WATERSHED SCIENCE BULLETIN

FALL 2010

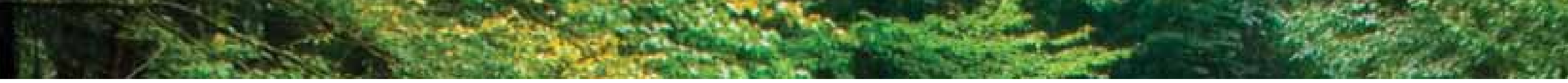
AWSPs
Association of Watershed & Stormwater Professionals

Journal of the Association of Watershed & Stormwater Professionals

A program of the Center for Watershed Protection, Inc.

Total Maximum Daily Loads (TMDLs)

Innovations and Implementation



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8390 Main St. 2nd Floor • Ellicott City, MD 21043 • 410-461-8323 (phone)
410-461-8324 (fax) • www.awsps.org • Bulletin@awsps.org

Watershed Science Bulletin (ISSN: 2156-8545) is the journal of the Association of Watershed and Stormwater Professionals (AWSPs), and is published semi-annually by the Center for Watershed Protection, Inc. (CWP).

KEY CONTACTS:

Co-Editors-in-Chief
Karen Cappiella (kc@cwp.org)
Neely Law (nll@cwp.org)

Associate Editor
Lisa Fraley-McNeal (bulletin@awsps.org)

Sponsorship Coordinator
Erin Johnson (etj@cwp.org)

AWSPs Membership
(membership@awsps.org)

MISSION: The mission of the *Watershed Science Bulletin* (the *Bulletin*) is to synthesize research and experience from the numerous disciplines that inform watershed management and transmit this valuable information to researchers, regulators, practitioners, managers, and others working to protect and restore watersheds everywhere.

POSTMASTER: Please send address changes to the Watershed Science Bulletin address listed above.

SUBSCRIPTIONS AND BACK ISSUES: Subscription is included for AWSPs members as part of member dues. The subscription rate for non-members is $89/year. Single copies and back issues can be purchased for $49 each. For a complete listing of back issues or to purchase a subscription, please visit www.awsps.org.

SUBMISSION: To submit an article, please visit www.awsps.org.

Graphic Design by Down to Earth Design, LLC (d2edesign.com)

Copyediting by Elizabeth Stallman Brown

Printed by the YGS Group, York, PA.

Cover photo courtesy of Bryan Seipp (www.btseippphotography.com), Watershed Manager, Center for Watershed Protection
This photo was taken along Pocono Creek in Monroe County, PA, near Camelback Mountain. Like many streams in Pennsylvania, it is dominated by a forested watershed and provides critical habitat for trout populations. Some tributaries in the Pocono Creek watershed qualify for the highest level of water quality protection under Pennsylvania regulations. Population growth and the resulting urbanization and hydrologic changes are a threat to the health of the watershed.

Monroe County, New York, Field Tests the Watershed Treatment Model 2010 Beta Edition

Paula Smith,[a] Andy Sansone,[b*] and Deb Caraco[c]

The Center for Watershed Protection is continually seeking to test new tools or new applications of tools and incorporate them into our watershed analysis and planning process. We also encourage partner organizations and communities to test the tools that we develop. In this issue of the Bulletin, our first brave volunteers, Andy Sansone and Paula Smith of the Monroe County Environmental Services, tested the Watershed Treatment Model (WTM) in Shipbuilders Creek (SC), a small watershed draining directly to Lake Ontario. Originally released in 2003, we recently updated the WTM, and Andy and Paula have tested the revised version, referred to as the WTM 2010 beta edition. This article describes the WTM 2010 beta edition, details Paula and Andy's bold adventure, and recounts some important lessons learned.

What Is the WTM and How Can I Use It in My (Total Maximum Daily) Life?

The WTM (Caraco, 2002) is a spreadsheet-based, decision-making and pollutant-accounting tool that calculates annual runoff volumes and pollutant loads (including total suspended solids, total nitrogen, bacteria, and total phosphorus) in small watersheds. Since the WTM is a simple modeling tool (i.e., it is not physically based and it calculates on an annual basis), watershed practitioners need to consider when to apply it in a total maximum daily load (TMDL) watershed, and when other, more complex, models may be appropriate.

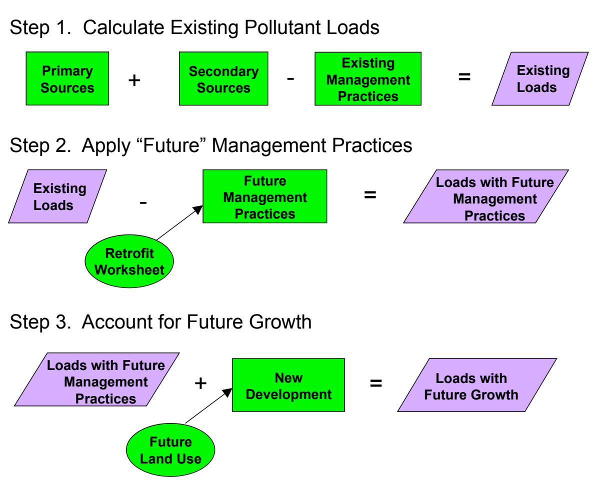

Figure 1. Model structure of the WTM. Note that the purple boxes refer to loads, including both pollutant loads and runoff volumes. The oval shapes are "support" worksheets of the WTM that provide input to another calculation sheet.

When the practices needed to meet the requirements of a TMDL will be costly or widespread, an intense modeling and monitoring effort may save money in the long term. Since the WTM is not a physically based model, it does not have the ability to produce hydrographs that reflect watershed processes and does not reflect seasonal variability. As a result, the WTM may not be the best tool for *developing* TMDLs in these cases. On the other hand, TMDLs increasingly must be developed and implemented rapidly, particularly in small urban or urbanizing watersheds where changing land use requires immediate action. In some cases, even simple surrogates, such as impervious cover (see Arnold et al., this issue), have been used to develop TMDLs. The WTM offers another alternative in these watersheds, allowing the watershed manager to focus in some detail on particular pollutants and to compare a range of treatment options quickly.

Another role for the WTM is as a *tracking tool*. Even for TMDLs that warrant more complex modeling, implementation ultimately happens at the local level. For example, the requirements of a TMDL may be integrated into a municipal separate storm sewer system (MS4) permit. With rare exceptions, local governments are facing tight budgets and need tools that they can implement with existing staff resources. Since the WTM is a spreadsheet, local government staff can maintain it and can update it over time without hiring an outside consultant. One potential application is to populate the WTM with data from an initial monitoring effort, such as pollutant loads and practice efficiencies, then use the WTM to track practice implementation over time.

Some Details about the WTM

The WTM is structured to answer three questions (Figure 1):

- What is the current pollutant load and runoff volume in the watershed?

a Stormwater Specialist, Monroe County Soil and Water Conservation District
b Senior Industrial Waste Technician, Monroe County Department of Environmental Services, Rochester, NY, ASansone@monroecounty.gov
c Water Resources Engineer, Center for Watershed Protection
*Corresponding author

- What is the load or volume with future (i.e., proposed) management practices?
- What is the load or volume after growth occurs in the watershed?

Each component of the figure represents one Excel worksheet that calculates the total load or load reduction.

The major inputs to the WTM (shown in green in Figure 1) include primary pollutant sources, secondary pollutant sources, and management practices (current and future). Primary sources include any pollutant source that can be determined by land use alone, while secondary sources require additional data (Table 1). Many of the secondary sources are individual point sources (such as National Pollutant Discharge Elimination System [NPDES] dischargers), but others are more diffuse, and include sources such as illicit discharges or septic systems.

Table 1. WTM pollutant sources.

Primary Sources	
Residential Land (various densities) Commercial Land Industrial Land Roadway	Open Water Active Construction Rural Land (includes cropland and pasture) Other Land Uses (User-Defined)
Secondary Sources	
Septic Systems SSOs CSOs Illicit Connections Channel Erosion	Livestock Marinas Road Sanding NPDES Dischargers

Notes: CSO, combined sewer overflow; SSO, sanitary sewer overflow.

The WTM accounts for the benefits of management practices in both the "current" and "future" conditions. The WTM is unique in both the range of practices it characterizes and the techniques it uses to estimate their effectiveness. The wide range of practices encompasses nonstructural as well as structural practices, including programmatic measures such as lawn care education (Table 2).

Since ideal (i.e., literature value) load reductions can rarely be achieved with any management practice, the WTM accounts for these deficiencies using a series of *discount factors* to reflect practice implementation. For structural practices, these factors reflect a lack of space or poor maintenance and can hamper practice effectiveness over time. For programmatic practices, they reflect incomplete adoption of the practice by watershed residents. In both of these cases, specific design features (in the case of the structural practices), or outreach techniques (in the case of an education program) can make the practice more or less effective.

Table 2. Management practices in the WTM.

Structural Practices	
Stormwater Treatment Practices (e.g., Ponds and Infiltration)	Stormwater Retrofits Channel Protection
Nonstructural and Programmatic Practices	
Lawn Care Practices Street Sweeping Riparian Buffers Catch Basin Cleanouts	Marina Pumpouts Illicit Connection Removal CSO Repair Septic System Inspection/Repair
Erosion and Sediment Control Lawn Care Education Pet Waste Education	Septic System Education Land Conversion Redevelopment with Improvements

Notes: CSO, combined sewer overflow.

The WTM accounts for the effects of future growth on pollutant loads, using future land use data (derived from a zoning map or other build-out projection) and applying programs that will be in place to control runoff from new development. The resulting load from new development is then added to the "load with future management practices" to calculate the load including growth.

New Updates for the WTM 2010 Beta Edition

Updates to the WTM 2010 beta edition, which we tested for this article, include (1) the incorporation of runoff reduction, (2) a description of the influence of turf and septic systems in more detail, and (3) the addition of a "retrofit worksheet" that allows model users to describe individual stormwater retrofit practices. Accounting for runoff reduction is a critical modification to the WTM because it brings to light the advantages of many low-impact development practices, which would otherwise receive very little credit. Assumptions for calculating runoff reduction were taken from Hirschman et al. (2008).

Example Application: Shipbuilders Creek in Monroe County, New York

Background

Shipbuilders Creek (SC) lies east of the City of Rochester, New York, originating in the town of Penfield and ultimately discharging to the Rochester Embayment of Lake Ontario (Figure 2). SC was elevated to the New York State 303(d) list of impaired waters in 2008, with impairments including high dissolved oxygen demand, phosphorus, pathogens, and silt/sediment. The list notes industrial, municipal, on-site/septic systems, construction, and urban/storm runoff as possible pollution sources.

Figure 2. Shipbuilders Creek watershed, which drains directly to Lake Ontario.

While no TMDL has been developed for SC, New York State's 2010 MS4 permit states that "…if a small MS4 discharges a stormwater pollutant of concern (POC) to impaired waters…the permittee must ensure no net increase in its discharge of the listed POC to that water. By January 8, 2013, permittees must assess their progress and evaluate their stormwater management program with respect to the MS4's effectiveness in ensuring no net increase…" (New York State DEC, 10). In anticipation of this requirement and as a part of a larger master planning effort to improve water quality within the county, a project team that included staff from the Monroe County Department of Environmental Services and the Monroe County Soil and Water Conservation District Monroe County selected the WTM as a modeling tool. The modeling effort described in this article focused on quantifying the benefits of specific management practices in this urban watershed and thus uses steps one and two illustrated in Figure 1.

Developing Model Inputs

A geographic information system (GIS) is an invaluable tool in developing the input data for the WTM, and we were fortunate to have high-quality data layers as well as a GIS unit and well-trained staff. Below, we describe the methods used to develop the model inputs using GIS data layers.

Land Use

The WTM characterizes land use into categories, such as "single-family residential" (at various densities), "commercial," or "forest," and assigns default values of impervious cover and turf cover (as a percentage) for each land use category. While this portion of the model appears simple, the project team found that developing the layers accurately required a multistep process to develop inputs that accurately reflected the watershed.

In the first step, clips were created from GIS layers—such as parcels, soils, roads, sewers, and waterways—to the watershed boundary. The parcel layer included data regarding the property class and parcel size. The property class gave a very accurate description of how the land was being used, allowing us to distinguish the areas of single-family residential from multifamily residential parcels as well as various types of commercial property (Figure 3). Residential parcels were further subdivided into various densities (e.g., high-density versus low-density) based on the parcel size.

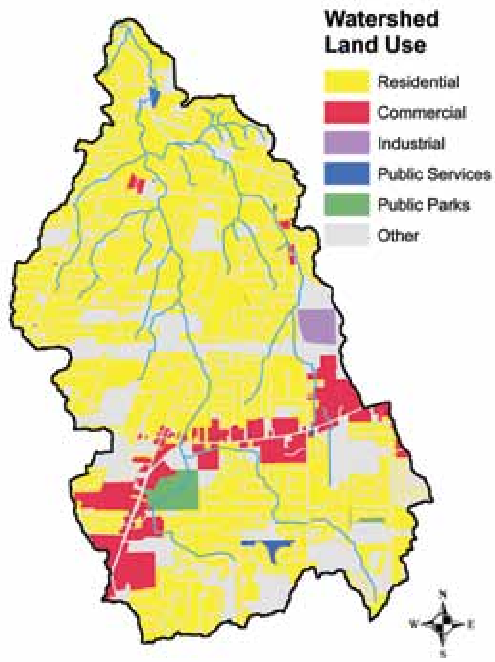

Figure 3. Land use data derived from Monroe County's parcel layer.

The Monroe County Department of Environmental Services also maintains a very high–quality land use/land cover data layer developed from a model using remotely sensed data created from four band ortho imagery and using IDRIS Andes software. The data were extremely helpful, but at first seemed at odds with the land use information derived from the parcel layers. While the imagery data indicated that approximately 30% of the SC watershed was forested, the data developed using WTM standard assumptions and the parcel layer indicated a far lower forest cover. This discrepancy resulted because a number of parcels in the low-density residential category (< 1 dwelling/acre) in the watershed are heavily forested. To resolve this discrepancy, we modified the WTM default of 70% turf cover to 44% turf to provide a more realistic characterization of this land use category.

Soils

The WTM requires soils data, including hydrologic soil group (groups A, B, C, and D), and depth to groundwater. We obtained soil types from existing GIS layers. To determine both the depth to groundwater and the hydrologic soil group, project staff used the US Department of Agriculture Natural Resources Conservation Service's Web Soil Survey, an interactive soil mapping site.

Secondary Sources

Secondary sources in SC included storm sewer overflows (SSOs), septic systems, illicit connections, and channel erosion. The team used known information gathered from field analyses to improve the estimates derived from WTM model defaults. For example, project team members had completed a detailed analysis of illicit connections in the watershed and had conducted stream assessments using the unified stream assessment (USA) technique (Kitchell and Schueler 2005). This integration of known watershed data and model defaults allowed project staff to more accurately characterize these diffuse sources (Table 3).

Table 3. Characterizing secondary sources in Shipbuilders Creek

Source	Model Defaults	Supplemental Data or Confirmation
Septic Systems	Failure rates and effectiveness determined based on soil type, density, system type, and maintenance.	No modifications to defaults. Input data based on known number of customers and detailed knowledge of maintenance policies.
SSOs	Default based on number of SSOs per mile of sewer.	Used defaults and confirmed results based on wet weather flow at WWTPs.
Illicit Connections	Default number per household.	Adjusted to reflect known number of connections based on IDDE field surveys.
Channel Erosion	Monroe County selected a generalized option that characterizes erosion as high, medium, or low.	Characterized as "low" based on stream surveys using the USA

Notes: IDDE, illicit discharge detection and elimination; WWTP, wastewater treatment plant; USA, unified stream assessment.

Structural Stormwater Practices

The WTM requires an assessment of existing practices, including the area draining to each practice type as well as discount factors to reflect practice design, maintenance, and design volumes. Monroe County did not have a single database of stormwater practices and drainage areas, so project staff reviewed aerial photos with storm sewer overlays to determine if developed areas were discharging to stormwater management practices, the type of the practice, the area draining to the practice, and the percentage of impervious cover within the drainage area. While this was time-consuming, good GIS data made it possible. The discount factors reflected staff knowledge of design and maintenance of practices within the watershed.

Residential Turf Management

The WTM estimates loads and runoff volumes from turf based on the area of turf and current turf management practices in the watershed. Some input data include the number of new homes, which typically use more fertilizer than older homes, the number of "highly managed" lawns, and the area of compacted lawns. In addition to accurately calculating the area of turf in the landscape using LIDAR data, we conducted an upland watershed assessment, using techniques similar to the *urban site and subwatershed reconnaissance* described by Wright et al. (2004). Data gathered from these assessments allowed staff to accurately characterize both the area and the condition of turf throughout in the watershed.

Pet Waste Education

The WTM quantifies the effectiveness of pet waste education programs using generalized model defaults that characterize the behavior of pet owners. In the SC watershed, an active educational program is in place, and three professional phone surveys have been conducted in the region that includes SC to measure and track awareness and behavior related to water pollution. Using these survey data, team members modified the WTM's default estimates of pet owner behavior to reflect actual conditions in the SC watershed.

Results

The WTM 2010 beta edition reports loads to groundwater and loads to surface waters separately. The surface loads are then further subdivided into storm and nonstorm loads. In the SC watershed, managers focused on the load to surface waters, assuming that the loads to groundwater do not ultimately reach the receiving water. Table 4 indicates results for phosphorus and bacteria for illustrative purposes. The loads from urban land (i.e., stormwater runoff) dominated the loads for all pollutants. This result is consistent with watershed characteristics since about 75% of the land use in the watershed is residential. The relatively small pollutant loads from active construction reflect the current slow pace of construction.

The project team also evaluated future management practices, including a comprehensive stormwater retrofit program, coupled with some modest, watershed-wide improvements such as increased public educational programs for pet waste and lawn care, repairs and removal of some existing septic systems, and elimination of some illicit discharges. Collectively, these practices would reduce loads of phosphorus and bacteria by 13% and 17%, respectively.

In addition, staff investigated the effectiveness of each practice (Figure 4). While the retrofit program represents 60% of the total load reduction achieved for phosphorus, practices such as illicit connection removal are much more important for bacteria. These results indicate that a combined approach will be needed to address all POCs in the SC watershed.

Table 4. Surface Surface Water Loads (Phosphorus and Fecal Coliform) Before and After Proposed Management Practices

	Total Phosphorus (kg/year)			Fecal Coliform (billion/year)		
	Load Before	Load After	Reduction (%)	Load Before	Load After	Reduction (%)
Urban Land	2,433	2,054	16%	919,641	742,213	19%
Active Construction	14	8	42%	-	-	
SSOs	29	27	8%	291,960	270,063	8%
Channel Erosion	472	463	2%	-	-	-
Rural Land	187	187	0%	22,924	22,924	0%
Livestock	22	22	0%	1,600	1,600	0%
Open Water	3	3	0%	-	-	-
Illicit Connections	44	0	100%	256,238	-	100%
Septic Systems	62	48	22%	32,906	25,886	21%
Total Storm Load	3,090	2,695	13%	1,090,145	901,769	17%
Total Non-Storm Load	176	118	33%	435,124	160,917	63%
Total Load to Surface Waters	3,266	2,812	14%	1,525,269	1,062,686	30%

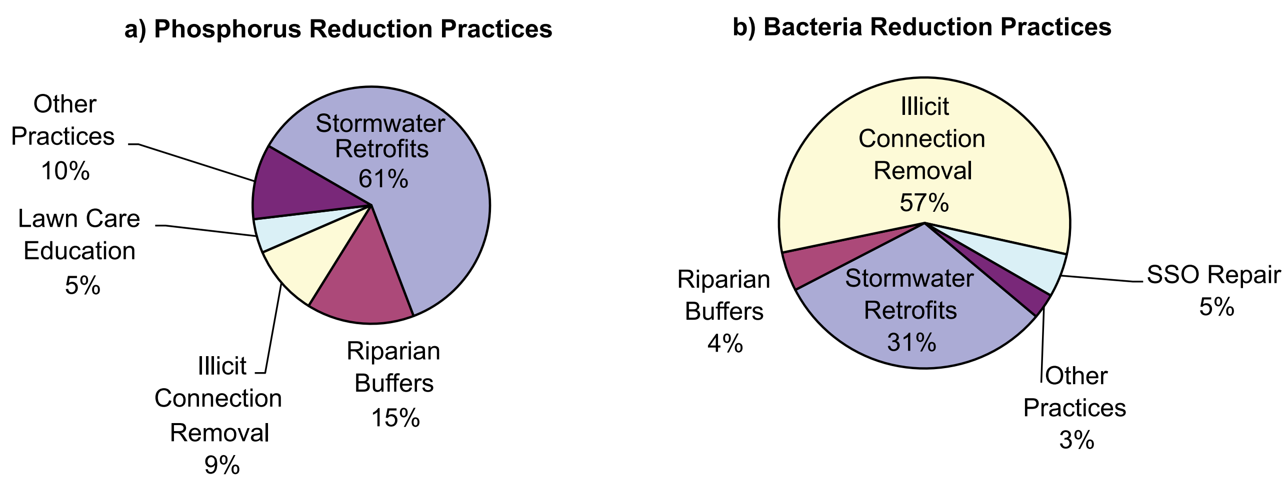

Figure 4. Estimated pollutant removal attributable to various management practices for phosphorus (a) and for bacteria (b).

Next Steps

This initial modeling exercise represents a first step in ongoing watershed planning activities in SC. It also provides an effective demonstration toward future efforts to meet New York State's requirements to model and demonstrate that future growth will not result in an increase in any POC. Along with ensuring no net increase, an additional goal is to improve water quality wherever possible in the most cost-effective manner. Future efforts to support these goals will include the following:

- A detailed build out analysis to examine future growth
- A full retrofit analysis to prioritize and evaluate individual retrofit options
- Cost estimations to compare the cost-effectiveness of various options
- Ongoing surveys and tracking of implementation and land use to continually update the "existing loads" portion of the model

Summary and Lessons Learned

To date, the WTM has proven to be an appropriate and relatively flexible tool for evaluating stormwater treatment options in SC. Key lessons learned include the following:

- Model default data are based on research but should always be adjusted with local data where available.
- While the mapping data required appear relatively simple, the best results are derived from multiple sources (e.g., aerial photography and land cover and land use).
- Good GIS data are needed to successfully use the WTM.
- The WTM is designed to be used hand in hand with field assessment methods, such as stream and upland surveys, and results improve as these data are incorporated.
- One strength of the WTM is that, while data input can be time-consuming, the model can be operated by nonmodelers and retained as a program tool.

Where To Get a Copy

The WTM is posted on the Center for Watershed Protection's website (www.cwp.org) for free download. The WTM 2010 beta edition reflects the authors' knowledge of the best science and incorporates comments from users. The Center is currently incorporating agricultural management practices into the model. In the longer term, the Center intends to create (1) a graphical user interface to ease data input; (2) an interface to import GIS data for land use inputs; and (3) a web-based version of the model to allow for tracking and compilation of progress at a national, regional, or state level.

If you would like to use the WTM, or if you have used it and have questions or comments, please email Deb Caraco at dsc@cwp.org.

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