing leaf collection program as currently implemented throughout the city. Residents would be discouraged from putting leaves in the streets as they are now. In the third year, both test basins will maximize the effort to reduce leaf-related sources of P and N to urban runoff by implementing an "escalated" leaf collection program. Residents would be supplied compostable paper or plastic leaf bags to store collected leaves. Collection crews would collect the bags, without emptying them, with street cleaning to follow as close as possible (same day). In addition to testing the effectiveness of using collection bags, the city

will be able to survey residents on the merits of paper vs. plastic compostable bags compared to terracing piles of leaves near the curb. Data from the test basins will be compared to data from the control as a means to statistically quantify changes to P and N as a result of each program. The fourth year will serve as an opportunity to collect additional data from any one leaf collection program that may have experienced an unusually dry period. If a sufficient number of precipitation events are represented in each year, then all four basins will once again return back to a no control scenario in the fourth year. The fifth year will summarize and publish the results of the study.

Procedure

Selection of both the control and test basins will focus on limiting external variability that may increase uncertainty in measured data. This will primarily be accomplished by minimizing the drainage area of each study basin. Runoff from each basin will be routed to existing storm drains where a water-quality monitoring station will be placed for collection of water quality and quantity data. Ancillary data will be collected as needed including, but not limited to, precipitation, traffic density, density of overhead tree canopy, estimates of street dirt in lbs/curb-mile, and photo-documentation of unusual or unaccounted sources of error. Approximately 10 water-quality samples will be collected over the duration of a single sample season spanning both fall and spring seasons (September – November; April - June). Each water-quality sample will be composited into a single event-mean concentration. Additional samples will be collected to ensure compliance with normal QA/QC guidelines.

In addition to water-quality samples, a mesh trash net (figure 1) will be placed at the outfall of each storm drain to collect large organic detritus and other gross solids that are too large for collection by normal autosamplers. The mesh nets will be removed for processing after storms of a certain magnitude (to be determined) pass through the study area. City of Madison personnel will collect and transfer each mesh net to a storage facility at the Madison Metropolitan Sewerage District (MMSD) where the contents will be removed, dried, sorted, and weighed by USGS personnel. Estimates of P and N loads will be made based on previously determined P and N concentrations of leaves native to the study area, or values published in peer-reviewed literature, or both. Additionally, street cleaners will collect street dirt load from one or more streets in an area adjacent to each study basin. The contents of the sweeper hopper will be transferred to MMSD for processing similar to the trash nets. Results from the sweeper will be used as an estimate of street load available for wash-off in the study basins.

Figures 2 and 3 identify the geographic location of each study basin.

Data Analysis

Data will be compiled and analyzed by the USGS. All runoff and precipitation data will be stored in the USGS data base and posted on the USGS National Water Information System (NWIS) website as it becomes available. The city of Madison will provide in-kind services to purchase trash nets as well as collect and deliver material contained in the trash nets to a storage facility at MMSD.

Results from both the water-quality samples and debris in the trash nets will be used to create regression relationships for concentrations of P and N between the control and test basins. If the regressions between the control and test basins changes significantly from year to year, the difference will be attributed to a

change in leaf-collection and street cleaning practices. Use on ANCOVA will be used to statistically quantify changes due to changes in treatment.

Products

Results from this study have potential benefits to federal, state agencies with permitting authority or MS4s who have the responsibility to meet permit requirements through TMDLs or other state and federal programs. There will be opportunity for have immediate application to phosphorus load calculations done by Wisconsin's cities. A number of communication/outreach activities will be implemented by the WDNR to insure the cities know about the results of the study. The following is a list of those activities:

- Reports and fact sheets will be available on the WDNR and USGS web sites
- A webinar will be scheduled to present the results of the study. The WDNR will announce the webinar to most cities, counties, and consulting firms in the state.
- Presentations will be made at appropriate national and regional conferences such as ASCE, NASECA, and APWA.
- Instruction on calculations for leaf collection phosphorus reductions will be included in future WinSLAMM workshops.
- WDNR staff reviewing stormwater plans will insure cities are taking advantage of any phosphorus reductions due to leaf collection programs.

The USGS will post real-time water-quantity data on their public website. Water-quality data will also be posted to the public on the website as it becomes available. Additionally, signage will be posted at each monitoring location that describes the study objectives and lists the cooperating partners.

Interim reports will summarize preliminary findings after monitoring of each leaf collection program period (see table 1) is complete. This will be done through an informal data report, powerpoint presentation, or both. At the conclusion of this study, a final report will summarize characterization of P and N concentration and load reductions (if any) through implementation of a leaf-collection and street cleaning program. The format of the report will be a USGS Scientific Investigation Report, a peer-reviewed journal article or a journal article with inclusive supporting data tables.

Timeline

Table 1. Estimated timeline of leaf collection monitoring.

Type of Monitoring	**Type of Program for Test Basins** (Control sites will always be no control)				
	Year 1	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Water Quality	No control	Existing	Escalated	TBD	Report
Gross Solids	No control	Existing	Escalated	TBD	Report
Street Loads	No control	Existing	Escalated	TBD	Report

TBD – to be determined

Budget

The estimated cost to complete this study is $443,500 including in-kind services. Annual project costs are broken down as follows:

Year	Cooperator[1]	FFLM	Yahara Wins	USGS	Madison	Dane Co.	WDNR	Total
2013		$40,000		$39,000	$10,000[2]	$20,000	$25,000	$134,000
2014	$3,000		$20,000	$26,500	$20,000		$15,000	$84,500
2015	$37,500			$25,000	$15,000		$15,000	$92,500
2016	$37,500			$25,000	$15,000		$15,000	$92,500
2017	$8,000			$12,000	$5,000		$15,000	$40,000

[1] The dollar amount needed from additional cooperating partners for successful completion of this study

[2] in-kind services

Capacity to Conduct Project

This project is harnessing the technical and education/outreach expertise of the WDNR, U.S. Geological Survey, Dane County Land Conservation, and the Madison Metropolitan Sewerage District. Representatives from each of these organizations will form the Project Steering Committee. The Steering Committee will provide primary guidance for the project to satisfy project objectives.

The USGS will be responsible for data collection and analysis. The USGS has the expertise necessary to successfully implement nonpoint runoff monitoring programs. They have had decades of experience evaluating the effectiveness of various stormwater best management practices on improving water-quality including street sweeping, low-impact development, rain gardens, and numerous proprietary treatment devices.

Figure 1. Example trash net to collect gross solids entrained in runoff.

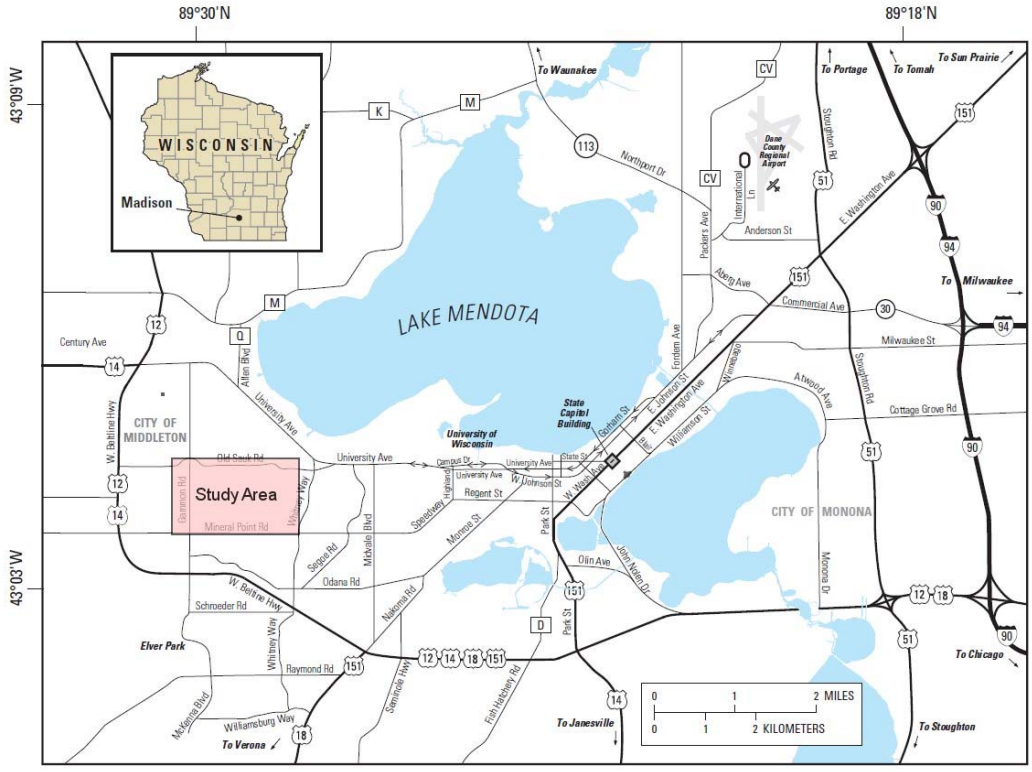

Figure 2. Location of study area, Madison, WI.

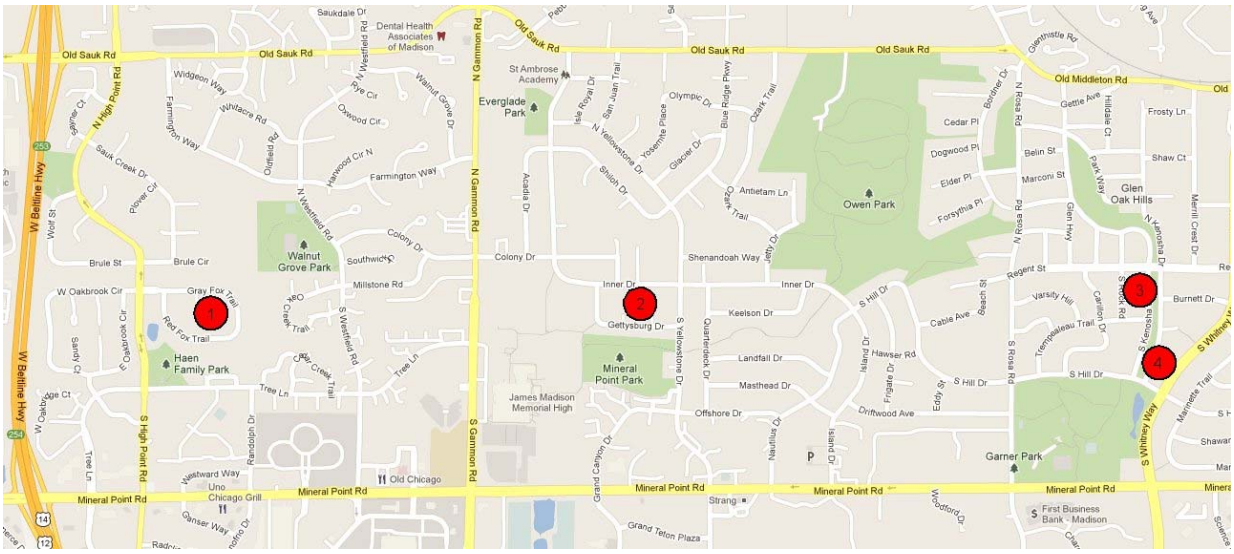

Figure 3. Location of study basins, Madison, WI.

References

Berretta, C., Raje, S., and Sansalone, J., 2011, Quantifying nutrient loads associated with urban particulate matter (PM), and biogenic/litter recovery through current MS4 source control and maintenance practices, Florida Stormwater Association Educational Foundation, Final Report, available online at: http://www.florida-stormwater.org/content.asp?pl=18&contentid=19 (accessed March 29, 2012).

Waschbusch, R.J., Selbig, W.R., and Bannerman, R.T. 1999., Sources of Phosphorus in Stormwater and Street Dirt from Two Urban Residential Basins in Madison, Wisconsin, 1994-95. U.S. Geological Survey, WRIR 99-4021., 47 pp.