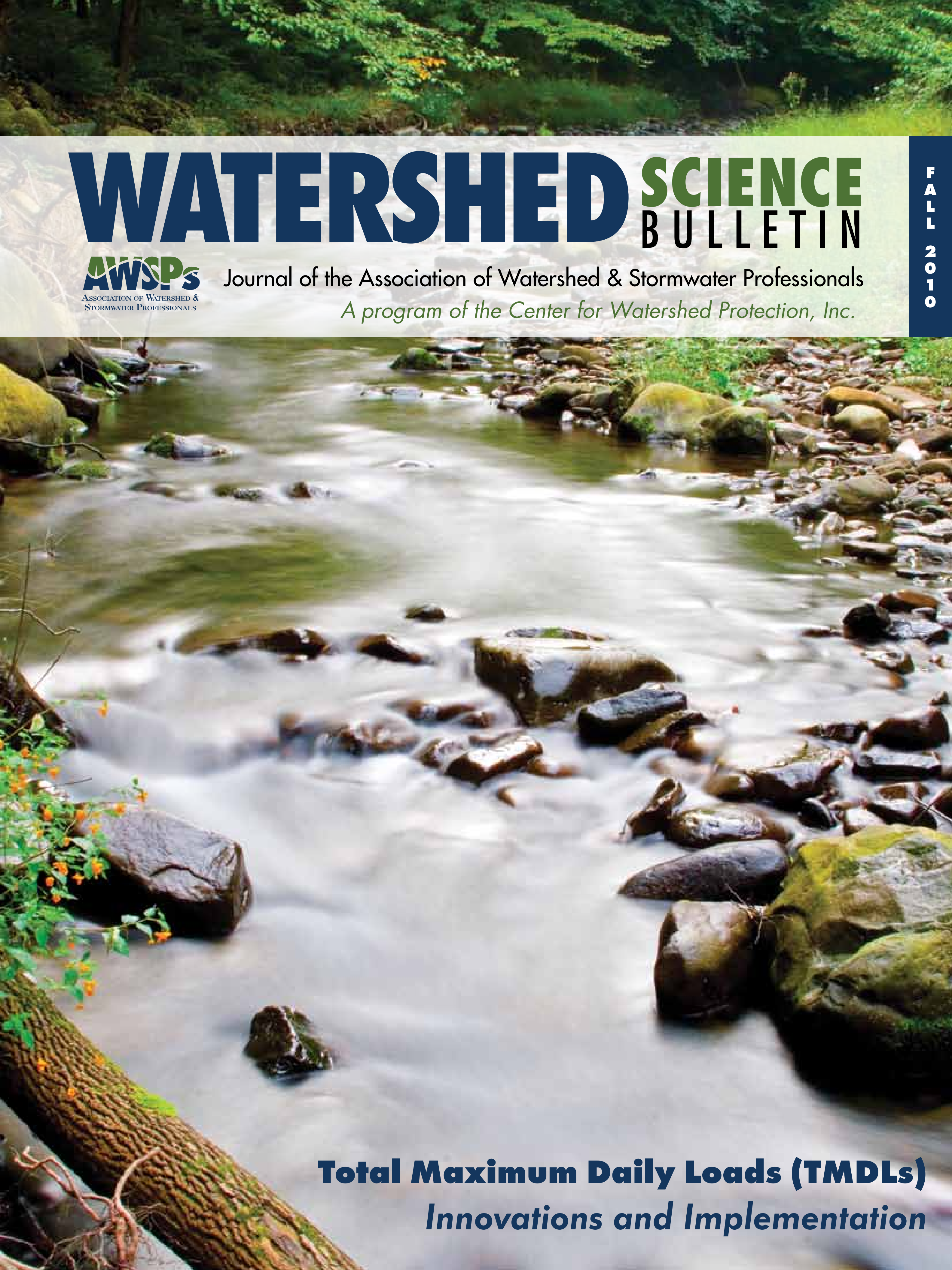


WATERSHED SCIENCE BULLETIN

AWSPs
Association of Watershed & Stormwater Professionals

Journal of the Association of Watershed & Stormwater Professionals

A program of the Center for Watershed Protection, Inc.

FALL 2010

Total Maximum Daily Loads (TMDLs)

Innovations and Implementation

KINGFISHER SPONSOR

Creating Value ...

Baker brings a balanced approach to water resources and floodplain management, facilitating regulatory compliance and environmental protection while implementing sustainable solutions.

Baker is a leader in Integrated Water Resources Management. We use the right tools and methods to address your water challenges.

... Delivering Solutions

Watershed Planning & Management • Water Quality & TMDL Services • Coastal Engineering
Flood Risk Mapping & Management • Floodplain Management • Emergency Management
Program & Project Management • H&H Modeling • GIS • Ecosystem Restoration
Stormwater Management • Source Water Protection • Water Supply • Wastewater Management

Creating value by delivering
innovative and sustainable solutions
for infrastructure and the environment.

Baker

To learn more about Baker's comprehensive services, visit www.mbakercorp.com or contact **Fernando Pasquel** (fpasquel@mbakercorp.com) at 703.317.6219 or **Doug Plasencia** (dplasencia@mbakercorp.com) at 602.798.7552.

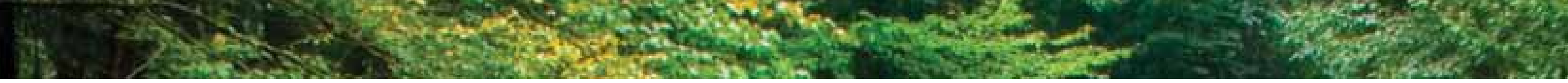


TABLE OF CONTENTS

FEATUREDCONTENT

Exploring Alternatives to Pollutant-Based TMDLs

Integrating TMDLs and MS4 Permits

Adaptive Implementation of TMDLs

Center for Watershed Protection Feature

Vignettes

BULLETINDEPARTMENTS

Bulletin Board

Ask the Experts

Watershed Spotlight

Latest News from AWSPs

Book Review

WATERSHED SCIENCE BULLETIN

AWSPs Journal of the Association of Watershed & Stormwater Professionals

A program of the Center for Watershed Protection, Inc.

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.

EDITORIAL COMMITTEE

GUEST REVIEWERS

CENTER FOR WATERSHED PROTECTION STAFF CONTRIBUTORS

Hye Yeong Kwon, *Executive Director*
Sadie Drescher, *Watershed Planner*
Dave Hirschman, *Program Director*
Laurel Woodworth, *Stormwater and Watershed Planner*

From the Editor's Desk

Welcome to the inaugural issue of the Watershed Science Bulletin! *This journal has been a long time coming, as we at the Center for Watershed Protection have ruminated for years about reviving our well-received journal Watershed Protection Techniques. We decided to launch a new journal that differs substantially from Techniques by featuring peer-reviewed content from researchers and professionals in the watershed and stormwater discipline, rather than using primarily Center-generated content. We strive to find and feature the best work from our colleagues to appeal to a broad range of people who are working or volunteering to protect and improve our watersheds. The Bulletin also serves the members of the Center's newly formed Association of Watershed and Stormwater Professionals, who look to the Center to help translate the research and require easy access to this information.*

We decided to tackle one of the most difficult topics first, since most watershed and stormwater professionals will have to deal with total maximum daily loads (TMDLs) in some way, shape, or form, given that *at least half* of our country's waters are impaired. We quickly learned that, because TMDLs are so complex and because they address watershed issues, it is nearly impossible for one person to be an "expert" in all things TMDL. So we've pulled together an issue that represents the collective expertise in topics such as modeling, monitoring, best management practice (BMP) design, TMDL policy, watershed planning, stormwater permitting, stakeholder outreach, and more. The Bulletin content is tailored to its unique audience—which includes a range of folks from academics to advocates—and contains both peer-reviewed research papers and case studies as well as short "vignettes" to highlight innovative aspects of some TMDL programs that can be transferred to other communities. Perspectives from professionals having extensive experience with TMDLs provide additional context on both the history and the future of TMDLs.

While not applicable for all TMDLs, we at the Center believe strongly in taking a watershed approach to water resource management issues; therefore, we are always seeking opportunities to use watershed planning to meet TMDL implementation goals in order to reduce costs and duplication of effort and to provide other benefits. In its 2008 draft *Handbook for Developing Watershed TMDLs*, the US Environmental Protection Agency (USEPA) lists such benefits as: the ability to prevent future impairments that necessitate the development of new TMDLs, a quantitative linkage between on-the-ground actions and the attainment of water quality standards, and the provision of a framework for implementing other watershed-based source controls, such as watershed-based permitting and water quality trading.

In developing this issue, we found that many questions related to TMDLs spark healthy (and sometimes heated) debate in the watershed community. Below is a selection of the two most pertinent questions and how they are addressed by the enclosed articles and vignettes.

How can we address the challenges of developing TMDLs for urban watersheds?

Stormwater discharges from municipal separate storm sewer systems (MS4s) are treated as point sources in the context of a TMDL, yet this approach does not reflect the variety and number of urban pollution sources, the variety of pollutants associated with these sources, and the complex interactions among watershed variables that ultimately determine water quality at the outfall. This also causes difficulty with translating numeric water quality–based waste-load allocations into National Pollutant Discharge Elimination System (NPDES) permit requirements. A second challenge is that many urban streams are impaired by runoff from portions of the watershed that are not regulated under NPDES permits, making it difficult to enforce implementation. Third, the specific causes of impairment in many urban streams are unknown, and the sources of impairment are biological instead of pollutant-specific, making TMDL development more challenging. Fourth, the TMDL and NPDES stormwater programs have very different structures and political boundaries. Lastly, because states are not explicitly required to account for future urban growth in the TMDL (a symptom of the broader disconnect between land use control and environmental mandates such as TMDLs), it is unknown whether communities will be able to meet the required load reductions under their planned growth scenarios.

Papers by **Arnold et al.** and **Hubbart et al.** in this issue describe TMDLs that use impervious cover and flow, respectively, as surrogates for specific pollutants when the sources of impairment are unknown. In both cases, TMDL implementation involves reducing runoff in the watershed to a certain extent and measuring progress toward improvements by evaluating the instream biological community. **Lindow et al.** provide an example of how one community is using its MS4 permit to help meet its TMDL requirements. Owen et al. also discuss the integration of TMDLs and NPDES, focusing on a collective permitting approach to the problem of meeting TMDL goals in a watershed with urban sources of impairment that are primarily unregulated under NPDES. Similarly, **Thermal Load Trading in the Tualatin River Basin: A Watershed-based NPDES Permit** describes an example in which the MS4 permit provides a mechanism to restore riparian areas throughout both the urban and rural areas of a watershed, as the loss of shade in these areas has significantly contributed to the river's impairment.

What basic level of modeling and monitoring is needed to develop and implement a TMDL?

This is one of the top questions asked by state and local governments and consultants who are tasked with developing and/or implementing TMDLs. Additionally, results with high certainty and low cost are key. Uncertainty exists at all levels of TMDL development and implementation as a result of modeling assumptions and parameter limitations as well as gaps in the data on BMP performance, pollutant loads, and the cumulative effects of implementation on stream health. Little consistency can be found in the type or extent of modeling used in the TMDL process. This is evident from a quick glance through USEPA's 2007 report, *TMDLs with Stormwater Sources: A Summary of 17 TMDLs*. The report lists 30 unique models that were used to develop the 17 TMDLs reviewed in the study; 1 TMDL alone used 7 different models.

An adaptive approach to TMDLs (as recommended by the National Research Council's 2001 report *Assessing the TMDL Approach to Water Quality Management*) has been touted as one way to address the uncertainty inherent in TMDLs in a cost-effective and timely manner. In theory, an effective adaptive implementation approach—sometimes called adaptive management (AM)—allows local governments to immediately begin implementing pollutant reduction measures (usually focusing on measures with known benefits, low cost, and/or high public acceptance), even in the face of uncertainty. Concurrent with implementation, additional data are collected to improve understanding about the causes of impairment and the appropriateness of the TMDL targets and to determine whether the TMDL goals are being met. The results are then used to revise the TMDL if needed or to make adjustments to the implementation plan. An AM approach to TMDL implementation in the Lake Tahoe region is described by **Grismer et al.**, while **Lake Clarity Crediting Program for Lake Tahoe: An Adaptive Management Approach for Water Quality Credits** highlights how the data being collected inform how credits are awarded for restoration actions. One critical piece of the AM approach is to clarify up front what additional information will be collected and how it will be collected and used to revise the TMDL process.

While complex models are often used to develop TMDLs, it may not be practical for many local governments to extend the use of these models to support implementation decision-making and tracking because of their cost and complexity. In addition, most models used for TMDL development are not designed to track pollutant reductions associated with the wide range of activities that may be recommended as part of a TMDL (e.g., street sweeping or education programs). **Smith et al.** and **Lindow et al.** describe the use of a simple spreadsheet model for tracking TMDL implementation that is easy and inexpensive for local governments to use; this model also accounts for load reductions associated with nonstructural BMPs. Another modeling approach that supports decision-making for TMDL implementation and emphasizes cost-effectiveness is illustrated in **Optimizing Resources to Achieve Pollutant Reductions in Wisconsin**. This vignette describes the use of an optimization model to identify the optimal combination of load reduction strategies for the Lower Fox River and Green Bay.

In urban watersheds where surrogates, such as impervious cover or flow, are used as TMDL targets in lieu of specific pollutants, supporting data are required to establish the links among the surrogate metric, pollutants, and stream conditions. **Hubbart et al.** describe a monitoring approach to collecting data that can be used to support and refine a flow-based TMDL. To make the most of limited resources, this monitoring approach was designed to collect data that are scalable and transferable. **Reducing DDT and Sediment Loads in the Yakima River: A Success Story** also illustrates good use of limited monitoring resources, as the parties involved used sediment as a surrogate for DDT based on an established correlation between the two pollutants and the significantly lower cost of monitoring sediment. This example also shows that we are indeed making progress, as an 80% reduction in daily sediment loads was measured after the first four years, allowing the state department of health to lift the fish consumption advisory. We anticipate having a future issue of the Bulletin dedicated to the ongoing discussion about watershed modeling and monitoring.

We hope you enjoy this issue. Thanks for reading!

–Karen Cappiella, *Editor-in-Chief*

Overview: The ABCs of TMDLs

> *A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards.*
>
> (US Environmental Protection Agency n.d.[b])

TMDL Basics

Section 303(d) of the Clean Water Act (CWA) requires each state, territory, and authorized tribe to develop water quality standards for all water bodies under its jurisdiction. This process includes the identification of designated uses (e.g., fishing, swimming, or water supply) for each water body, the definition of numeric or narrative water quality criteria that correspond to these designated uses, and the establishment of provisions to maintain and protect the uses. These jurisdictions must then monitor their waters to identify water bodies or water body segments that are *impaired*, meaning that they are too polluted or otherwise degraded to meet the water quality standards. The cause(s) of each impairment must also be included in the listing. The CWA requires that these jurisdictions develop total maximum daily loads (TMDLs) for their impaired waters (Figure 1). A TMDL, often described as a *pollution budget*, is "a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards," according to the US Environmental Protection Agency (USEPA n.d.[b]), who administers the TMDL program.

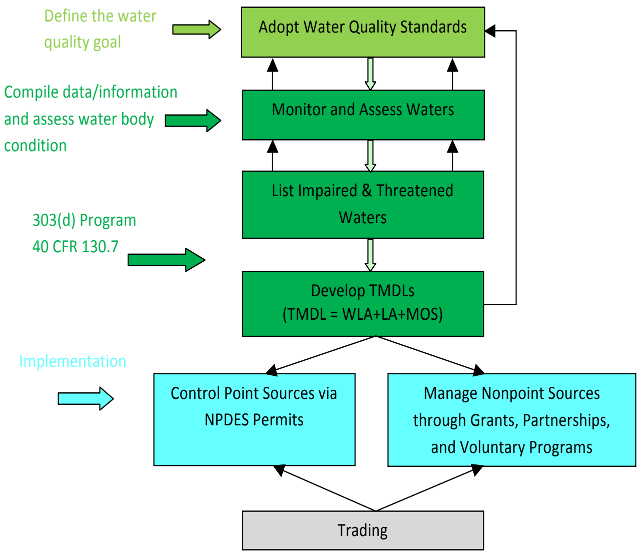


Figure 1. Water quality–based approach of the CWA. (Source: USEPA n.d.[b]) LA, load allocation; MOS, margin of safety; NPDES, National Pollutant Discharge Elimination System; WLA, wasteload allocation.

A TMDL, which also describes how pollutant loads coming from various sources must be reduced to meet the water quality standards, is usually based on modeling, monitoring data, or a combination of both. Each TMDL includes three major components:

1. Wasteload allocations from point sources
2. Load allocations (LAs) from nonpoint sources and natural background conditions
3. A margin of safety (MOS) to account for uncertainty in the various aspects of TMDL development

Typically, a TMDL is developed for a single impaired stream segment. USEPA recently published guidance for the development of watershed TMDLs such that multiple impaired segments within the same watershed can be addressed within a single TMDL. As noted in USEPA (2008, 3), "watershed TMDLs can help states to reduce their per-TMDL costs and address more pollutant–waterbody combinations with the given resources while recognizing a number of environmental and programmatic benefits."

TMDL implementation plans are not specifically required under the CWA, although they are often developed by states as part of the TMDL or as a separate document. TMDL implementation plans describe more specifically the actions needed to meet the required point source and nonpoint source reductions. These actions include a wide range of best management practices as well as the enforcement of more stringent permit requirements for industrial and wastewater discharges, which can be met using enhanced treatment technologies. Typically, implementation falls to the counties, cities, and other municipalities located within the TMDL watershed since these entities are primarily responsible for local land use regulation and implementation of National Pollutant Discharge Elimination System (NPDES) permits.

USEPA encourages the use of water quality trading for certain pollutants where it can help achieve CWA goals. In water quality trading, one entity compensates another entity to reduce a defined amount of pollution. Such trading costs less than the implementation of pollution control measures by the original entity itself and provides the same or greater

Table 1. TMDLs: Who's responsible?

Entity	Responsibilities
USEPA	• Approve or disapprove impaired waters lists and TMDLs • Develop impaired waters lists and TMDLs if states/territories/ tribes are unable to do so • Enforce TMDL program
States, territories, authorized tribes	• Set water quality standards • Monitor water bodies • Develop impaired waters lists • Develop TMDLs • Develop TMDL implementation plan
Municipalities	• Implement TMDLs

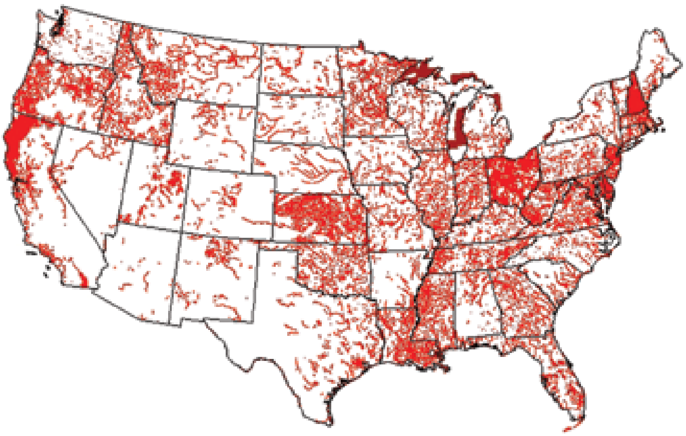


Figure 2. Map of impaired waters in the conterminous United States. (Source: USEPA n.d.[a])

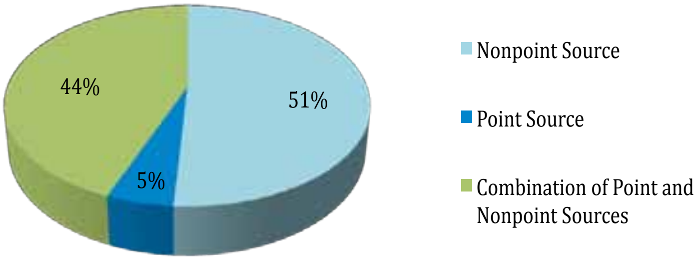


Figure 3. Breakdown of TMDLs by type of pollutant source. (Source: USEPA 2009d)

water quality benefit. Point source facilities with NPDES permits that receive more stringent discharge limits as a result of a TMDL are motivated to seek lower-cost, environmentally equivalent pollutant reductions (USEPA 2004). Thus, trading may be appealing to such facilities.

USEPA is primarily responsible for ensuring that states, territories, and tribes are meeting their TMDL requirements (Table 1). However, enforcement actions undertaken by USEPA are generally limited to those related to regulated point sources because these are pollution sources over which the agency has clear authority under the CWA. Examples of potential enforcement actions by USEPA include taking over state permitting programs, adjusting individual permits or taking state grant funds, limiting or prohibiting new or expanded discharges of pollutants, and making NPDES discharge permits significantly more stringent.

Facts and Figures

According to the latest national summary of state information contained in USEPA's Watershed, Assessment, Tracking and Environmental ResultS database, *at least half* of our nation's assessed streams, rivers, lakes, reservoirs, ponds, bays, estuaries, oceans, and near-coastal waters are threatened or impaired (USEPA n.d.[a]; Figure 2).

As of mid-2009, the national list encompassed over *43,000 impaired waters* with more than *73,000 impairments* (USEPA 2009a). Table 2 provides more detail on the percentage of assessed waters that are threatened or impaired and the top five impairments and probable causes of impairment for the major water body types in the United States (excluding the Great Lakes).

To begin to address these impairments, *more than 37,000 TMDLs* have been developed, according to data collected through EPA's TMDL Program Results Analysis Project (USEPA 2009d). Of these TMDLs, 51% were developed for nonpoint pollution sources, 5% for point sources, and the remaining 44% to address a combination of both types of sources (Figure 3; USEPA 2009d). A review of 100 TMDL documents from across the country generated some additional knowledge about TMDL trends (USEPA 2009c):

- 76% were written to numerical standards, and 24% to narrative standards
- 41% provided significant opportunities for stakeholder involvement

Table 2. Facts and figures on US impaired waters.

Water Body Type	Threatened or Impaired Waters (% of Assessed)	Top Five Impairments	Top Five Probable Sources Contributing to Impairment
Rivers & Streams (miles)	50%	• Pathogens • Sediment • Nutrients • Organic enrichment/oxygen depletion • Habitat alterations	• Agriculture • Unknown • Atmospheric deposition • Hydro-modification • Natural/wildlife
Lakes, Reservoirs, & Ponds (acres)	66%	• Mercury • PCBs • Nutrients • Organic enrichment/oxygen depletion • Metals (other than mercury)	• Atmospheric deposition • Unknown • Agriculture • Natural/wildlife • Hydro-modification
Bays & Estuaries (square miles)	64%	• Organic enrichment/oxygen depletion • PCBs • Pathogens • Mercury • Noxious aquatic plants	• Municipal discharges/sewage • Atmospheric deposition • Unknown • Natural/wildlife • Industrial
Coastal Shoreline (miles)	38%	• Mercury • Pathogens • Metals (other than mercury) • Turbidity • Pesticides	• Unspecified nonpoint source pollution • Natural/wildlife • Urban runoff • Municipal discharges/sewage • Industrial
Ocean & Near-Coastal (square miles)	82%	• Mercury • PCBs • Organic enrichment/oxygen depletion • Pesticides • Pathogens	• Unknown • Atmospheric deposition • Municipal discharges/sewage • Recreational boating and marinas • Hydro-modification
Wetlands (acres)	36%	• Organic enrichment/oxygen depletion • Mercury • Metals (other than mercury) • Habitat alterations • Nutrients	• Agriculture • Unknown • Atmospheric deposition • Industrial • Natural/wildlife

Notes: Top five based on size—for example, mercury is the top impairment for coastal shoreline based on shoreline miles. PCBs, polychlorinated biphenyls.
Source: USEPA n.d.[a]

- 66% included some form of an implementation plan, but only 34% had a plan with specific targets and milestones
- 79% mentioned follow-up monitoring specific to the watershed
- 43% used models of low complexity, 24% used models of medium complexity, and 22% used highly complex models
- Only 6% allocated for future growth

The number of TMDLs that have been implemented, either fully or in part, is not known. To gain insights on implementation, USEPA conducted a sample-based analysis of TMDL implementation rates and characteristics in five states: Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin. This assessment demonstrated that an estimated 80% of TMDLs in this region were at least partially implemented (USEPA 2009b). Full implementation was uncommon. The assessment found no implementation in approximately 20% of the sample (USEPA 2009b). Verification of TMDL implementation at the national, or even state, level can be very difficult because of the diffuse nature of nonpoint source control practices and the often myriad agencies and organizations responsible for managing them.

Evolution of the TMDL Program

Although TMDLs have been required by the CWA since 1972, the program was largely overlooked during the 1970s and 1980s as states focused on reducing point sources of pollution by issuing permits under the NPDES program. During the 1980s and 1990s, citizen organizations began bringing legal actions against USEPA, seeking the listing of waters and the development of TMDLs. This forced USEPA to develop guidance for the TMDL program and, in 1985, the agency issued TMDL regulations that included provisions for nonpoint sources and LAs. The agency also began to take a more aggressive approach towards the program as a result of this litigation.

> *As of mid-2009, the national list encompassed over 43,000 impaired waters with more than 73,000 impairments*

In 1992, USEPA revised the TMDL regulations to require that states submit their listings of impaired waters to USEPA every two years. In 1999, USEPA proposed regulatory revisions to strengthen the TMDL program, based in part on recommendations from a USEPA federal advisory committee. These highly controversial proposed regulations generated more than 34,000 comments during the public input process. USEPA published the final rule in 2000 but later withdrew it.

In 2000, a General Accounting Office report raised concerns about a lack of available data on which to base water quality standards, impaired waters listings, and TMDLs. In response to this report and the 1999 proposed regulations, Congress commissioned a National Research Council (NRC) study to assess the scientific basis of the TMDL program. The NRC panel found that adequate data were available to move forward with the TMDL program but made more than 20 recommendations for improving its foundation.

Today, the TMDL program continues to operate under the 1992 regulations and agreements reached by litigation. Environmental groups have filed lawsuits against USEPA and, in many states, the agency is required by court order or consent decree to ensure that TMDLs are established. Nevertheless, states and other jurisdictions responsible for TMDL development are beginning to change how they approach TMDLs based on some of the recommendations in the NRC study.

–Karen Cappiella,
Center for Watershed Protection

REFERENCES

US Environmental Protection Agency. 2004. Water quality trading assessment handbook: Will trading help you achieve a cleaner watershed? EPA 841-B-04-001. Washington, DC: US Environmental Protection Agency Office of Water.

———. 2008. Handbook for developing watershed TMDLs. Draft. Washington, DC: US Environmental Protection Agency Office of Water.

———. 2009a. Fact sheet: 2002 Impaired waters baseline national geospatial dataset. EPA-841-F-09-005. TMDL program results analysis fact sheet. Washington, DC: US Environmental Protection Agency, Office of Water.

———. 2009b Fact sheet: Analysis of TMDL implementation rates in EPA Region 5. EPA 841-F-09-008. TMDL program results analysis fact sheet. Washington, DC: US Environmental Protection Agency, Office of Water.

———. 2009c. Fact sheet: Summary of EPA's "100 TMDLs Review". EPA 841-F-09-004. TMDL program results analysis fact sheet. Washington, DC: US Environmental Protection Agency, Office of Water.

———. 2009d. Fact sheet: Total maximum daily loads. EPA 841-F-10-001. TMDL program results analysis fact sheet. Washington, DC: US Environmental Protection Agency, Office of Water.

———. No date[a]. National Summary of Impaired Waters and TMDL Information. http://iaspub.epa.gov/waters10/attains_nation_cy.control?p_report_type=T

———. No date[b]. Overview of Impaired Waters and Total Maximum Daily Loads Program. http://www.epa.gov/owow/tmdl/intro.html

Responding to the First Impervious Cover–based TMDL in the Nation

Chester L. Arnold,[a] Christopher J. Bellucci,[b] Kelly Collins,[c] and Rich Claytor[d]*

Abstract

In 2007, the Connecticut Department of Environmental Protection promulgated the first total maximum daily load (TMDL) in the country based on impervious cover. This TMDL, developed as a way to deal with streams impaired by poorly understood urbanization-related impacts, is for Eagleville Brook, a small watershed that drains much of the University of Connecticut campus. What is an *impervious cover TMDL*? This article reviews the status and findings of an ongoing project designed to devise an effective and pragmatic response to this new approach. Using the language in the TMDL itself as a starting point, the project team focused on impervious cover disconnection and the related goal of reducing stormwater runoff volume. However, the "bottom line" of improving biota-based indicators of stream health will also require approaches beyond what would result from a strict focus on impervious cover. Based on geospatial data analysis followed by extensive field work, the project team has identified 51 retrofit opportunities, including a "Top Ten" list that attempts to maximize both the environmental and social or educational impacts of the response. Although the watershed plan has not yet been written, considerable progress has been made on campus, including the replacement of conventional parking lots with pervious materials and changes to plans for upcoming construction. The team's preliminary conclusion is that combining the simple framework of impervious cover with the force and accounting rigor of a TMDL can be an effective way to catalyze communities to plan and implement actions to remediate stormwater problems.

Introduction

Watershed professionals have long recognized that impervious cover is a useful indicator of the impact of watershed land use on the health of the receiving water body (Schueler 2003; Brabec et al. 2002). This relationship integrates a complex web of impacts resulting from urbanization. As an indicator, impervious cover has the potential to be widely applied to various land use planning and design scenarios (Arnold and Gibbons 1996)—an approach that has earned both praise and criticism for its simplicity. The total maximum daily load (TMDL) program mandated by the Clean Water Act, on the other hand, can be said to take quite the opposite approach. It is very site-specific and can be implemented with confidence only when scientific understanding of a particular water body and the fate and transport of specific pollutants within that system is sufficiently comprehensive. This approach, too, has both fans and detractors.

Can these two approaches be wedded successfully? The ongoing Eagleville Brook Impervious Cover TMDL Project, a partnership of the Connecticut Department of Environmental Protection (CTDEP), the University of Connecticut, and the Town of Mansfield, aims to answer this question. This article summarizes the project's progress to date, focusing on project approach and methods rather than technical results.

The Genesis of the Impervious Cover TMDL

Connecticut is an urbanizing state. During the 21-year period from 1985 to 2006, the state added approximately 616 km^2 of land comprising the *development footprint*, as determined by remote sensing land cover data. This represents almost 5% of the entire area of the state (Center for Land Use Education and Research [CLEAR], University of Connecticut n.d.). As might be expected, urbanization is a major cause of water quality impairment in the state. Of the 105 impaired stream segments listed by CTDEP in 2006 as *not meeting water quality standards*, CTDEP attributed this status to urbanization for at least 58%; for another 40%, the agency attributed it to unknown causes (Bellucci 2007).

Under Section 303(d) of the federal Clean Water Act, Connecticut is required to develop TMDLs for these 105 stream segments. But as a practical matter, how does one apply the data-intensive TMDL program to so many water bodies, most of which are suffering from what has been called *urban stream syndrome*, a complex and synergistic combination of hydrologic alteration and multiple pollutant stressors (Walsh et al. 2005)? As Bellucci (2007) notes:

---

[a] *Associate Director, Center for Land Use Education and Research, University of Connecticut, Haddam, CT, chester.arnold@uconn.edu*

[b] *Senior Environmental Analyst, Bureau of Water Protection and Land Reuse, Connecticut Department of Environmental Protection*

[c] *Water Resources Engineer, Center for Watershed Protection*

[d] *Principal, Horsley and Witten Group*

* *Corresponding author*

> *Developing TMDLs for "urbanization" presents an enormous challenge for Connecticut because of the number of impairments and the complicated nature of urban stream syndrome … Often, there is insufficient information that indicates any specific pollutant is causing or contributing to an exceedance of a particular water quality criterion. Rather, given the variability in types and concentrations of pollutants associated with stormwater, and the range in magnitude of storm events, a surrogate approach that aggregates the effects of multiple stressor syndrome is perhaps a more appropriate measure of impact.*

To investigate this hypothesis, in 2005–2006, CTDEP conducted statewide research comparing stream health, as indicated by metrics for benthic macroinvertebrate populations, to watershed impervious cover estimates provided by CLEAR models based on 30-m remotely sensed data (Chabaeva et al. 2007). A total of 125 stream segments were studied, and the results were compelling, if widely in keeping with the literature on the impacts of impervious cover: no stream with over 12% impervious cover in its immediate upstream catchment area met the state's aquatic life criteria for a healthy stream (Bellucci 2007; Figure 1).

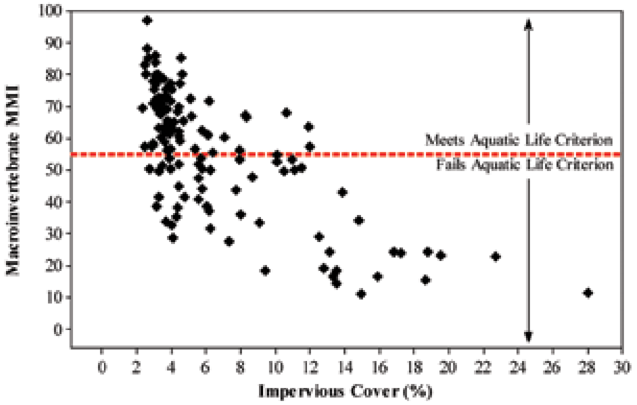


Figure 1. Scatter plot of the percentage of total impervious cover and macroinvertebrate multimetric index (MMI) for 125 stream monitoring locations in Connecticut. The MMI score is the average score of seven metrics and ranges from 0 to 100, with higher values representing the least stressed sites. Sites that plot above the horizontal line meet Connecticut's water quality criterion to support aquatic life.

Based on this result, and the need for a pragmatic regulatory response to urban stream syndrome in the face of insufficient local data, CTDEP developed the nation's first impervious cover TMDL for the Eagleville Brook watershed in Mansfield, Connecticut. The US Environmental Protection Agency approved this TMDL in 2007.

Eagleville Brook is typical of urban stream syndrome—it is included on the 2006 list of Connecticut waterbodies not meeting water quality standards (CTDEP, 2006) based on very low aquatic life use support scores, the causes of which are cited as "unknown." The brook has a 6.2-km^2 drainage area and is tributary to an impoundment of the Willimantic River, a tributary of the Thames River basin, which encompasses much of the eastern third of the state (Figure 2). The Eagleville watershed drains a large portion of the University of Connecticut (hereafter, "the University"), and for long stretches in the upper part of the watershed the brook is piped underground beneath the campus. The watershed surficial material is predominantly glacial till. Rainfall in the region is typical of the state, which has a long-term average of about 114 cm per year, distributed fairly evenly throughout the year (Miller et al. 2002).

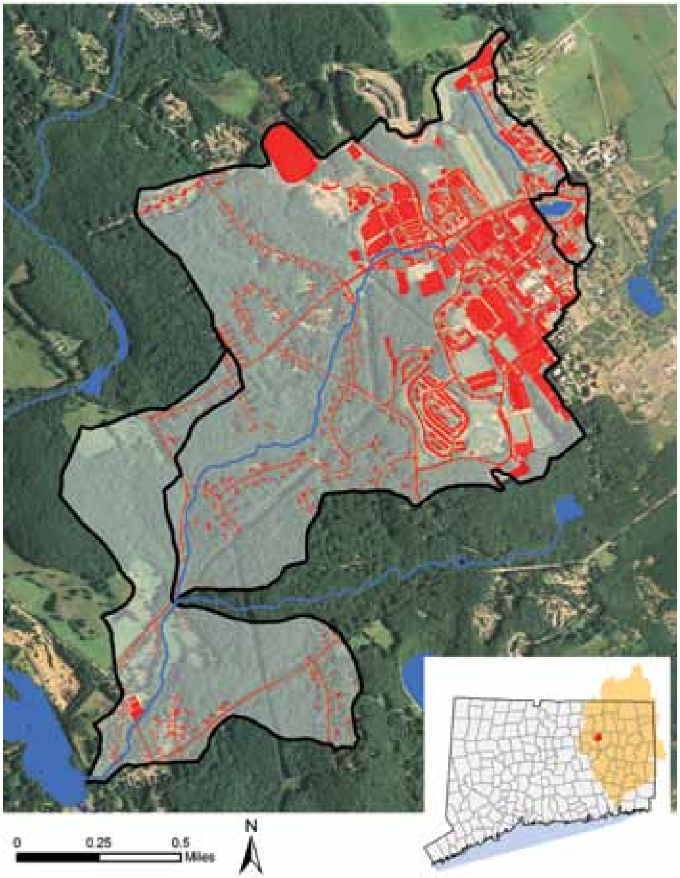


Figure 2. The Eagleville Brook watershed and its location (inset) within the state and within the Thames River major basin. Black lines depict the boundaries of the watershed and subwatersheds, blue lines represent water, and red areas depict impervious cover digitized from 2008 high-resolution imagery, that comprises the map background. The University of Connecticut campus can be seen as the concentration of impervious cover in the upper watershed.

Based on the statewide research, CTDEP set the TMDL target at 12% impervious cover (CTDEP, 2007). Applying a margin of safety factor—and noting that, for this analysis, "it is not feasible to draw a clear distinction between stormwater originating from [National Pollutant Discharge Elimination System (NPDES)]-regulated point sources and non-NPDES regulated sources (point and nonpoint)"—CTDEP (2007, 8) set both the wasteload allocation and the load allocation for this TMDL at 11% impervious cover for the entire basin. Based on the statewide modeling estimates, the three subbasins of the brook varied in impervious coverage from 5% in the lower watershed to 27% in the upper (campus) area (CTDEP 2007).

Interpreting the Impervious Cover TMDL's Bottom Line

Does the impervious cover TMDL constitute a mandate to get out the jackhammers? Not necessarily. The TMDL specifically states that the goal is to have the watershed ecosystem look and act *as if* the watershed were no more than 11% impervious, and it takes pains to remind the regulated community that the bottom line is ultimately not land cover, but stream biology:

> *…[impervious cover] is being used in this TMDL as a surrogate for the impacts that pollutants and other stressors from stormwater have on aquatic life in streams. The goal of the TMDL is to reduce impacts from stormwater on the aquatic life in Eagleville Brook. In the absence of actual [impervious cover] reduction, stormwater management techniques that offset the negative effect of [impervious cover] should be implemented in the Eagleville Brook watershed. Meeting the TMDL will be assessed by measuring the aquatic life directly. Tracking the [impervious cover] elimination/disconnection or equivalent [impervious cover] reduction in the watershed during BMP implementation may be used as an interim measure to assess progress. (CTDEP 2007)*

Thus, the language of the TMDL itself makes clear that this is not a strict acre-by-acre accounting exercise. In fact, we would argue that it lends itself to flexible solutions more readily than does a conventional TMDL. In addition, this approach is in keeping with several strong and emergent themes in watershed management. First, it recognizes the growing consensus that it is *effective* or *connected* impervious cover that should be the focus of remediation efforts, rather than total impervious cover (Booth and Jackson 1997; Brabec 2002). Although the research providing the technical basis for the impervious cover TMDL uses estimates of total impervious cover—the only feasible method given that it was a statewide study—implementation must focus on impervious cover disconnection, and for that, detailed site-level work is necessary. In a recent watershed study, Roy and Shuster (2009) conclude that on-site assessments are necessary to accurately tease apart total impervious cover from directly connected impervious cover, and that parcel-scale field work is needed for the management of suburban and urban watersheds. Our project team's experience corroborates this (see next section).

Second, the impervious cover TMDL can also be seen as taking a *runoff reduction* approach (Hirschman et al. 2008), which places a high degree of emphasis on volume-based hydrologic mitigation as a major method of watershed management (Reese 2009). In Connecticut, the importance of runoff reduction was a key lesson of the Jordan Cove project, a long-term nonpoint source monitoring project comparing runoff quantity and quality before, during, and after construction in paired low-impact development (LID) and conventional watersheds. Notably, that project concluded that the lower pollutant load in the LID watershed, versus that in the conventional watershed, was mainly due to the dramatically lower runoff volume in the LID watershed (Dietz and Clausen 2008).

The Project

Subsequent to the issuance of this unique TMDL, a partnership was formed to determine the overall framework and specific elements of a response. The objectives of this project are twofold: (1) develop a plan for the University and the town to respond to the TMDL and (2) in the process, evaluate the feasibility of the impervious cover TMDL concept and document a general methodology by which others can implement a similar program.

Key elements of the project include: (1) geospatial data gathering and mapping; (2) field work to further refine the mapped information and to identify stormwater retrofit opportunities; and (3) educational and technical assistance to the Town of Mansfield, as well as more general educational efforts intended to help other communities navigate the impervious cover TMDL process. The project team includes the University of Connecticut's CLEAR Nonpoint Education for Municipal Officials Program, the Center for Watershed Protection (CWP), and the Horsley Witten Group.

Data and Mapping

During the winter of 2008–2009, the project team collected all potentially relevant geospatial data. Both the Town of Mansfield and the University have fairly detailed data sets on drainage, roads, and other infrastructure. CLEAR used 2008 high-resolution color imagery to update and correct previously digitized information on impervious cover and its component parts (e.g., roads, rooftops, parking lots, and walkways) on campus, and to digitize impervious cover for the noncampus portion of the watershed (Figure 2). Since the original TMDL estimate was based on a model using 30-m resolution data from 2002,it is not surprising that updated data show an increase in the amount of impervious cover in the watershed (Table 1). In addition, the team used the imagery to update and correct the location of storm drains on campus. The project team used these data not only to refine the original CTDEP estimates of impervious cover, but to formulate preliminary ideas on retrofit opportunities and to help plan the field analysis. All data were placed on an internet geographic information system mapping site, using ArcGISServer® software, to make them easily accessible to the team and, eventually, to the public.

Field Verification and Analysis

In July 2009, the project team conducted a four-day field analysis of the watershed. Field work identified important features that could not be determined from the mapping exercise alone. First, the team identified discrepancies in the original watershed boundary as contained in the state hydrography data layer; the revised watershed boundary was about 0.11 km^2 (26 acres) less than the original. Second, the team estimated that about 0.21 km^2 (51 acres) of the impervious cover in the watershed were effectively disconnected via sheet flow to a large forested area, undetected diversion to another watershed, or through treatment by a recently constructed stormwater practice (Table 1). In addition, although the drain locations had been updated, the data on the location of the pipes themselves were not always up-to-date. In many cases, drainage patterns had been altered multiple times and did not necessarily follow what might be assumed from topography and drain locations.

Table 1. Existing conditions in Eagleville Brook. The original estimates were based on modeling using 2002 land cover data with 30-m resolution.

Eagleville Brook Watershed	Existing Conditions		
	TMDL Estimated	Adjusted and Updated with Imagery[a]	Field-Adjusted[b]
Watershed drainage area, km2 (acres)	4.96 (1,225)	4.96 (1,225)	4.85 (1,199)
Watershed impervious cover, km2 (acres)	0.59 (145)	0.87 (216)	0.67 (165)
Watershed impervious cover , %	11.8	17.6	13.8
11% impervious cover TMDL target, km2 (acres)	0.55 (135)	0.55 (135)	0.53 (132)
Impervious cover to disconnect/manage to reach target, km2 (acres)	0.04 (10)	0.33 (81)	0.13 (33)

[a] The middle column shows additional impervious cover resulting from updates and improvements using 2008 high-resolution satellite imagery. [b] The far right column includes field adjustments that decreased the watershed area by 0.11 km^2, and "removed" 0.21 km^2 of disconnected impervious cover.

Retrofit Opportunities

The project team assessed potential stormwater retrofit opportunities at 51 project sites in the Eagleville Brook watershed, using methods identified by Schueler et al. (2007). Sites were almost entirely located on the University campus, where the dominant fraction of the watershed's impervious cover is found. The Town of Mansfield portion of the watershed is largely rural residential, representing a small amount of the total impervious cover and composed mostly of relatively narrow secondary roads and private rooftops and driveways (see Figure 2). For the town section of the watershed, the focus will be on future development rather than retrofits, emphasizing proactive LID approaches and changes to road standards and maintenance.

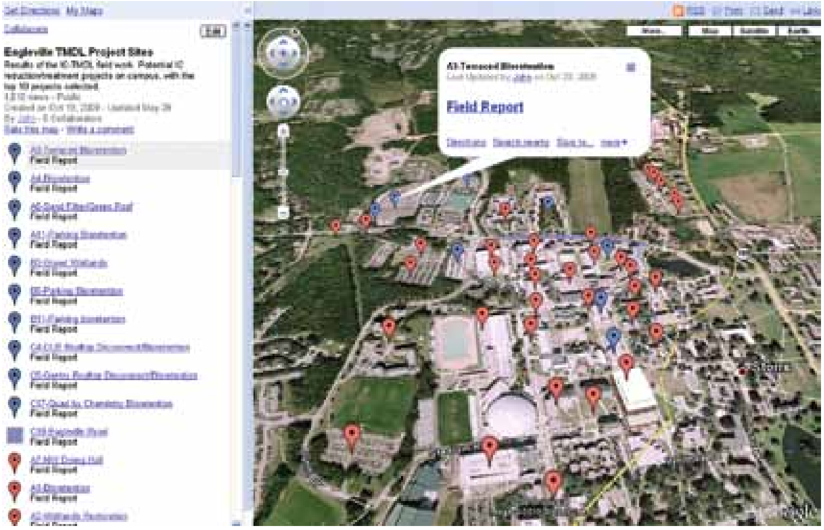


Figure 3. A Google Earth "mashup" from the project website, showing most of the University campus and a portion of the 51 retrofit locations; Top Ten sites are in blue. The markers can be linked to maps, drawings, documents, photos, or other content and will be populated as the project proceeds. IC, impervious cover.

The 51 retrofit opportunities include a variety of stormwater management practices, including rain gardens, bioretention, downspout disconnection, green roofs, swale enhancement, soil amendments, dry swales, porous pavement, cisterns, sand filters, constructed wetlands, floodplain reconnection, impervious cover removal, tree plantings, pervious area restoration, and stormwater planters. CWP and Horsley Witten evaluated each of these opportunities using professional judgment and the following technical factors: impervious area treated, pollutant removal capability, runoff reduction estimates, cost, and maintenance requirements.

The project team as a whole then reviewed the 51 sites with respect to nontechnical factors such as feasibility, educational or demonstration potential, and opportunity (e.g., upcoming plans to repave a parking lot). Out of these discussions came a "Top Ten" list of priority retrofits based on both technical and nontechnical factors (the number ten was determined not by analysis but by the limitations of the work plan). The list does not necessarily reflect the ten retrofits that would remove or disconnect the maximum amount of impervious cover, but rather the projects that, as a package, would have a large impact while creating the greatest momentum on campus for further change. Thus, the list includes a range of retrofit types, geographically spread about campus and applied to different types of land use and impervious cover patterns (e.g., dormitories, academic buildings, and parking lots). As per the project plan, the team created *25% design* conceptual drawings for the Top Ten. We do not necessarily assume that these practices will be built exactly as designed; rather, as construction, renovation, and landscaping take place on a project-by-project basis in the future, they will provide ideas and guidance that will foster creative TMDL implementation.

Project Status and Implementation

At the time of this writing, the project is in transition from the technical phase of the work to the plan writing, outreach, and implementation phase. The retrofit technical report is complete. Work with the Town of Mansfield on land use regulation review and changes will begin during fall 2010 and will be ongoing. The project team will develop educational materials in late 2010, using the project website as a repository for all project information. For instance, Figure 3, taken from the project website, shows a Google Earth–based display of a portion of the 51 retrofit sites, each of which is linked to technical documents, photos, and other information.

At this early stage, much remains to be worked out in terms of implementation strategies. However, three simple but important concepts have emerged. First, implementation will take place during the course of ongoing University and Town of Mansfield activities, as opportunities occur during the design process at the site level. Second, there is general agreement that the impervious cover TMDL approach will extend beyond the boundaries of the Eagleville watershed to other portions of the town and campus. Finally, University and town officials increasingly recognize the enormous role that the maintenance of these practices will play in the ultimate success of the effort. The University has already contracted to develop maintenance manuals for pervious pavements and has purchased new vacuum equipment. Similar manuals for the operation and maintenance of other LID practices will be developed as these practices are put into place.

> *… the growing consensus that it is effective or connected impervious cover that should be the focus of remediation efforts, rather than total impervious cover*

Implementation will be ongoing for the foreseeable future and has, in fact, already begun even before the issuance of the project's final report or the formal TMDL response. In summer 2009, the University repaved two parking lots—one with permeable concrete, and one with permeable asphalt (believed to be the first permeable asphalt parking lot in the state). Plans for extensive remodeling to upgrade the safety sprinkler system of an off-campus graduate housing unit now include plans for pervious parking stalls and rain gardens receiving both road and rooftop runoff. Plans for the construction of a new building in the heart of campus will include a green roof, bioswales, and pervious paving. Although these projects were conceived prior to the determination of the Top Ten, they can be directly attributed to the University's desire to respond to the TMDL.

The consonance of the impervious cover TMDL practices with separate but parallel efforts on campus offers enormous potential. Promising coordination has taken place between the TMDL team and the team developing a landscape master plan for the campus; these plans have many areas of agreement on the use of vegetation, specifically trees, as both aesthetic and stormwater amenities. And in 2007, the University established a sustainable design and construction policy that requires that all new construction and renovation projects costing over $5 million attain a Leadership in Energy and Environmental Design "silver" rating as a minimum standard (US Green Building Council n.d.).

Tracking Progress

One thing yet to be worked out in detail is the project accounting process. Ultimately, the ability to measure progress is a major factor that separates the impervious cover TMDL approach from a simple urban retrofit analysis. Based on the guidance contained in the TMDL language itself and the project team's experience to date, the team envisions that progress will be measured in three tiers:

The amount of impervious cover removed or disconnected. This seems relatively straightforward, and our current estimates show that the 11% goal is more than achievable (Table 2). However, complexities still must be worked out. As one might expect on a large college campus, the results of soil compaction tests performed on many of the pervious areas, particularly large quads and greens, were closer to those of concrete than turf. While the project implementation plan is expected to address this issue (in concert with a campus landscape master plan), to date these areas have not been accounted for in any quantitative tracking system. In addition, no provision yet exists in Connecticut for assigning certain retrofit practices (e.g., pervious paver areas) with partial credit toward disconnection, as has been done in several states (North Carolina Division of Water Quality 2007). Finally, the 11% target was set for the entire watershed, while most of the impervious cover (about 75% of the total acreage) is in one subwatershed containing the campus. Discussions are under way about means of tracking progress at both the watershed and subwatershed levels; this would serve to focus even more attention on the University portion of the watershed.

Improvements in reestablishing a more natural hydrologic regime in Eagleville Brook. The project team has renovated and reactivated an abandoned research weir located on the brook just downstream of the campus portion of the upper watershed, for the purpose of conducting long-term monitoring of streamflow as the TMDL is implemented. In addition, the University has provided funds for monitoring of the runoff from, and flow through, the two new pervious parking lots. Project partners are discussing the value of modeling the runoff reduction effects of the recommended LID practices, both as a predictive tool and to compare to the weir data.

The health of the stream, as indicated by the macroinvertebrate and fish sampling conducted by CTDEP. This ultimate objective is a reminder that, while volume reduction is the primary concern, it should not be the sole focus of the impervious cover TMDL. Thus, the final report and management plan also will include (1) source reduction strategies for likely

Table 2. Estimated progress toward the TMDL target of 11% impervious cover if the recommended retrofits were implemented.

Estimated Result of Retrofit Implementation						
Sites	**Drainage Area Treated, km2 (acres)**	**Impervious Area Treated, km2 (acres)**	**Watershed IC after Implementation km2 (acres)**	**Target IC (11% of watershed), km2 (acres)**	**Watershed IC after Implementation (%)**	**Estimated Cost ($)**
Top Ten Retrofit Sites	0.30 (74)	0.13 (32)	0.54 (133)	0.53 (132)	11.1%	$1,350,000
All 51 Retrofit Sites	0.47 (115)	0.25 (61)	0.42 (104)	0.53 (132)	8.7%	$5,800,000

Notes: The Top Ten retrofits bring the watershed to 11.1% impervious cover, essentially in compliance with the target; implementing all 51 retrofits would far exceed the target, reducing impervious cover to just over 3%. These estimates do not factor in new impervious cover added with additional building or renovations. IC, impervious cover.

"hot spot" areas, like the motor pool; (2) innovative water quality practices, like a gravel wetland; and (3) projects focused on wetlands and/or riparian restoration.

Is It Working?

Based on our experience to date, we believe that the impervious cover TMDL is on its way to success. In the minds of project team members, the acid test is this: *does the impervious cover TMDL make it easier, or more difficult, for a regulated community to develop and implement a response to a TMDL that is likely to improve the health of the water body in question?*

We believe that the impervious cover TMDL makes a response easier, primarily because impervious cover provides a framework that communities can use to assess the problem and make decisions (Arnold and Gibbons 1996). Coupling the impervious cover framework with the regulatory driver of a TMDL provides an approach well-suited to catalyze local action. Certainly, a town manager asked to reduce the effective amount of impervious cover may more easily develop next steps than one who is asked to reduce bacterial concentrations from *a* to *b* and zinc concentrations from *x* to *y*. Although not yet quantifiable, the progress made to date in Eagleville Brook supports this view.

Conclusion

An impervious cover TMDL does require detailed, and often painstakingly acquired, information as its basis. However, one could argue that digitizing parking lots, evaluating storm drains, and conducting soil testing (for example) are more easily understood and achieved than modeling and monitoring a suite of pollutants. So, for those who can marshal the wherewithal to do the field work required, an impervious cover TMDL seems like a viable alternative for urban or urbanizing watersheds. Urban stream syndrome is widespread, and the resources needed to take the traditional, data-intensive, pollutant-by-pollutant TMDL approach are limited. Based on our experience in Eagleville Brook, combining an integrative indicator like impervious cover with an accounting system like a TMDL provides a promising approach for helping communities move in positive directions regarding land use planning and design that is protective of water resources.

More information is available at the project website:

http://clear.uconn.edu/eagleville/Eagleville_TMDL/Home.html

Acknowledgments

The Impervious Cover TMDL Project receives major funding from a Clean Water Act Section 319 nonpoint source grant from the Connecticut Department of Environmental Protection, with additional funding from the University of Connecticut and from the Town of Mansfield.

REFERENCES

Arnold, Chester L., and C. J. Gibbons. 1996. Impervious surface coverage: The emergence of a key environmental indicator. Journal of the American Planning Association 62(2): 243–258.

Bellucci, Christopher. 2007. Stormwater and aquatic life: Making the connection between impervious cover and aquatic life impairments for TMDL development in Connecticut streams. In Proceedings of the Water Environment Federation TMDL Conference, Bellevue, WA. Alexandria, VA: Water Environment Federation, 1003–1018.

Booth, Derek, and C. Jackson. 1997. Urbanization of aquatic systems—degradation thresholds, stormwater detention, and the limits of mitigation. Water Resources Bulletin 33:1077–1090.

Brabec, Elizabeth, S. Schulte, and P. L. Richards. 2002. Impervious surfaces and water quality: A review of current literature and its implications for watershed planning. Journal of Planning Literature 16(4): 499–514.

Center for Land Use Education and Research, University of Connecticut. No date. Connecticut's Changing Landscape: 1985–2006. http://clear.uconn.edu/projects/landscape.

Chabaeva, Anna, James Hurd, and D. L. Civco. 2007. Quantitative assessment of the accuracy of spatial estimation of impervious cover. In Proceedings of the 2007 American Society for Photogrammetry and Remote Sensing (ASPRS) Annual Conference, Tampa, FL. Bethesda, MD: American Society for Photogrammetry and Remote Sensing, 11.

Connecticut Department of Environmental Protection. 2007. A total maximum daily load for Eagleville Brook, Mansfield Connecticut. Hartford, CT: Connecticut Department of Environmental Protection.

Connecticut Department of Environmental Protection. 2006. 2006 Integrated Water Quality Report to Congress, Prepared Pursuant to Federal Clean Water Act Sections 305(b) and 303(d).

Dietz, Michael E., and J. Clausen. 2008. Stormwater runoff and export changes with development in a traditional and low impact subdivision. Journal of Environmental Management 87:560–566.

Hirschman, David H., K. A. Collins, and T. Schueler. 2008. Technical memorandum: The runoff reduction method. Prepared for the US Environmental Protection Agency Office of Wastewater Management. Ellicott City, MD: Center for Watershed Protection and Chesapeake Stormwater Network.

Miller, David R., F. Ogden, G. Warner, and A. DeGaetano. 2002. Precipitation in Connecticut. Special report of the Connecticut Institute of Water Resources. Storrs, CT: University of Connecticut.

North Carolina Division of Water Quality. 2007. Stormwater best management practices manual. Raleigh, NC: North Carolina Department of Environment and Natural Resources.

Reese, Andrew J. 2009. Volume-based hydrology: Examining the shift in focus from peak flows and pollution treatment to mimicking predevelopment volumes. Stormwater, September.

Roy, Allison H., and W. D. Shuster. 2009. Assessing impervious surface connectivity and applications for watershed management. Journal of the American Water Resources Association 45(1): 198–209.

Schueler, Thomas R. 2003. Impacts of impervious cover on aquatic systems. Watershed protection research monograph no. 1. Ellicott City, MD: Center for Watershed Protection.

Schueler, Thomas, D. Hirschman, M. Novotney, and J. Zielinski. 2007. Urban stormwater retrofit practices. Urban subwatershed restoration manual no. 3. Ellicott City, MD: Center for Watershed Protection.

US Green Building Council. No date. Website. http://www.usgbc.org/.

Walsh, Christopher J., A. H. Roy, J. W. Feminella, P. D. Cottingham, P. M. Groffman, and R. P. Morgan II. 2005. The urban stream syndrome: Current knowledge and the search for a cure. Journal of the North American Benthological Society 24(3): 706–723.

TMDLs: Improving Stakeholder Acceptance with Science-Based Allocations

Jason A. Hubbart,[a] John Holmes,[b] and Georganne Bowman[c]*

Abstract

Although mitigating water quality impairment through total maximum daily load (TMDL) implementation can sustain natural resource commodities and development practices, it is challenging. Research-based land use planning can substantially reduce or eliminate error in TMDL decision-making processes while improving stakeholder acceptance. To address water quality issues in the central United States, the Hinkson Creek watershed was equipped with state-of-the-art monitoring instrumentation in 2008. Results from this and similar studies will support future urban development by validating engineering strategies that may overlook land use, topography, and site-specific development constraints.

Introduction

Pollution of streams, lakes, and other surface waters is a greater issue for society than ever before. The successful restoration of water quality in impaired watersheds requires an understanding of the interconnections between hydrology, climate, land use, water quality, ecology, and socioeconomics. Current understanding of these interactions is limited primarily by a lack of innovation, investment, and interdisciplinary collaboration. Pollution from diffuse sources is most often driven by meteorological events (i.e., precipitation). Pollutant loadings from a given watershed are correlated with rainfall volume, infiltration, runoff, and storage characteristics (Novotny and Olem 1994). Hydrologic modification resulting from development can increase or decrease diffuse pollution loads, illustrating the need to quantify the pollutant-transporting mechanism(s) and consider the various pathways by which contaminants may travel from source areas to receiving water bodies. In Missouri, more than 150 water bodies have been identified as impaired or limited for a variety of beneficial uses since 2000. This figure is 15% higher than the national average of 25% freshwater impairment in a given state. This is particularly important considering that Missouri is one of nine central US states that contribute more than 75% of upland nitrogen and phosphorus to the Gulf of Mexico (Alexander et al. 2008).

Given the complexity of climate stochasticity and landscape interactions, not surprisingly, meeting water quality goals such as total maximum daily loads (TMDLs) is a challenge, particularly in rapidly urbanizing watersheds where jurisdictions must also meet the US Environmental Protection Agency's (USEPA) National Pollutant Discharge Elimination System (NPDES) requirements. Often, the information necessary to accurately estimate and model rainfall and runoff relationships and to calculate accurate stormwater flow is not available, making it difficult for stormwater managers to make the best management decisions. Faced with the lack of information and the scope of NPDES program requirements, stormwater managers struggle to predict the effect of local ordinances on water quality and receiving water bodies. While scientifically validated TMDLs can energize a community, the opposite may be true in watersheds implementing mandated TMDLs that lack substantive information, data, and validation. Unfortunately, states under pressure from federal mandates and limited by staff expertise are instituting such incomplete TMDLs. With these complications in mind, this article supplies a possible avenue forward (i.e. science-based decision making) towards ameliorating complex contemporary TMDL allocations.

A common strategy for estimating TMDL allocations for urban watersheds is to use flow as a pollutant surrogate. One method used to calculate a flow-based TMDL, flow duration analysis, is generally intended to set stormwater volume reductions for the impaired stream by estimating predevelopment flow conditions (USEPA 2007a). Unfortunately, the method often fails to account for many local watershed process interactions among topography, soils, development, imperviousness, and legacy effects persisting from previous agriculture and/or development. Addressing such interactions is critical to the quantifiable validation of land use effects on runoff processes (Hibbert 1966; Stednick 1996; Hubbart et al. 2007). As a result of the disconnect, instead of working toward a common objective, state and federal regulators and municipalities vehemently debate the efficacy of volume reductions to achieve water quality standards, the cost of implementation, and the potential harm that single flow criteria could exact on watershed form and function. Recently, the Vermont Department of Environmental Conservation (VT-

---

a Professor of Hydrology and Water Quality, University of Missouri, Department of Forestry, Columbia, MO, HubbartJ@Missouri.edu

b Professional Engineer, Allstate Consultants, LLC

c Stormwater Coordinator, Boone County Public Works

** Corresponding author.*

DEC) established a TMDL wasteload volume reduction requirement of 16% for high flows and an increase of 11.2% for base flow for Potash Brook, an 18.47-km^2 watershed in Vermont (VTDEC 2006). Current estimates to achieve a 16% and 11.2% flow alteration include extensive retrofits at a cost of $25.5 million (VTDEC 2010). Considering the amount of taxpayer investment in TMDL mandates such as Potash Brook, demand is increasing for the thorough evaluation and validation of TMDL estimates prior to implementation. A viable solution lies in formal research methods that result in accurate hydrographs that better reflect local watershed process interactions and thus produce more accurate flow duration estimates.

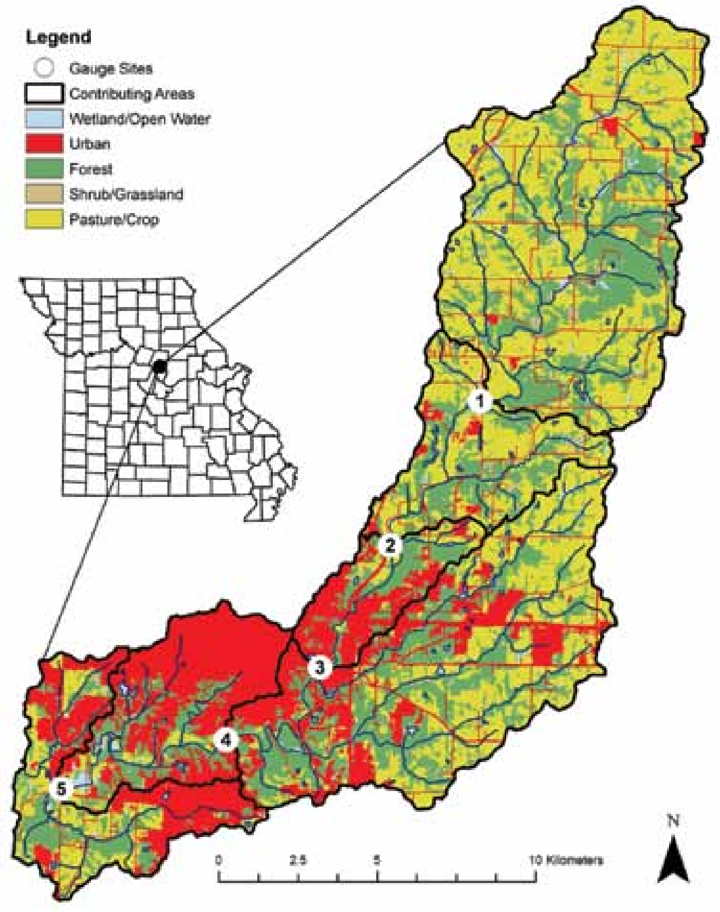


Figure 1. Locations of gauge sites (where #4 includes the USGS gauging station) in the Hinkson Creek watershed in central Missouri, USA. The 16 classes of 30-m resolution land use/land cover defined in the National Land Cover Database (NLCD) 2001 were combined to form the five generalized classes shown here. NLCD 2001 is based on Landsat Thematic Mapper imagery dating from 2001 and was produced by the Multi-Resolution Land Characteristics Consortium, a collaboration among multiple US federal agencies (NLCD 2001).

Hydrograph analysis is one of many methods for analyzing land use, surface runoff and flow relationships (Viessman and Lewis 2003). Methods of hydrograph estimation range from direct measurement (i.e., automated or manual streamflow measurements over time), to model-generated hydrographs (USEPA 2007b) and unit hydrograph methods (Sherman 1932), which synthesize hydrographs from rainfall. Seminal hydrograph work by Seaburn (1969) demonstrated dramatic alterations in urban settings, where runoff was as much as 4.6 times greater than runoff prior to urbanization. Deriving methodologies of hydrograph estimation and synthesis is beyond the scope of this article. However, it is worth noting that direct measurement will almost always result in the most accurate TMDL estimates. While direct measurement is expensive in terms of instrumentation and labor, if a study is designed correctly (e.g., nested-scale and paired watershed study designs; Clausen and Spooner 1993; Hewlett and Pienaar 1973), results are often scalable and transferrable. It is therefore critical to support properly designed regionally representative watershed studies and to avoid scattered investments in various landscapes (i.e., a "shotgun" approach), which can cost millions of taxpayer dollars but never supply the data sets necessary to estimate an accurate TMDL. Projected future increases in urbanization necessitate research investigations to better understand development impacts at the watershed scale (Nowak and Walton 2005; Wolf and Kruger 2010).

An Emerging Case Study: The Hinkson Creek Watershed

The Hinkson Creek watershed (HCW), located within the Lower Missouri–Moreau River basin (LMMRB) in central Missouri (Figure 1), encompasses approximately 231 km^2, ultimately draining to the Missouri River. Urban areas are primarily residential with progressive commercial expansion from the city of Columbia (population 90,000). Land use in the watershed is approximately 34% forest, 38% pasture or cropland, and 25% urban area. The remaining land area is wetland, open, or shrub/grassland areas (Table 1).

The Missouri Department of Natural Resources (MDNR) targeted a portion of the LMMRB as critical for controlling erosion and nonpoint source pollution in 1998 (MDNR 2006). Watershed restoration efforts in the LMMRB were accelerated by mandates of the Clean Water Act (CWA) and subsequent lawsuits. HCW is representative of the LMMRB with respect to hydrologic processes, water quality, climate, and land use and was one of the first water bodies in Missouri to be placed on the CWA 303(d) list. The impaired use for Hinkson Creek is "protection of warm water aquatic life" from unknown pollutants with the source attributed to urban runoff (MDNR 2006, 4). In such cases, it is not uncommon to calculate a reduction in stormwater runoff as a surrogate for any pollutants of concern. USEPA has approved this approach for many states, as supported by the federal rule for TMDL development, 40 CFR 130.2(i). Estimating a TMDL is therefore a reasonable goal in the HCW. However, translating pollutant loading to specific land uses to validate the assumption that reducing flow will reduce pollutants is a difficult task without understanding water and pollutant transport at multiple locations throughout the watershed (Tim and Jolly 1994; Frankenberger et al. 1999). Furthermore, relating aquatic biological health to pollutant loading adds an additional layer of complexity to the task of resolving potential water quality impairment.

To generate data that address these uncertainties while providing a scientific basis for developing the TMDL target, the watershed was equipped with state-of-the-art instrumentation in fall 2008. The project is designed to supply quantifiably validated scalable and transferrable results. Instrumentation is complemented by a US Geological Survey gauging station (USGS-06910230) that has collected data intermittently since 1966. Five fully equipped hydroclimate stations, including the USGS station, are co-located along Hinkson Creek following a nested-scale watershed study design (Figure 1). Each fully automated gauging station monitors water depth, suspended sediment (using laser-based, in situ particle analyzers), and a complete suite of climate variables. Water samples are collected for analyses of total nitrogen (nitrate, nitrite, and ammonia), phosphorus, chloride, pH, and many other constituents. The project, currently in its second successful year, will soon begin to generate the information necessary to produce validated TMDL estimates of the above-listed constituents. With as little as four years of data collection, it is anticipated that the project will generate the information necessary to quantify cumulative effects as well as comparisons of land use types. This information will be used by policy-makers to improve current and future TMDL efforts in the watershed.

Table 1. Cumulative contributing area and corresponding land use areas for each of five hydroclimate gauging sites located in the Hinkson Creek watershed in central Missouri, USA.

Component Sub-Watersheds	Total Area (km2)	Wetland/Open Water (% Area)	Urban (% Area)	Forest (% Area)	Shrub/Grassland (% Area)	Pasture/Crop (% Area)
Site 1	77	2	5	36	2	55
Site 2	101	2	6	36	2	54
Site 3	114	2	11	36	2	49
Site 4	180	2	16	36	1	44
Site 5	206	2	23	34	1	39
Entire HCW	231	2	25	34	1	38

Discussion

Volume-based approaches, a current trend of stormwater management and stream corridor protection, are encouraged by USEPA and the National Research Council (2008) for the mitigation of problems with water quality, instream biota, low flow, groundwater recharge, stream temperature, and channel stability. Volume-based approaches can be more effective than traditional peak flow–based detention because they do not create the extended durations of elevated flow that are typical with traditional detention. However, some of these problems can be exacerbated by poorly designed volume-based solutions. For example, if streamflow during moderately sized events is reduced by increased retention but pollutant loading is not, an increase in pollutant concentration could result. Likewise, if volume reductions are so successful that some stream reaches support flow only during large events, streams could become clogged with debris and sediment.

In a complex watershed such as the HCW, where significant fractions of the watershed have been influenced by agriculture for a century, urbanization for half a century, and ongoing development, it is difficult to predict the extent of stream system adaptations to previous impacts. Although indications of reductions in stream health in highly urbanized HCW subcatchments are clear (MDNR 2006, 2010), no mitigation strategy yet found is likely to restore the health of such streams (Booth et al. 2004). Previous studies indicate that it is not uncommon for streams to have adapted to urbanization that occurred more than 20 years ago (Finkenbine et al. 2000; Henshaw and Booth 2000). Thus, stream systems of the Midwest could have adapted to agricultural activities that have been ongoing for the past century. In that case, reversion of the hydrologic regime to predevelopment conditions could destabilize the stream. Whether this is a wise strategy in contemporary watersheds is worthy of substantial investigation.

In addition, it remains unclear whether a one-size-fits-all flow reduction solution is possible. Some authors (e.g., Brown 2010; McCuen and Davis 2010) have asserted recently that returning to predevelopment runoff conditions to meet TMDL objectives is not as simple as one might assume. Previous studies showed that much can be learned from replicated gauging sites with complementary long-term time series data about land use effects on the hydrologic regime (Hibbert 1966; Stednick 1996; Hubbart et al. 2007). Therefore, the establishment of an urban experimental watershed like the HCW, which encompasses the majority of land uses, will help us to better understand, quantifiably, how urban development is changing the flow regime.

A volume reduction target of approximately 50% was recently set for the HCW in the wasteload allocation (WLA; MDNR 2010). The WLA runoff reduction is required to come from existing urban and developed areas, and the load allocation must come from agricultural and open areas. Although the extent of agricultural and open areas in the basin is more than twice that of urban and developed areas, each type of area is required to contribute approximately half of the total reduction. This is not an unusual approach in developing urban watersheds. Given this scenario, if policies disallowed increased runoff from future development, municipalities would need to find a way to reduce runoff from the existing developed area by 50% to meet the WLA. Therefore, to meet the TMDL requirements, the municipality will need to encourage landowners to retrofit existing development to capture 50% of current runoff volumes. Notably, the 50% volume reduction target for the HCW was set using USGS data alone. The current study is collecting data at multiple sites simultaneously; researchers of the Interdisciplinary Hydrology Laboratory (IHL) of the University of Missouri will use these data to validate and refine the current TMDL target. Published study results will be used by MDNR, Boone County, and the City of Columbia to revise TMDL policy.

Current local (city and county) policies require that developed areas undergoing redevelopment must address stormwater quality and peak flow for newly added impervious area plus a proportion of existing impervious area. Design challenges in reducing runoff include stormwater storage space allocations (i.e., retention facility space), conveyance to treatment facilities, stormwater release rates and timing, maintenance, and design and regulation conflict resolution. These challenges exist both for newly developed sites and for retrofitted sites but are intensified on retrofit projects where constraints are generally more stringent. The National Research Council (2008) recently found that redevelopment primarily occurs in areas that are (a) already challenged by medium to high levels of imperviousness, (b) space limited, and (c) high-value properties. These complexities drive up the costs of stormwater runoff mitigation. It may therefore be argued that holding developers in high-development areas to standards equal to those of *greenfield* (i.e., previously undeveloped) developments is a financial disincentive for redevelopment. Ultimately, without careful planning, stormwater and volume-based reduction requirements may discourage redevelopment in areas where it should be occurring—in already developed urban areas.

…much can be learned from replicated gauging sites with complementary long-term time series data about land use effects on the hydrologic regime

Another design challenge is that not all development situations are appropriate for infiltration mitigation. For example, many of the soils in the HCW and in northern Missouri generally have a relatively strong shrink and swell potential, as shown through an analysis by the Boone County Soil Survey (US Department of Agriculture 1997) and the University of Missouri's Center for Applied Research and Environmental Systems (CARES) watershed evaluation tool (CARES n.d.) for the HCW (HU 1030010206). These sources indicate that 84% of the soils in the HCW are classified as moderate to very limited for use as building sites because of the shrink and swell potential. Therefore, it would be inappropriate to intentionally introduce water into these soils if they are serving as the base for pavement. Based on research reported by North Carolina State University (Hunt and Collins 2008), USEPA (n.d.) acknowledged the need to use an impermeable liner when placing permeable pavement on soils with shrink and swell potential. In general, soils with limited infiltration capacity or a need for impermeable liners could be problematic for flow reduction regulations that assume increased groundwater recharge with increased detention.

Ultimately, without careful planning, stormwater and volume-based reduction requirements may discourage redevelopment in areas where it should be occurring—in already developed urban areas.

Stormwater storage for later use is currently a preferred method for reducing runoff volume. Although this method can be effective, it presents other challenges that limit its applicability to existing development. Challenges include water conveyance to storage and reuse areas, space allocations, and management of the storage volume to maximize the availability of useable water while ensuring that the storage volume is available when a storm event occurs. The challenges are often not insurmountable but, at a policy-making level, the realities of accomplishing significant reductions in stormwater volume are often overlooked. For example, to store the excess stormwater runoff from a water quality design storm of 3.3 cm (1.3 in) for a typical 186-m^2 (2,000-ft^2) home in central Missouri, 22 standard 55-gallon rain barrels would be required. A more reasonable solution might be to use four rain barrels, one at each corner of the house; this setup would allow storage of the excess runoff from a 0.94-cm (0.37-in) storm. This is a worthwhile approach but would not come close to meeting a typical requirement to manage 90% of annual runoff. Ultimately, lacking incentive, relatively few homeowners are likely to install four rain barrels, the barrels may be partially full when storm events occur, and the distribution systems will be far from perfect. Regardless, policy-makers contend that rain barrels will make a significant contribution to achieving a volume-based TMDL. How this would be incentivized has not been resolved.

Problems such as those discussed here are not isolated to the HCW, Missouri, or the United States; instead, they speak to the general potential for excessive optimism regarding the applicability of volume-based flow reduction among policy-makers. Given difficulties in site assessments, development, and flow processes, it is conceivable that inadequately administered TMDLs could result in as many (or more) problems as those that they were created to solve. This further emphasizes the value of properly conducted studies leading to science-based TMDL allocations. The investment in such studies is easily justified by the potential to save millions of taxpayer dollars that might otherwise be wasted on misinformed, unevaluated, and thus ineffective management strategies.

Conclusions

Watershed studies, such as the HCW, using established study design protocols (i.e., nested-scale design) can provide validated data on the relationships between land use, runoff, and water quality to lend support for volume-based TMDLs. Through this and similar studies, state and federal agencies will justify the appropriateness of applying a single volume criterion to an entire watershed or of setting expectations for a return to predevelopment conditions. By means of extensive watershed-scale studies conducted in regionally representative watersheds, scientists can conclusively determine the appropriateness of volume-based approaches and true TMDL pollutant allocations. Because many watersheds have been extensively altered since pre-urban settlement, many urban water bodies have probably experienced a shift in the average magnitude and frequency of high-flow events and pollutant flushing, possibly achieving or approaching new flow and transport equilibria. In watersheds the size of Hinkson Creek, it is imperative that a comprehensive management approach be undertaken to examine not only the volume of water causing impairments, but also the variable-use landscape and the pollution load being transported. In the HCW, this work is timely given the legal mandate to provide quantifiable TMDLs in the watershed. Additional studies will be implemented in the HCW to investigate future management and climate change scenarios. The study is encouraging cooperation, trust, and innovation among watershed stakeholders to reach a common goal of improving and sustaining water quality. In this manner, the HCW serves as a model urban watershed for similar studies.

Acknowledgments

Current funding for the Hinkson Creek watershed project is provided by the US Environmental Protection Agency Region 7, through the Missouri Department of Natural Resources (PN: G08-NPS-17) under Section 319 of the Clean Water Act, and the Missouri Department of Conservation. Collaborators include (but are not limited to) Boone County Public Works, The City of Columbia, The University of Missouri, Allstate Consultants LLC, the US Environmental Protection Agency, and the US Geological Survey. ..

REFERENCES

Alexander, R. B., R. A. Smith, G. E. Schwarz, E. W. Boyer, J. V. Nolan, and J. W. Brakebill. 2008. Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River basin. Environmental Science & Technology 42(3): 822–830.

Booth, D. B., J. R. Karr, S. Schauman, C. P. Konrad, S. A. Morley, M. G. Larson, and S. J. Burges. 2004. Reviving urban streams: Land use, hydrology, biology, and human behavior. Journal of the American Water Resources Association 40(5): 1351–1364.

Brown, T. 2010. Can volume-based stormwater criteria make a difference to receiving stream health? Water Resources Impact 12(2): 5–8.

Center for Applied Research and Environmental Systems. No date. Watershed evaluation and comparison tool. http://ims.missouri.edu/website/watershedtool/selecthu.asp.

Clausen, J. C. and J. Spooner. 1993. Paired watershed study design. EPA-841-F-93-009. Washington, DC: Office of Water, US Environmental Protection Agency.

Finkenbine, J. K., J. W. Atwater, and D. S. Mavinic. 2000. Stream health after urbanization. Journal of the American Water Resources Association 36(5): 1149–1160.

Frankenberger, J. R., E. S. Brooks, M. T. Walter, M. F. Walter, and T. S. Steenhuis. 1999. A GIS-based variable source area hydrology model. Hydrological Processes 13:805–822.

Henshaw, P. C., and D. B. Booth. 2000. Natural restabilization of stream channels in urban watersheds. Journal of the American Water Resources Association 36(6): 1219–1236.

Hewlett, J. D., and L. Pienaar. 1973. Design and analysis of the catchment experiment. In Proceedings: Use of small watersheds in determining effects of forest land use on water quality, ed. E. H. White. Lexington, KY: University of Kentucky.

Hibbert, A. R. 1966. Forest treatment effects on water yield. In International symposium on forest hydrology, ed. W. E. Sopper and H. W. Lull, 527–543. New York: Pergamon Press.

Hubbart, J. A., T. E. Link, J. A. Gravelle, and W. J. Elliot. 2007. Timber harvest impacts on hydrologic yield in the continental/maritime hydroclimatic region of the US In Headwater forest streams, special issue, Forest Science 53(2): 169–180.

Hunt, W. F., and K. A. Collins. 2008. Permeable pavement: Research update and design implications. Publication # AGW-588-14. Raleigh, NC: North Carolina State University Cooperative Extension.

McCuen, R. H., and A. P. Davis. 2010. Sensitivity of BMP system designs to the sustainability objectives defined by predevelopment conditions. Water Resources Impact 12(2): 3–4.

Missouri Department of Natural Resources. 2006. Stream survey sampling report. Phase III. Hinkson Creek stream study, Columbia, Missouri, Boone County. Jefferson City, MO: Missouri Department of Natural Resources, Field Services Division, Environmental Services Program, Water Quality Monitoring Section.

———. 2010. Total maximum daily load (TMDL) for Hinkson Creek, Boone County, Missouri, draft. Jefferson City, MO: Missouri Department of Natural Resources, Water Protection Program.

National Land Cover Database. 2001. National Land Cover Database, Landsat Thematic Mapper (TM), Multi-Resolution Land Characteristics Consortium (MRLC), US.

National Research Council. 2008. Urban storm water management in the United States. Washington, DC: The National Academies Press.

Novotny, V., and H. Olem. 1994. Water quality. Prevention, identification, and management of diffuse pollution. New York: Van Nostrand Reinhold.

Nowak, D. J., and J. T. Walton. 2005. Projected urban growth (2000–2050) and its estimated impact on the US forest resource. Journal of Forestry 103(8): 383–389.

Seaburn, G. S. 1969. Effects of urban development on direct runoff to East Meadow Brook, Nassau County, Long Island, New York. Professional paper 627-B. Washington, DC: US Government Printing Office.

Sherman, L. K. 1932. Stream-flow from rainfall by the unit-graph method. Engineering News-Record 108:501–505.

Stednick, J. D. 1996. Monitoring the effects of timber harvest on annual water yield. Journal of Hydrology 176:79–95.

Tim, U. S., and R. Jolly. 1994. Evaluating agricultural nonpoint source pollution using integrated geographic information systems and hydrologic/water quality model. Journal of Environmental Quality 23:25–35.

US Department of Agriculture. 1997. Soil Survey of Boone County, Missouri. Developed by the Natural Resources Conservation Service in cooperation with MDNR, Missouri Agricultural Experiment Station and the United States Department of Agriculture, Forest Service. Washington, DC: Natural Resources Conservation Service.

US Environmental Protection Agency. 2007a. An approach for using load duration curves in the development of TMDLs. EPA 841-B-07-006. Washington, DC: US Environmental Protection Agency.

———. 2007b. Total maximum daily loads with stormwater sources: A summary of 17 TMDLs. EPA 841-R-07-002. Washington, DC: US Environmental Protection Agency.

———. No date. National menu of stormwater best management practices: Pervious concrete pavement fact sheet. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/.

Vermont Department of Environmental Conservation. 2006. Total maximum daily load to address biological impairment in Potash Brook (VT05-11), Chittenden County, Vermont, October 2006. Waterbury, VT: Vermont Department of Environmental Conservation.

———. 2010. Annual report on the management of stormwater impaired waters in Vermont. State fiscal year 2010. Waterbury, VT: Vermont Department of Environmental Conservation, Agency of Natural Resources.

Viessman, W., and G. L. Lewis. 2003. Introduction to hydrology. 5th ed. Upper Saddle River, NJ: Pearson Education Inc.

Wolf, K. L., and L. E. Kruger. 2010. Urban forestry research needs: A participatory assessment process. Journal of Forestry 108(1): 39–44.

Collaboration, Clean Water Act Residual Designation Authority, and Collective Permitting: A Case Study of Long Creek

Dave Owen,[a] Curtis Bohlen,[b] Peter Glaser,[c] Zach Henderson,[d] and Christopher Kilian[e]*

Abstract

Water quality degradation in urban watersheds is a pervasive problem, and many urban waterways fail to attain water quality standards set pursuant to the Clean Water Act. Finding mechanisms to close this gap has proven difficult. As traditionally implemented, none of the Clean Water Act's primary mechanisms for addressing urban water quality has offered consistent and effective solutions. This article discusses an innovative effort to develop an alternative approach. To address degradation of Long Creek, a small urban stream in southern Maine, regulators used the residual designation authority created by Section 402(p) of the Clean Water Act to substantially expand the number of landowners required to obtain stormwater permits. Concurrently, regulators, local governments, local businesses, and other participants in a collaborative planning process developed a collective permitting approach, which should substantially reduce the economic cost of fulfilling the new permit obligations. The initiative holds promise as a model for restoration of other urban watersheds.

Introduction

According to a growing body of scientific research, urban[1] waterways are pervasively degraded (National Research Council 2008). Particularly in small watersheds, a confluence of stressors typically elevates pollutant concentrations, increases variation in flows and temperatures, changes stream morphology, and reduces native biodiversity—a combination of symptoms often referred to as *urban stream syndrome* (Walsh et al. 2005). Many of those stressors are ultimately traceable to the movement of stormwater across urban landscapes, and the development of impervious surfaces—roads, parking lots, and roofs, primarily—appears to play a particularly important role. Even sparse development adversely affects waterways. Suburban-fringe development densities commonly correspond with watershed impairment and, at higher densities, degradation is almost always present. Consequently, most, if not nearly all, urban streams have impaired water quality, and many larger water bodies are similarly impacted (National Research Council 2008; Center for Watershed Protection 2003).

This pervasive impairment of urban waterways creates legal challenges. The Clean Water Act requires states to set water quality standards for all waterways, and most states' standards are stringent enough to support fishing and contact recreational use (Shabman et al. 2007). But few urban streams actually meet those standards. And while the Clean Water Act ostensibly requires the attainment of water quality standards, regulators and watershed groups have often struggled to find effective mechanisms for moving beyond problem identification and actually achieving watershed protection and restoration (Owen forthcoming).

This article discusses one innovative effort to address those challenges. To spur the restoration of Long Creek, a small urban stream in southern Maine, the Conservation Law Foundation (CLF), a New England–based environmental advocacy organization, invoked a previously obscure provision of the Clean Water Act. CLF argued, and the US Environmental Protection Agency (USEPA) agreed, that the act's residual designation authority provision requires permitting for any landowner with an acre or more of impervious cover in the watershed (CLF 2008; USEPA 2008). In response to CLF's petition, regulators, local communities, and businesses developed a collective permitting program that should allow for compliance with the Clean Water Act's requirements and restoration of the stream at a fraction of the cost of individual permits. The actual physical restoration process is now just beginning, but participants hope that they are creating a model approach to stormwater discharge permitting and ultimately to urban stream restoration.

The Long Creek Process

Long Creek is a small, sandy-bottomed stream that flows through coastal southern Maine (Figure 1). The creek's main-

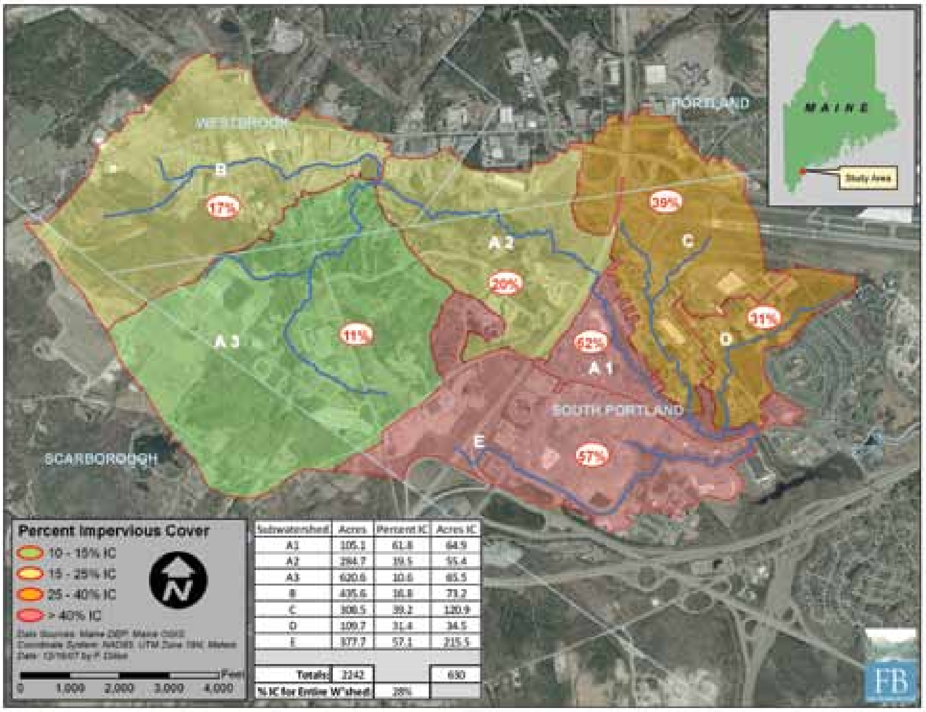
---

[1] In this article we use the term urban broadly to refer to any developed landscape.

a Associate Professor, University of Maine School of Law, Portland, ME, dowen@usm.maine.edu
b Director, Casco Bay Estuary Partnership
c J.D. (2010), University of Maine School of Law
d Watershed Scientist, Woodard & Curran, Inc.
e Director, Clean Water and Healthy Forests Program, Conservation Law Foundation
** Corresponding author.*

Professor Owen's research for this article was supported in part by National Science Foundation award EPS-0904155 to Maine EPSCoR at the University of Maine

stem is just over 6 km long, with several smaller tributaries. The total watershed area is approximately 9 km^2 (FB Environmental Associates 2009). Long Creek discharges to Clark's Pond, a small impoundment, then into the Fore River, a tidal estuary, and ultimately into Casco Bay. Four cities—Portland, South Portland, Scarborough, and Westbrook—share the watershed.



Subwatershed	Acres	Percent IC	Acres IC
A1	105.1	61.8	64.9
A2	284.7	19.5	55.4
A3	620.6	10.6	65.5
B	435.6	16.8	73.2
C	308.5	39.2	120.9
D	109.7	31.4	34.5
E	377.7	57.1	215.5
Totals:	2242		630
% IC for Entire W'shed		28%	

Figure 1. Map of the study area showing the acreage and percentage impervious cover (IC) for each subwatershed. Reprinted with permission from FB Environmental Associates (2009).

Pollution Problems

Fifty years ago, the Long Creek watershed was lightly developed, and water quality was high enough to support contact recreational use. Longtime South Portland residents still recall swimming in Clarks Pond and fishing for trout in the stream (Owen forthcoming). In the late 1960s, however, a development boom began, and the result was the kind of commercial development (residences are almost completely absent) that recurs across much of the American suburban landscape. The watershed now hosts many shopping centers, several office buildings, a few industrial facilities, part of an airport, and a network of roadways, including a portion of Interstate 95. Impervious surfaces now cover approximately 28% of the watershed, with much higher percentages in two of the lower subwatersheds (Figure 1; FB Environmental Associates 2009). Despite all of this development, no industrial effluent pipes, wastewater treatment plants, or combined sewer overflows can be found in the watershed. While portions of the upper watershed remain lightly developed, the watershed includes no farms.

Studies conducted by the Maine Department of Environmental Protection (DEP; Varricchione 2002) and USEPA (2007a) documented nonattainment of water quality standards throughout much of the watershed. The studies found lowered dissolved oxygen levels, elevated temperatures, high suspended solid levels and metals concentrations, and reduced populations of native macroinvertebrates. Brook trout were entirely absent, in contrast to an adjacent, lightly developed watershed that still hosts a robust population. Both Maine DEP and USEPA identified the watershed's impervious cover as a root cause of impairment. Long Creek, in short, was a classic example of an urban impaired stream.

Traditional Responses

For almost four decades, Americans have turned primarily to the Clean Water Act to restore polluted waterways. But for Long Creek and many streams like it, traditional methods of Clean Water Act implementation have provided poor solutions.

The Clean Water Act's primary mechanism for addressing water quality problems has been the National Pollutant Discharge Elimination System (NPDES), a permitting program that applies to *point sources* of pollution. For some pollutant sources, like wastewater treatment plant effluent or industrial outfalls, the NPDES program has been quite effective. And, as discussed below, the program could still spur major improvements in urban water quality. But as traditionally applied, the program has not been particularly effective at addressing urban stormwater (National Research Council 2008; Wagner 2006).

The NPDES program's limitations stem partly from statutory definitions. Some urban runoff flows overland without passing through any sort of discrete conveyance, and those flows therefore do not qualify as point source discharges and are not subject to NPDES permitting. 33 USC §§ 1311(a), 1362(12). Additionally, under USEPA's interpretation of 1987 amendments to the Clean Water Act, only a subset of urban stormwater point sources[2] is covered. Industrial and most municipal discharges are regulated, as are larger construction sites. But under USEPA's current interpretation of the act, private, nonindustrial point sources, including postconstruction discharges from commercial development, can discharge without permits unless state or federal NPDES regulators affirmatively establish permitting requirements. 33 USC § 1342(p); *Conservation Law Foundation v. Hanaford Bros. Co.*, 327 F. Supp. 2d 325 (D. Vt. 2004).[3] Even for the sources that are covered, permitting requirements typically focus on a subset of the stressors that impact urban waterways, with little attention to many of the stressors associated with impervious cover. Monitoring of compliance with those requirements also is uneven. Consequently, where development patterns are a root cause of watershed impairment, the NPDES program, as traditionally implemented, provides only a partial remedy (Owen forthcoming). For the Long Creek watershed, that traditional approach held particularly little promise. Only a few industrial properties were covered by NPDES stormwater permits, and most of the watershed lay outside of areas covered under municipal permits. For NPDES purposes, the watershed was essentially unregulated.

The Clean Water Act also includes a backup approach. Section 303(d) requires states to create pollution budgets, or total maximum daily loads (TMDLs), for water bodies not expected to attain water quality standards solely through the application of traditional technology-based standards. For two reasons, however, the TMDL approach has fallen well short of comprehensively addressing impaired urban watersheds. First, writing TMDLs for urban waterways is a challenge. Section 303(d) requires states to identify a maximum allowable daily load of each individual pollutant affecting the watershed. But urban waterways like Long Creek typically are impacted by the combined effects of many stressors, some of which do not meet the Clean Water Act's definition of *pollutant*. TMDLs that treat each pollutant separately, therefore, are difficult to write and, if completed, address only a subset of the sources of impairment (Owen forthcoming).

Second, while TMDLs do provide pollution budgets, the Clean Water Act provides only a partial mandate and method for turning those budgets into controls on individual sources. Under both the act itself and USEPA's implementing regulations, permits for sources already covered under the NPDES program should be consistent with TMDL requirements. But in urban watersheds, the sources already covered typically include only a small subset of the stressors, so this requirement alone is rarely sufficient to compel comprehensive restoration efforts. States also are obligated to create a budget for loading from noncovered sources, but neither the Clean Water Act nor USEPA's regulations provide much guidance on translating that overall budget into source-specific controls. Finally, states should generate watershed restoration plans, but the act does not establish specific requirements or guidance for the content of those plans, and states have no obligation to actually put them into effect.[4] As one federal court put it: "States must implement TMDLs only to the extent that they seek to avoid losing federal grant money; there is no pertinent statutory provision otherwise requiring implementation of § 303 plans or providing for their enforcement." *Pronsolino v. Nastri*, 291 F.3d 1123 (9th Cir. 2002). Consequently, TMDLs are likely to generate actual water quality improvements only to the extent that states—many of which were highly resistant to drafting TMDLs in the first instance—and local governments are highly motivated to use the TMDLs to achieve water quality improvements. As longtime observers of the TMDL program have noted, such motivation often is absent (Houck 2002).

Innovations

Because of these limitations, neither traditional NPDES permitting nor traditional TMDLs offered full solutions to Long Creek's problems.[5] If the watershed was to be restored, some other mechanism was necessary.

---

[2] Studies sometimes refer to all urban runoff as nonpoint source pollution. Legally, this is incorrect. The Clean Water Act defines a point source to include discrete manmade conveyances, and the discharge pipes through which most stormwater flows clearly meet that definition. 33 USC § 1362(14).

[3] If private dischargers convey their stormwater into municipal systems, the municipal permittee may impose some regulatory requirements. But municipal officials may be reluctant to pass stringent regulatory requirements on to private property holders (Owen forthcoming). And some privately developed areas—particularly areas with commercial development, where impervious cover may be abundant but the residential population is sparse—do not meet the census-based criteria for inclusion in the traditional regulatory program, even if a municipal stormwater system exists (Owen forthcoming). Most of the Long Creek watershed, for example, was not covered by any municipal separate storm sewer system (MS4) permit.

[4] If states do want to give regulatory effect to TMDLs, a variety of mechanisms, such as watershed planning, the integration of TMDL load limits into existing permitting schemes, and the enactment of new legislation, are available.

[5] In fact, Maine DEP never did draft a TMDL for Long Creek. It instead took the view, which no one has yet disputed, that with detailed studies of the watershed already completed and a collaborative planning process underway, it had a more thorough diagnosis of the watershed's problems and a better process for planning restoration efforts than a TMDL would provide.

Residual Designation Authority

In 2006, CLF activated one key legal mechanism when it informed Maine DEP and the City of South Portland that it was considering filing a residual designation authority petition for the Long Creek watershed. Residual designations are mandated by Clean Water Act Section 402(p)(2)(E), which requires NPDES permitting for any stormwater discharge that "the Administrator or [a state with delegated NPDES permitting authority] determines … contributes to a violation of a water quality standard or is a significant contributor of pollutants to waters of the United States," even if the source does not fall within the categories of traditionally regulated stormwater sources. USEPA's implementing regulations extend this authority to categories of dischargers within specific geographic areas, such as watersheds. They also allow any interested person to petition USEPA or a state with NPDES authority to exercise this authority. 40 CFR §§ 122.26(a)(9)(i)(C), 122.26(f)(2). USEPA and Maine DEP studies, CLF argued, demonstrated that violations of water quality standards existed in the watershed, and that landowners with point source stormwater discharges from impervious surfaces constituted the category of dischargers contributing to those violations (CLF 2008).

> *… under USEPA's interpretation of 1987 amendments to the Clean Water Act, only a subset of urban stormwater point sources is covered*

Though the Clean Water Act's residual designation authority provision had existed for two decades by the time the Long Creek process began, it was still quite obscure. USEPA and the states had hardly ever invoked it, and agency and academic discussions of the Clean Water Act essentially ignored the provision's existence. In 2003, however, CLF had filed a similar petition in Vermont—the first such petition ever filed—which also focused on watersheds containing heavy commercial development. The Vermont Agency of Natural Resources and development interests fought the petition, ultimately unsuccessfully, through years of litigation. *In re Stormwater NPDES Petition*, 180 Vt. 261, 910 A.2d. 824 (Vt. 2006). In Maine, however, USEPA and the state DEP decided against resistance. By the time CLF filed its petition addressing Long Creek, DEP and local governments already had begun a collaborative watershed restoration planning process. When CLF did file its petition, USEPA granted it, requiring NDPES permits from any landowner with over an acre (4,047 m^2) of impervious cover and associated point source stormwater discharges (USEPA 2008).[6] No one sued to challenge USEPA's decision. Consequently, where previously only a few landowners were covered by NPDES permits, and the permits' requirements were focused on only a subset of the stressors impacting Long Creek, 120 landowners now were subject to potentially rigorous new permitting requirements.[7]

Collective Permitting

If USEPA's residual designation had merely increased the number of individual NPDES permit holders in the Long Creek watershed, a successful cleanup process still would have been unlikely. In Maine, as in most other states, the costs of administering the existing NPDES program stretch administrative capacities, and assimilating 120 new permittees into the program would not have been easy. Compliance with individual permits would have been expensive, at least if the permits were sufficiently stringent to restore the watershed, and landowners might have fought to delay any regulatory requirement. The process also would have been hard to repeat. Even a sparsely populated state like Maine has dozens of impaired urban waterways, and individually permitting every landowner with an acre or more of impervious cover in every one of those waterways could create a crushing administrative burden (Owen forthcoming).

To address these problems, local government entities and Maine DEP obtained a grant under Section 319 of the Clean Water Act, and they and local businesses used the funding to initiate a multiyear, professionally facilitated collaborative watershed management planning process. That collaborative process generated a promising alternative permitting approach. Instead of allowing only individual permitting, Maine DEP has issued a collective general permit

---

[6] USEPA reserved its ability to require permitting from smaller landowners.

[7] The change in regulatory coverage was particularly dramatic because the Long Creek watershed was largely outside the area of any MS4 permit. But even in areas with MS4 coverage, residual designation authority could change the regulatory approach by creating direct state or federal regulation of private dischargers (Owen forthcoming).

to cover a newly created entity known as the Long Creek Watershed Management District.[8] That district will enter into contracts with any landowners, municipalities, and highway agencies that elect to participate in the implementation of the Long Creek Watershed Management Plan (hereinafter "the Plan"). Outside of the collaborative process, Maine DEP also created a stringent individual permitting approach that will require landowners not participating in the collective approach to meet cleanup objectives on their own—which may mean eliminating their discharge—and within a much shorter timeframe than if they participate in the collective process. This individual permitting backstop ensures ultimate compliance with the Clean Water Act and provides a powerful incentive for dischargers to participate in the collective approach.

In several ways, that collective approach can facilitate a more effective restoration effort. First, one of the Plan's core elements is a mechanism by which to pool restoration funding. Rather than separately funding work on his or her own property, each participant will pay annual fees to the management district. The fees will be proportional to the amount of impervious cover on the landowner's property, with discounts given for stormwater control work already completed, and will be set at a level collectively sufficient to cover the overall cost of the Plan. Project participants anticipate typical annual fees ranging from $2,000–$3,000 per impervious acre (FB Environmental Associates 2009),[9] though the amounts could change if monitoring reveals that a different amount of work is necessary to attain water quality standards.

The Plan also creates mechanisms for working across property boundaries. Through months of negotiations, project participants developed a standard contract under which each participating landowner will allow the district to perform restoration work on the landowner's property.[10] Thus, rather than working only on public property or on a few private parcels where it can negotiate access, the district will be able to pursue restoration efforts on any participating parcel, or on the areas—often underused—that straddle parcel boundaries. It therefore will be able to select projects primarily on the basis of financial cost and environmental benefit rather than feasibility of legal access.

To make those selections, environmental consultants used aerial photographs, storm sewer infrastructure maps, and field inventories to identify more than 150 potential structural stormwater retrofit projects. As in any watershed, some of these projects are likely to be more cost-effective than others (Figure 2). Projects that are built on underused landscape or setback areas or that can piggyback on existing stormwater infrastructure are particularly attractive, for example, as are projects that focus on "hot spot" areas with high levels of vehicle traffic. Rather than propose projects on every regulated parcel, as might be required under an individual permitting approach, the consultants identified a subset of projects expected to have particularly attractive cost–benefit ratios.

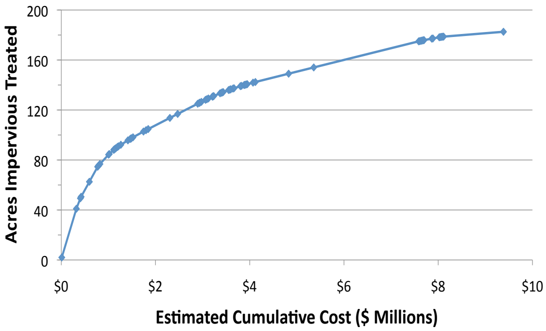


Figure 2. Varying cost-effectiveness of identified structural stormwater retrofits in the Long Creek watershed.

The final plan selects nine highly developed, directly connected impervious catchment areas to be remediated through a tiered adaptive management approach. The first two tiers of implementation include stormwater management retrofits with the highest anticipated cost–benefit ratios. The final tier, which would be implemented only after the first two

[8] Under Maine law, the district is technically a "non-capital stock nonprofit corporation and quasi-municipal special purpose district" (Long Creek Watershed Management District 2010, Exhibit A at 1). In lay terms, that means that it has a nonprofit corporation's organizational structure and that it exercises governmental responsibilities delegated by the participating municipalities. Much of the planning process was devoted to defining this organization's responsibilities and to creating the contracts and other legal instruments that would allow it to function.

[9] This funding mechanism is somewhat analogous to that employed by a stormwater utility, which typically charges all served properties a fee and uses the revenue to fund stormwater management work. But there are important differences. A detailed discussion is beyond the scope of this article but, in short, the contractual/permitting approach used in Long Creek allows enforcement under contract law or under the Clean Water Act itself, creates broader access to private properties, and focuses the financial burdens on a subset of property owners.

[10] The agreement is available at http://www.restorelongcreek.org/docs/landowner_agreement/pla_final.pdf.

tiers are completed and only if monitoring reveals that the stream still does not meet water quality standards, includes projects for which cost–benefit ratios are less promising. In total, participants anticipate retrofitting roughly 150 acres of impervious cover over the next ten years and will devote most of the project funds to these efforts (FB Environmental Associates 2009).

In addition to structural restoration measures, project participants also will implement pollution prevention, monitoring, planning and policy, and streamside habitat restoration actions. Here as well, the collective approach creates benefits. Some control measures, like pavement sweeping and other pollution prevention operations efforts, are much more cost-effective if coordinated across multiple properties. Other key measures, like riparian habitat restoration, probably could not be compelled under a traditional regulatory approach, and even if compelled could be difficult to coordinate across property boundaries. Because it allows managers greater flexibility in selecting monitoring points, the coordinated monitoring program should produce more meaningful data at lower cost than a property-by-property approach. Finally, the planning and policy initiatives should facilitate communication and innovation. Participants already anticipate creating technical subcommittees for Plan implementation elements ranging from targeted commercial landscaper outreach to winter deicer workgroups.

The collective effect of these measures should be to produce better environmental outcomes than a traditional individual permitting approach, and to do so at lower cost. Though subject to some uncertainty, the differences are potentially dramatic. According to preliminary estimates prepared by one of us (C.B.), the overall cost of a collective approach should be at least 60% less than the cost of an approach based solely on individual permitting.

Collective permitting also improves some of the institutional dynamics of watershed restoration. Normally, one might expect landowners to actively resist any expansion in the NPDES program. But by presenting landowners with the possibility of a cost-effective alternative permitting approach, the Long Creek process participants defused some of the potential opposition to USEPA's designation and created an incentive for landowners to help the process succeed. Many businesses responded strongly to that incentive, and so far none has sought to undermine the process (Owen forthcoming). Commentators often lament the barriers created by common mismatches between watershed boundaries and political and jurisdictional lines (e.g., Arnold 2006). But by creating a new authority whose jurisdiction corresponds to the geographic extent of the watershed, the collective approach facilitates cooperation across those lines. Commentators also commonly stress the importance of adaptive management to watershed restoration, but adapting is hard when monitoring data are sparsely available and any shift requires amending dozens of individual permits. A collective approach cannot make adaptive management easy, but by creating a coordinated monitoring program and empowering a centralized entity to set, and shift, priorities, it can make adaptation somewhat less difficult.

Collective permitting thus serves as a way to coordinate and make feasible the permitting expansion necessitated by residual designation authority. But the relationship also is reciprocal: residual designation authority helps collective permitting actually produce environmental results. For years, USEPA has advocated *watershed-based permitting*, an approach designed to address all of the key environmental stressors within a watershed, prioritize the highest-value projects, and use innovative funding mechanisms to equitably defray the costs of the work (e.g., USEPA 2007b). But for watershed-based permitting to succeed, the property owners who control pollution sources need some incentive to participate. Under traditional permitting approaches, only a few properties have NPDES obligations, and USEPA and the states can either use financial carrots—which may not be sufficiently available—to buy widespread participation, or can simply focus all regulatory attention on a narrow subset of sources. Residual designation authority supplements financial carrots with a permitting stick, and thus can help create more comprehensive and equitable watershed-based restoration programs.

Beyond Long Creek

The Long Creek process is still unfolding and, because of the inherent uncertainties of urban watershed restoration, it still is too early to guarantee that a promising project design will actually translate into improved environmental conditions. But even at this early stage, the process offers several lessons, each with applicability to watersheds across the country.

Perhaps the most striking feature of the Long Creek process is its potential replicability. The Long Creek watershed is not unique; similar development patterns recur across the country. Further, watershed scientists have concluded that many urban watersheds have impaired water quality and similar mechanisms of impairment (National Research Council

2008; Center for Watershed Protection 2003). The Clean Water Act is a federal law. With some documentation specific to local conditions[11]—documentation that could come from TMDLs, which states already are obliged to prepare for every impaired waterway—similar residual designation authority petitions therefore could spur watershed protection across much of the nation (Owen forthcoming). And through local initiative and, perhaps, some borrowing from the Long Creek model, other watersheds could generate similar collective permitting processes that focus on the implementation of community-generated improvement plans. These processes would not be cheap; if done well, collaboration takes time and money, and even with the efficiencies and economies of scale generated by the collective permitting approach, the first prioritized actions of the Long Creek cleanup still will cost an estimated $14 million (FB Environmental Associates 2009). But they could help address urban water quality problems that often have proven difficult to resolve.

Those costs highlight another question raised by the Long Creek process. Is such an intense focus on heavily impaired urban watersheds appropriate? According to existing law, the answer is clearly yes; the relevant provisions of the Clean Water Act function primarily in reaction to, rather than in anticipation of, water quality problems, and therefore apply with greatest force where watershed problems are at their worst (Owen forthcoming). But preventing the degradation of a relatively healthy waterway, or even restoring one that is impaired but not heavily degraded, is usually much less expensive than attempting to restore a heavily urbanized stream. Many of the most common techniques for protecting developing watersheds—emphasizing the conservation of lands, the use of low-impact design, and promoting cluster or infill development, for example—can actually raise property values, improve community cohesion and aesthetics, and reduce some of the other adverse environmental and financial impacts associated with urban sprawl (Schueler 2000). Much of the recent literature on watershed protection therefore suggests that attempts at full restoration of urban watersheds like Long Creek, while laudable, involve suboptimal allocations of resources, and that more environmental good could be accomplished by shifting effort to watersheds at the suburban fringe and by reforming regulatory policies to facilitate that reallocation of priorities (Center for Watershed Protection 2003; Schueler 2008; National Research Council 2008).

The cost of restoring Long Creek highlights the basis for those concerns, but the Long Creek process also suggests several reasons why focusing on highly urbanized streams may still be appropriate. First, because urban streams are typically in or adjacent to densely populated areas, many people can benefit from the restoration. Along Long Creek, for example, a local land trust already has begun developing a network of walking trails, and while few people live in the watershed, the thousands who work there or live nearby could take advantage of those conveniently available recreational opportunities (T. Blake, mayor, City of Portland, ME, personal communication). Second, because of the density of development and proximity to residential areas and road systems, property in the Long Creek watershed is economically valuable; that value, along with the large number of landowners in this urban area, create a much larger pool of potential restoration funders than would exist in a sparsely developed area. Third, and perhaps most importantly, some preliminary evidence suggests that, rather than diverting effort from the protection of less-impacted streams, the Long Creek process will actually motivate proactive protections. The process—particularly the emergence of residual designation authority as a legal lever—has signaled to other communities that an impacted urban stream is a potential legal problem and financial liability. Those signals already have inspired a few communities to take preliminary steps to protect other watersheds (Owen forthcoming).

Conclusion

The combination of residual designation authority and collective permitting may not be an optimal response for every impaired urban waterway. Heavily residential watersheds, for example, may require different sets of responses. But across the nation, many watersheds have development patterns and water quality impairment similar to those of Long Creek; therefore, many elements of the Long Creek process could be imitated elsewhere. That process provides a promising example of a way to engage a broad group of stakeholders, combine legal incentives and local initiative, and cost-effectively restore an impaired urban stream.

---

[11] Here, despite their inherent limitations, TMDLs could still play an important role. TMDLs are mandatory for impaired watersheds and, while most TMDLs do not delineate clear paths to watershed restoration, they should at least diagnose some of the waterway's problems. That diagnosis then could provide a basis for a residual designation (Owen forthcoming).

REFERENCES

Arnold, Craig Anthony. 2006. Clean-water land use: Connecting scale and function. Pace Environmental Law Journal 23:291–350.

Center for Watershed Protection. 2003. Impacts of impervious cover on aquatic systems. Ellicott City, MD: Center for Watershed Protection.

Conservation Law Foundation. 2008. Petition for a determination that existing, non-de minimis, un-permitted stormwater discharges from impervious surfaces into Long Creek South Portland, Maine require a Clean Water Act permit. March 6.

FB Environmental Associates Inc. 2009. Long Creek watershed management plan. Portland, ME: FB Environmental Associates Inc.

Houck, Oliver A. 2002. The Clean Water Act TMDL program: Law, policy, and implementation. Washington, DC: Environmental Law Institute.

Long Creek Watershed Management District. 2010. Articles of incorporation. January 13.

National Research Council. 2008. Urban stormwater management in the United States. Washington, DC: The National Academies Press.

Owen, Dave. Forthcoming. Urbanization, water quality and the regulated landscape. Colorado Law Review 82.

Schueler, Thomas R. 2008. Implications of the impervious cover model: Stream classification, urban subwatershed management and permitting. Catonsville, MD: Chesapeake Stormwater Network.

Schueler, Thomas R. 2000. The economics of watershed protection. Watershed Protection Techniques 2(4): 469–481.

Shabman, Leonard, K. Reckhow, M. B. Beck, J. Benaman, S. Chapra, P. Freedman, M. Nellor, et al. 2007. Adaptive implementation of water quality improvement plans: opportunities and challenges. Nicholas School of the Environment and Earth Sciences. Durham, NC: Duke University.

US Environmental Protection Agency. 2007a. Causal analysis of biological impairment in Long Creek: A sandy-bottomed stream in coastal southern Maine. EPA/600/R-06/065F. Washington, DC: US Environmental Protection Agency.

———. 2007b. Watershed-based National Pollutant Discharge Elimination System (NPDES) permitting technical guidance. EPA 833-B-07-004. Washington, DC: US Environmental Protection Agency.

———. 2008. Preliminary residual designation pursuant to Clean Water Act. Washington, DC: US Environmental Protection Agency.

Varricchione, Jeffrey T. 2002. A biological, physical, and chemical assessment of two urban streams in southern Maine: Long Creek & Red Brook. Augusta, ME: Maine Department of Environmental Protection.

Wagner, Wendy E. 2006. Stormy regulation: The problems that result when stormwater (and other) regulatory programs neglect to account for limitations in scientific and technical information. Chapman Law Review 9:191–232.

Walsh, Christopher J., Allison H. Roy, Jack W. Feminella, Peter D. Cottingham, Peter M. Groffman, and Raymond P. Morgan II. 2005. The urban stream syndrome: Current knowledge and the search for a cure. Journal of the North American Benthological Society 24:706–723.

Up River: A Novel of Attempted Restoration, by George Ivey.

Indianapolis, IN: Dog Ear Publishing, 2009. Print (Fiction)

Reviewed by Sadie Drescher, Center for Watershed Protection

Summary

Up River: A Novel of Attempted Restoration tells the story of one person's attempt to restore a river in a rural setting. The story begins just after Peter Bailey is hired by a Washington, DC, environmental group, The Global Alliance for River Defense, to restore the Akwanee River in southern Appalachia. Peter grew up in Charleston, SC, and has just finished working on a political campaign in Greensboro, NC, so he seems to be a perfect fit for this southern restoration project. A successful restoration means that Peter needs to be quick on his feet to maneuver the small town politics and win people over—one person at a time.

When Peter arrives in a close-knit farming community he is seen as "an outsider" and struggles to figure out not only what to do first but also how to get people motivated. Peter meets the usual rural environmental stakeholders: the farmers, the naturalists, the local environmental activist group, the skeptics, the loons, the indifferent individuals, and the people who are listening and concerned but are waiting for a reason to join the effort. His employer's tendency to flex its DC legal muscles becomes a liability, thwarting Peter's efforts as he struggles to build trust and make a difference for the river and its resources.

As a first step, Peter purchases a "no-till drill" that the farmers share to till cover crops and reduce stream sediment and pollutant loading. Then he moves to smaller efforts, such as river trash pick-ups, a school tree planting project, and efforts to fence cows out of the river. Finally, he links up with two local researchers to protect brook trout. This is a journey to bring a community together around the river as a natural resource centerpiece.

Review

The book will be useful as a way to introduce undergraduates to an environmental restoration project with expected and unexpected outside influences. The story gives a land steward's inside perspective and shows how important it is to identify and frame an objective to the community. However, the underdeveloped and unnecessary subplots can be distracting to seasoned practitioners working in the midst of these environmental struggles daily.

AWSPs Photolog Contest Winner

The Association of Watershed and Stormwater Professionals (AWSPs) sponsored a photolog contest as a way to feature the watersheds in which we live, work, and play. Semifinalists were selected by the Center for Watershed Protection, Inc. and were featured on the AWSPs website (www.awsps.org). AWSPs members then had the opportunity to vote on the winning photo. AWSPs is now accepting entries for the next photolog contest. The winning photo will be featured in the Spring 2011 issue of the Watershed Science Bulletin. Deadline for submissions is November 1, 2010. For additional information and to submit your entry, please visit www.awsps.org.

And the winner is....

By popular vote, Bill Bonner is the winner of the photolog contest for his photo of Palouse Falls in Washington State. Palouse Falls is hidden in a very secluded canyon in the southeastern corner of Washington State. The canyon itself is an amazing site to see, but the falls showcase the monstrous power of water. The approximately 180-foot drop can vary by as much as 12 feet as the elevation of the plunge pools rises or falls with variations in flow. In 2009, the highest flow reading was 8,300 cubic feet per second. Palouse River terminates four miles downstream, where its waters are received by the Snake River; ultimately, it pushes its way to the Columbia River and the Pacific.

The majority of the runoff received by the river consists of the region's fertile soils. Agriculture dominates the region and, in turn, increases the watershed's sediment loading. The fertilizers and pesticides in the agricultural runoff also introduce nitrates and other chemicals to the system, further diminishing the river's water quality. In recent years, local extension specialists, conservation professionals and advocates have promoted soil conservation methods, such as no-till farming and crop rotation. Local, state, and federal agencies will continue these efforts by sponsoring critical outreach and education programs focusing on how we can all get involved to keep our waters clean.

Tracking Watershed Restoration in Montgomery County, Maryland

Nick L. Lindow,[a]** Steven P. Shofar,*[b] *and Meosotis C. Curtis*[c]

Abstract

To track its ongoing effort to treat impervious cover and reduce pollutants in its surface waterways, the Montgomery County (Maryland) Department of Environmental Protection (MCDEP) applied the Watershed Treatment Model (WTM) to inventory the baseline status and forecast the results of watershed restoration practice implementation. The countywide watershed restoration modeling effort required consistency across the complicated regulatory environment in Montgomery County and a flexible countywide pollutant load estimation and progress tracking tool. The model used event mean concentration and discretized urban land use from geographic information system data to track total maximum daily loads (TMDLs), which included those for nutrients, sediment, bacteria, and trash, depending on the watershed. The modeling assumptions for Montgomery County's watershed restoration implementation plan were consistent with the Chesapeake Bay Program and with state and federal regulations for pollutant loading and removal estimates. The WTM proved to be an accurate modeling framework that estimated the baseline bacterial loading to Rock Creek within 10% of the measured load for the TMDL. Meeting bacterial loading limits set forth in the Rock Creek TMDL proved to be a challenging task, despite the focus in the restoration plan on implementing state-of-the-art structural stormwater management practices to all suitable public and private areas in the watershed. Results of the initial analysis illustrated that a pet waste education program could provide cost-effective pollutant removal and better targeting than structural stormwater management and land conversion practices.

Introduction

Montgomery County, Maryland, covers approximately 1,295 km^2 (500 mi^2) in central Maryland and has a population of 940,000 people; in terms of the average number of people per square kilometer, Montgomery County is second only to Baltimore City within Maryland. Overall, the county has 12% impervious cover and drains to the Potomac and Patuxent Rivers, which drain to the Chesapeake Bay.

The county's location in Maryland and in the Chesapeake Bay watershed places it in a unique situation vis-à-vis a number of recent policy and programmatic changes in Maryland: the state permitting authority (Maryland Department of the Environment [MDE]) has issued new 2010 stormwater regulations requiring environmental site design (ESD), the governor has established a Bay restoration program with two-year and 2020 milestones, and the federal government has issued an executive order to improve the Bay's water quality under the authority of the US Environmental Protection Agency (USEPA). In addition, as of June 2010, USEPA had approved ten total maximum daily load (TMDL) limits in the county, in seven different water bodies, regulating sediment, nutrients, and bacteria. TMDLs for additional water bodies and pollutants are planned for approval in the future, including a Chesapeake Bay TMDL, which will include a wasteload allocation (WLA) for nutrients and sediment in the Potomac and Patuxent Rivers and will cover the entire county. MDE is also currently in the final public commenting phase of a trash TMDL for the Anacostia River.

MDE issued the county's current National Pollutant Discharge Elimination System (NPDES) municipal separate storm sewer system (MS4) stormwater permit on February 16, 2010—the first of its kind in Maryland to require the use of ESD and low-impact development (LID) to capture stormwater. These changes were made in conjunction with the improvement of the county's stormwater management regulations and modification of the county's planning and zoning codes. The permit includes the following major new components:

- Watershed restoration
- TMDLs
- Trash and litter
- Pollutant reduction estimating and tracking

In this article, we describe efforts by the MCDEP to accomplish these four permit goals by developing a countywide watershed restoration implementation plan. We also present some challenges and lessons learned from this process.

---

a Water Resources Engineer, Biohabitats, Inc., Baltimore, MD, nlindow@biohabitats.com

b Division Chief, Watershed Management Division, Montgomery County (MD) Department of Environmental Protection

c Manager, Watershed Planning and Monitoring, Montgomery County (MD) Department of Environmental Protection

** Corresponding author.*

Working within the Regulatory Framework

The countywide watershed restoration modeling effort required consistency across the complicated regulatory environment in Montgomery County as well as a flexible countywide pollutant load estimation and progress tracking tool. The permit requires MCDEP to provide an estimating and accounting framework, which (a) should include information on the types of stormwater management practices implemented, pollutant reduction tracking conducted, and total area treated to the maximum extent practicable (MEP) and (b) can be used to estimate pollutant reductions from varying scenarios of watershed restoration implementation. A system that provides for geographically referenced calculation and accounting was necessary for proper accounting and estimating since field verification was not possible. MCDEP used the Watershed Treatment Model (WTM; Caraco 2001) to develop an innovative tracking and accounting tool, incorporating pollutant load, structural stormwater management, and municipal programmatic practice modeling within a single framework. The WTM is a spreadsheet modeling approach using output from a geographic information system (GIS) for land use and stormwater BMPs. In addition, the WTM is able to explicitly model the volume reduction benefits of ESD practices.

> *The countywide watershed restoration modeling effort required consistency across the complicated regulatory environment in Montgomery County as well as a flexible countywide pollutant load estimation and progress tracking tool*

The current stormwater permit requires the implementation, over the next five years, of restoration on 20% of the impervious surfaces not currently controlled to the MEP, in addition to the 10% restoration requirement from the previous permit cycle. This goal requires runoff control for an additional 16.6 km^2 (6.4 mi^2) of impervious surface countywide. The MEP definition includes structural best management practices (BMPs), nonstructural BMPs, programmatic practices, and stream restoration projects. The structural restoration program includes BMPs for ESD and LID—a decentralized, distributed stormwater management approach. The county's stormwater permit also requires the implementation of projects to make progress toward achieving the WLAs of the TMDL.

The last major piece of the stormwater permit includes a requirement to complete a trash and litter reduction strategy as set forth in the Trash Free Potomac Watershed Initiative 2006 Action Agreement. The agreement, signed by 105 elected officials, pledges their commitment to a trash-free Potomac by 2013 and their agreement to (a) work with regional leaders, businesses, government agencies, nonprofits, and communities to implement strategies aimed at reducing trash and increasing recycling; (b) increase education and awareness of the trash issue; and (c) reconvene annually to discuss and evaluate measures and actions addressing trash reduction. In addition, regulatory limits on trash are being developed by MDE for the Anacostia River. For the Anacostia watershed, MCDEP is working to establish a trash pollution baseline, implement a trash abatement program, expand education to citizens, and monitor trash loading to the Potomac.

We present two case studies below describing MCDEP's effort to develop a coordinated implementation plan and track progress using the WTM. These include a summary, issues, and lessons learned from tracking implementation and from targeting practices to meet bacterial loading limits.

Tracking Implementation Case Study

MCDEP staff applied the WTM (v3.1) to inventory the baseline status and forecast the pollutant load reductions associated with implementing the watershed restoration plan. MCDEP staff initially tested the WTM in the Rock Creek watershed, using event mean concentration (EMC) and discretized urban land use from GIS data to track the baseline stormwater pollutant load. An EMC is a method for characterizing pollutant concentrations in receiving water from a runoff event. The value is determined by compositing (in proportion to flow rate) a set of samples, taken at various points in time during a runoff event, into a single sample for analysis (Natural Resources Defense Council 1999). The project team estimated the existing level of stormwater management within the model by categorizing BMPs from the county's current inventory of urban BMPs according to their historic performance criteria, a national comparative review of pollutant removal and runoff reduction performance criteria (Center for Watershed Protection [CWP] 2007; CWP and Chesapeake Stormwater Network 2008), and performance studies on individual practices (Schueler, 1998a; and Schueler, 1998b). MCDEP staff then used the WTM to test a suite of future ESD practices on suitable public and private properties within the county and predicted the resulting reduction in nutrient, sediment, bacterial, and trash loads.

Our modeling approach used land use categories as the primary source to estimate pollutant loads of total nitrogen (TN), total phosphorus (TP), total suspended sediment (TSS), fecal coliforms (FC), and trash in stormwater runoff. The land use–based EMCs are well documented for TN and TP. However, the method is more difficult for FC, because of the lack of data, and for TSS, because of the differences in land-based sediment load, instream loads, and delivery factors. For bacteria, the baseline load and WLA in the TMDLs are from direct instream measurements, and are not based on land use distribution. Bacterial loads are typically from dispersed, mobile sources such as sanitary sewer overflows (SSOs), failed septic systems, wildlife, domestic pet waste, and livestock. However, the model produced acceptable results for Rock Creek, within 10% of the MDE baseline load. The EMCs used in the WTM were based on the National Stormwater Quality Database (Pitt 2008). And importantly, for the purposes of the TMDL, human and livestock sources were allocated to the nonpoint source load, which is not included in the county MS4 WLA.

We used the WTM to calculate reductions in pollutant loading from planned BMPs. Any BMPs approved prior to the data collection period for the TMDL were applied to the watershed to calculate a baseline load and were compared to the TMDL baseline load. BMPs approved after the TMDL data collection period, as well as any planned stormwater ponds and LID retrofits from the Capital Improvement Project (CIP) inventory, were applied to the model to track pollutant load reductions toward meeting the WLA. MDE has tentatively approved this method as an acceptable procedure. In addition, we used the model to test scenarios of pollutant load reductions beyond the planned CIP inventory, including reductions from retrofits of other public sites, nonstructural BMPs, and programmatic practices. We compared the results to the required reductions needed to meet the WLA of the TMDL.

The strategy required very detailed GIS data, including BMP types and locations with individual drainage areas delineated and impervious cover captured. Many drainage areas included multiple BMPs, requiring the project team to attach unique identifiers—called *sequence numbers*—to individual BMPs to appropriately assign pollutant removal and effectively automate the procedure to create reproducible results. We grouped the BMPs into five categories:

ESD practices: BMPs that maximize runoff reduction and pollutant mass reduction, such as bioretention, dry swales, working infiltration, and vegetated swales.

Effective practices: BMPs with limited runoff reduction capabilities but moderate to high pollutant removal, and which tend to have large drainage areas. Examples include wet ponds, extended detention, wetlands, sand filters, and infiltration practices.

Underperforming practices: BMPs with moderate to large drainage areas, no runoff reduction, and low to moderate pollutant removal capability. These BMPs have high retrofit potential and include infiltration basins and dry ponds with quality control.

Nonperforming BMPs: Practices that provide detention and peak discharge control but marginal pollutant or runoff volume reduction. These practices, which include dry detention ponds and underground detention, are ideal candidates for retrofits.

Pretreatment practices: This class of BMPs includes flow splitters, oil-grit separators, and plunge pools, which were never intended to provide significant pollutant removal or volume reduction and were, instead, designed to protect the function of a downstream practice. However, in certain situations, MCDEP staff installed these BMPs as standalone practices and provides intensive maintenance for them; thus, they provide limited pollutant removal and volume reduction.

These categories were developed to calculate treatment efficiencies across the watershed and to track retrofit opportunities (Table 1). Tracking retrofits also required using sequence numbers so that when a BMP was targeted for retrofit, the drainage area treated and pollutant removal efficiency could be incrementally increased and not double-counted.

Table 1. Pollutant removal efficiencies used in developing the implementation plan.

Performance Category	RR (%)	Discount Factor	TSS (%)	TN (%)	TP (%)	FC (%)
Pretreatment BMPs	5	0.15	20	5	5	10
Nonperforming BMPs	0	0.05	5	0	0	0
Underperforming BMPs	5	0.15	20	5	5	10
Effective BMPs	10	0.75	80	40	50	65
ESD Practices	60	1.0	90	65	65	75

Notes: Discount factor, fraction of contributing impervious acres effectively treated to the water quality volume, used to rate BMP treatability; FC, fecal coliform removal rate; RR, percentage annual reduction in post-development runoff volume for storms; TN, total nitrogen removal rate; TP, total phosphorus removal rate; TSS, sediment removal rate. Source: Schueler 2010, Appendix B.

We used the WTM to track pollutant load reductions due to BMP implementation from urban land. This assumption follows the protocol proposed by the typical TMDL, which uses urban land (residential and commercial areas) to allocate loading to the county MS4. To properly allocate loading between jurisdictions, the team excluded loading from other MS4 permitting entities, state and federal properties, Maryland–National Capital Park and Planning Commission property, and rural areas. However, the Maryland Department of Planning 2002 GIS data used in the model included some rural and forested areas within the county's MS4 area. These nonurban areas have an associated pollutant loading from wildlife sources, but the WTM only applies load reductions from stormwater BMPs to urban land use categories. For Rock Creek, the WTM predicted a bacterial load associated with forest and rural areas (wildlife sources) that was actually slightly higher than the WLA. Because it includes some of the wildlife sources, the WLA could not be met even if the entire urban area were treated to the MEP. This result was consistent with MDE's analysis of the MEP for the TMDL. Since the bacterial load attributed to wildlife in Rock Creek was a significant component, the reductions may be beyond practical limits (MDE 2007).

Each TMDL, whether the targeted pollutant is nutrients, sediment, bacteria, or trash, requires unique considerations. To target the pollutant of concern and properly track progress, the WTM allows the incorporation of programmatic restoration techniques such as pet waste education, SSO repair, septic system education, and cooperative riparian reforestation. The modeling assumptions are highly reliant on various subjective factors, including an *awareness of message* factor and a *participation* factor, but the model provides default values based on extensive survey data. For the purposes of tracking the pollutant load reductions associated with pet waste education, we assumed 80% awareness and 90% participation to calculate the source load eliminated by an applicable program. These are high percentages based on the default WTM values for education campaigns, but MCDEP is assuming an aggressive homeowner targeting strategy and enforcement policy.

Targeting Strategy: Bacteria Case Study

The strategy employed by the individual watershed implementation plans was intended to match the practices with the combination of watershed restoration and TMDL goals. Because of competition for county resources, the project team had to prioritize restoration efforts to allow for the allocation of staff and resources. The county budget had to be balanced across watersheds to properly meet competing TMDL, watershed restoration, and trash goals. For the Rock Creek bacteria TMDL, targeting programmatic practices such as pet waste education were far more cost-effective in reducing bacteria than new ESD retrofits or riparian reforestation.

Stormwater management in general only targets overland flow sources of bacteria, such as domestic pets and wildlife. MDE determined that the bacterial loading to Rock Creek was derived from a distribution of sources, including domestic animals, human waste, livestock, and wildlife, based on bacterial source tracking. The distribution of bacterial sources depended on location and flow, with the highest contribution of bacterial loading generally coming from wildlife, followed by livestock, domestic animals, and human sources. MDE allocated human, livestock, and a portion of the wildlife loads to the load allocation (LA), or nonpoint source loads within the watershed; therefore, this portion is not attributed to the county MS4 load. Results from WTM modeling showed only a moderate reduction in bacterial loading using structural stormwater BMPs, including ESD and LID practices and retrofits. In general, the maximum percentage of bacterial removal attributable to ESD practices is 75%, which will not achieve the 96% reduction required by the TMDL. Even riparian reforestation—which helps buffer streams from overland flow, removes potential source areas, and reduces runoff volume—only marginally reduces bacterial loading. A much more suitable approach was to target programmatic practices, including pet waste education.

Issues and Lessons Learned

Comparing the county GIS data with the TMDL results involved balancing the differences in baseline year for land cover and BMPs. MDE used land use data from different years to develop the various county TMDLs. The data sources differed in land use categories, and it was difficult to calibrate the model to a baseline LA and determine when to set the cut-off year for BMP approval. In addition, all of the individual watershed plans had to fit into the larger countywide implementation plan, which is why we aimed for a single land use data set.

To be compatible with the larger Chesapeake Bay TMDL in development, the BMP types and percentage removal efficiencies had to be compatible with the MDE assumptions for tracking purposes. We used the best science and literature values for setting BMP efficiency according to practice type. However, the Chesapeake Bay Program has developed a Chesapeake Bay Watershed Model, which is used to estimate the delivery of nutrients and sediments to the Bay and set tributary allocation caps. The Bay model uses BMP installation date to set the efficiency, with no pollutant removal credit for BMPs constructed prior to 1986 (before full implementation of the Maryland Stormwater law of 1984), an increased removal credit for BMPs constructed between 1986 and 2002, and the highest pollutant removal credit for BMPs constructed after 2002 (after the more stringent 2000 *Maryland Stormwater Design Manual* went into effect; see Table 2). The Bay model currently does not give credit for bacterial removal, give recommendations for treatability factors, or provide removal credit for ESD practices. It was for these reasons and the greater definition of removal efficiencies by BMP type that the categorization strategy in Table 1 was adopted for the county implementation plan. However, it was important that our strategy remain consistent within the larger Chesapeake Bay context.

Table 2. The Chesapeake Bay Program's Chesapeake Bay Watershed Model stormwater management efficiency, by era.

Development Era	Description	TSS (%)	TN (%)	TP (%)
Prior to 1986	No stormwater regulations	0	0	0
1986–2002	1984 Maryland Stormwater Management Act	50	20	30
2002–2010	2000 Maryland Stormwater Design Manual	80	30	40
Post-2010	ESD to the MEP required	TBD	TBD	TBD
Retrofits	Retrofits of pre-2002 BMPs	65	25	35

Notes: TBD, to be determined; TN, total nitrogen removal rate; TP, total phosphorus removal rate; TSS, sediment removal rate.

Before pollutant reduction estimates can be made, an accurate baseline condition for the watersheds must be set using a method compatible with federal guidelines. The *simple method* provides a simple way to calculate runoff and pollutant loads based on impervious cover, rainfall, and EMC data for various water quality parameters. The assumptions for EMCs used in the WTM's land use–based loading model tracked well with the Anacostia River model of the US Army Corps of Engineers (ACOE) and the county's NPDES sampling results model for TN and TP. The EMCs by land use are well documented by Pitt (2008). Table 3 shows the comparison among EMCs. We have found some difficulty justifying suitable EMCs for TSS because of the differences in upland-based sediment load, instream loads, and delivery factors. Current research-based EMCs yielded a baseline sediment load of roughly 50% of the total sediment load modeled by the TMDLs. We attributed this to the additional instream sources of sediment from stream bank erosion, which are not picked up by a primary source, land use–based model. The difference in a watershed's *wash load*, which is primarily from the upland areas, is significantly different from suspended loads and bed loads, which are hydraulically controlled and difficult to model in a land use–based approach. Literature values of land use–based sediment EMCs are roughly 50% of those in the ACOE Anacostia model and NPDES samples.

Table 3. EMCs used in the WTM compared to ICPRB 2007 Anacostia model (Montgomery County and Prince George's County data) and Montgomery County NPDES stormwater sampling.

Land Use Designation	TN (mg/L)	TP (mg/L)	TSS (mg/L)	Source
Residential	2.3	0.35	139	ICPRB, 2007
	1.9	0.24	116.94	MCDEP, 2006
	2	0.3	59	WTM; Pitt 2008
Commercial	3.5	0.2	132	ICPRB, 2007
	3.64	0.17	55.35	MCDEP, 2006
	2.2	0.22	55	WTM; Pitt 2008
Industrial	2.1	0.24	218	ICPRB, 2007
	2.21	0.21	256.63	MCDEP, 2006
	2.1	0.26	73	WTM; Pitt 2008
Municipal	1.3	0.11	125	MC in-stream Anacostia
	—	—	—	MCDEP, 2006
	1.8	0.22	18	WTM; Pitt 2008

Notes: Highlighted rows were used in the WTM modeling effort; MC: Montgomery County, MD.

An important lesson learned came from the overall targeting strategy, the need to balance budgets across watersheds, and the ability of CIP projects versus programmatic practices to reduce specific pollutants for the TMDL. From a cost perspective, structural stormwater practices are not the most cost-effective strategies for meeting a bacteria TMDL requirement. The average ESD practice has approximately 75% bacterial removal efficiency. Thus, even extensive ESD implementation would not provide adequate treatment to meet the strict 96% removal requirement of the Rock Creek TMDL. Rather, the programmatic practices are more cost-effective and result in greater bacterial removal. For instance, Table 4 illustrates results from Rock Creek bacterial modeling on how programmatic practices, such as pet waste education, were more cost-effective in reducing bacteria than new ESD retrofits. We assumed various costs for structural BMPs based on specific county data on previously installed practices. These may become cheaper in the future, given designer and contractor familiarity with the newer ESD practices. We assumed that riparian reforestation would cost $20,000 per acre planted. We estimated the pet waste education program at $15 per household and assumed that the program would target every household in the county. A similar trend is expected for trash TMDLs: the implementation of ESD retrofits will not yield the necessary reduction in trash to meet TMDL goals. The current county budget includes about $5.7 million for a countywide recycling program, household hazardous waste program, illegal dumping prevention and enforcement, right-of-way clean up, and the volunteer programs for Adopt-A-Road and storm drain marking.

Table 4. Comparison of the cost-efficiency of structural stormwater BMPs, riparian reforestation, and pet waste education in bacteria removal.

Restoration Strategy	Restoration Target	Bacteria Removal (billion MPN/yr)	Cost (million $)	Efficiency (billion MPN /million $)
Structural BMPs	3,265 Acres IC	131,262	$211	622
Riparian Reforestation	358 Acres	5,700	$7.2	796
Pet Waste Education	78,909	53,603	$1.2	45,286

Notes: Bacteria removal from WTM analysis. IC: impervious cover; MPN: Most Probable Number

The final lesson learned was the importance of flexibility. The base version of the WTM does not have an extension for calculated trash pollutant loading and reduction strategies. However, the model is an open source spreadsheet, and we adjusted it to accommodate trash. A similar land use–based load calculation was performed using trash loading rates from the draft Anacostia River trash TMDL in development, which is expected to be released in 2010. The TMDL includes a detailed approach to calculate trash sources and loading rates from different land uses, so the methodology fit well within the framework of the WTM. A spreadsheet-based modeling approach, rather than more complicated proprietary or closed-source programs, was an important component to adjust to the changing fields of TMDLs being developed.

Conclusion

The county's location in Maryland and in the Chesapeake Bay watershed places it in a unique situation in that the state, the federal government, and various regional government entities all have different, and sometimes conflicting, goals and guidance. Any restoration strategy must remain balanced within the regulatory framework and larger watershed goals. The modeling assumptions for Montgomery County's watershed restoration implementation plan were consistent with the Chesapeake Bay Program, MDE, and USEPA for pollutant loading and removal estimates. The next steps are to create a strategy and timeline for implementation that meets the goals of both the MS4 permit and the Chesapeake Bay TMDL.

Developing a countywide pollutant load accounting and tracking model is a data-intensive endeavor. However, the WTM has a robust modeling framework that provided accurate results (with 10% of the measured bacterial load for Rock Creek) and a simple data entry interface for rapid testing of complex restoration scenarios. The open-source spreadsheet format also permitted flexibility in the model, allowing us to add a trash loading component to the base version of the model.

Bacteria are a difficult pollutant to track and effectively remove to meet water quality standards, and domestic pet and wildlife sources are dispersed and mobile within the watershed. We explored how to target bacteria in the watershed and the bacterial removal efficiencies of the practices tested. For bacteria TMDLs, programmatic practices such as pet waste education and enforcement may be the most cost-effective treatment methods. Since the bacterial load attributed to wildlife is often a significant component, the required reductions to achieve water quality standards may be beyond practical limits.

Acknowledgments

The authors are grateful for the hard work of the Montgomery County Department of Environmental Protection, Biohabitats, Chesapeake Stormwater Network, Horsley-Witten, and Versar staff in developing the technical guidance for the work described herein.

REFERENCES

Caraco, D. 2001. The Watershed Treatment Model: Version 3.0. Prepared for the US Environmental Protection Agency, Region V. Ellicott City, MD: Center for Watershed Protection.

Center for Watershed Protection. 2007. National pollutant removal performance database version 3.0. Ellicott City, MD: Center for Watershed Protection.

Chesapeake Stormwater Network. 2008. Technical support for the bay-wide runoff reduction method, version 2.0. CSN technical bulletin no. 4. Baltimore, MD: Chesapeake Stormwater Network.

Interstate Commission on the Potomac River Basin (ICPRB). 2007. Anacostia sediment models: Phase 3 Anacostia HSPF Watershed Model and Version 3 TAM/WASP Water Clarity Model. Rockville, MD: Interstate Commission on the Potomac River Basin.

Natural Resources Defense Council. 1999. Stormwater strategies: Community responses to runoff pollution, glossary. http://www.nrdc.org/water/pollution/storm/gloss.asp.

Maryland Department of the Environment. 2007. Total maximum daily loads of fecal bacteria for the non-tidal Rock Creek basin in Montgomery County, Maryland. Baltimore, MD: Maryland Department of the Environment.

Montgomery County Department of Environmental Protection (MCDEP). 2006. Annual report NPDES municipal separate storm sewer system permit 00-DP-3320 MD 0068349. Rockville, MD: Montgomery County Department of Environmental Protection, Watershed Protection Division.

Pitt, R. 2008. National stormwater quality database. Version 3.0. Tuscaloosa, AL: University of Alabama.

Schueler, T. 1998. The performance of oil grit separators in removing pollutants at small sites. Technical note 119. Watershed Protection Techniques 2(4): 539–542.

Schueler, T. 1998. Performance of a Proprietary Stormwater Treatment Device: The Stormceptor©. Technical note 120. Watershed Protection Techniques 3(1): 605–608.

Schueler, T. 2010. Implementation plan guidance document. Ellicott City, MD: Chesapeake Stormwater Network.

Adaptive Management and Effective Implementation of Sediment TMDLs in the Lake Tahoe Basin, USA

Mark E. Grismer,[a] Kevin M. Drake,[b] Michael P. Hogan[c]*

Abstract

Sediment is a common pollutant across the United States, and determinations of total maximum daily loads (TMDLs) for sediment are under development through enforcement of the Clean Water Act. In the Lake Tahoe basin, developing a TMDL for fine sediment particles (FSPs; <16 mm) is especially important as a part of efforts to improve declining lake clarity as well as to protect and restore other beneficial uses. Local regulatory agencies are crafting guidelines directed at the determination of implementable strategies that actually achieve measurable sediment load reductions. Concurrently, adaptive management (AM) in various forms is being proposed as a potential approach to achieving TMDLs or success in other projects having environmental impacts. Here, we describe an application of the AM process to the determination of daily sediment and FSP loads from an urban redevelopment project and a watershed restoration project currently underway in the Tahoe basin. Measured upland soil treatment effectiveness and measured urban stormwater quality information is used in relatively simple distributed models of runoff and sediment delivery from the two sites. Briefly, we demonstrate how monitoring can provide a critical, potentially overlooked linkage between predicted and measured sediment loads and how AM can be used to refine sediment reduction strategies to meet TMDL targets.

Introduction

Section 303(d) of the Clean Water Act requires states to establish total maximum daily loads (TMDLs) for impaired waters in an effort to restore and maintain their chemical, physical, biological, and aesthetic integrity. Perhaps the two most challenging dimensions of the TMDL process are (a) the establishment of scientifically credible water quality standards necessary to protect beneficial uses, fisheries, and riparian habitat and (b) the development of proven stormwater best management practices (BMPs) that achieve the load reductions deemed necessary to meet the targeted water quality goals. Herein, we focus on the latter challenge applied to the Lake Tahoe basin, where an effort is underway to develop a TMDL crediting and tracking program designed to assist implementers in achieving the sediment and fine sediment particle (FSP; < 16 mm) load reductions desired to restore the famed clarity of Lake Tahoe. FSPs in the Lake Tahoe basin are of particular concern because of their light-scattering effects while in suspension and their propensity to transport nutrients (e.g., total phosphorus).

TMDL implementation programs vary widely, but because of hydrologic variability and system complexity, hydrologic models are often used to predict possible load reductions associated with the different load reduction methods deployed. However, after the generation of model predictions and project implementation, robust follow-up monitoring to evaluate project effectiveness—or whether anticipated load reductions were actually achieved—may be lacking. Without such monitoring, TMDL credits granted for the project cannot be verified.

Every TMDL program is faced with the task of linking the performance of site-specific stormwater BMPs and erosion control BMPs (e.g., straw sediment basins or vaults, disturbed soils restoration, or bioswales) to local site- or watershed-scale daily load reductions such that regulatory agencies can apply the proper TMDL credits. For sediment or FSP TMDLs, this is especially difficult since the quantitative factors controlling soil erosion and hydrologic processes—as well as changes associated with treatment efforts necessary for the credible prediction of streamflows and loads—may be unavailable, or inadequately quantified. Because urban stormwater is more readily collected and likely represents one of the greatest opportunities to resolve the lake clarity problem, Nevada Division of Environmental Protection (NDEP) and the Lahontan Regional Water Quality Control Board (Lahontan Board) developed the Lake Clarity Crediting program. One core piece of this program is the Pollutant Load Reduction Model that can be used to estimate average annual decreased sediment loads associated with various BMPs deployed by local entities to obtain "clarity credits" towards meeting TMDL goals. Several rapid assessment tools have been developed to annually assess the condition of specific treatment BMPs as a proxy for BMP performance or load reduction effectiveness. These annual condition as-

---

a Professor of Hydrology and Biological and Agricultural Engineering, University of California, Davis, Departments of Land, Air, and Water Resources and Biological and Agricultural Engineering, Davis, CA, megrismer@ucdavis.edu

b Senior Planner, Integrated Environmental Restoration Services, Inc.

c Principal Scientist, Integrated Environmental Restoration Services, Inc.

** Corresponding author.*

sessments for specific BMPs determine the number of clarity credits awarded for a project each year. Many explicit assumptions built into the Lake Clarity Crediting Program provide opportunities for hypothesis testing and the use of applied adaptive management (AM) in the TMDL program.

While we have measured soil restoration or treatment effectiveness at the plot (1 m^2) and, to a lesser extent, hillslope (1 ha) scales in the Tahoe basin, these results are difficult to link directly to watershed-scale sediment-loading response without appropriate scaling (Grismer et al. 2008; Grismer, forthcoming [a]). Moreover, changes in daily loads are very difficult to attribute to specific land use conditions or treatment actions across the watershed because treated areas are often small relative to the overall watershed, and in-stream channel sediment transport variability can be large. Similarly, in urban settings, researchers often do not evaluate the performance of stormwater treatment *trains* (i.e., the use of BMPs in series) in terms of actual daily or annual sediment load reductions following implementation. In both cases, modeling efforts are required to organize the information, predict future performance (load reductions), and form testable hypotheses after project implementation. In practice, however, researchers often do not verify some of the model's critical assumptions and/or hydrologic and erosion factors with direct field measurements.

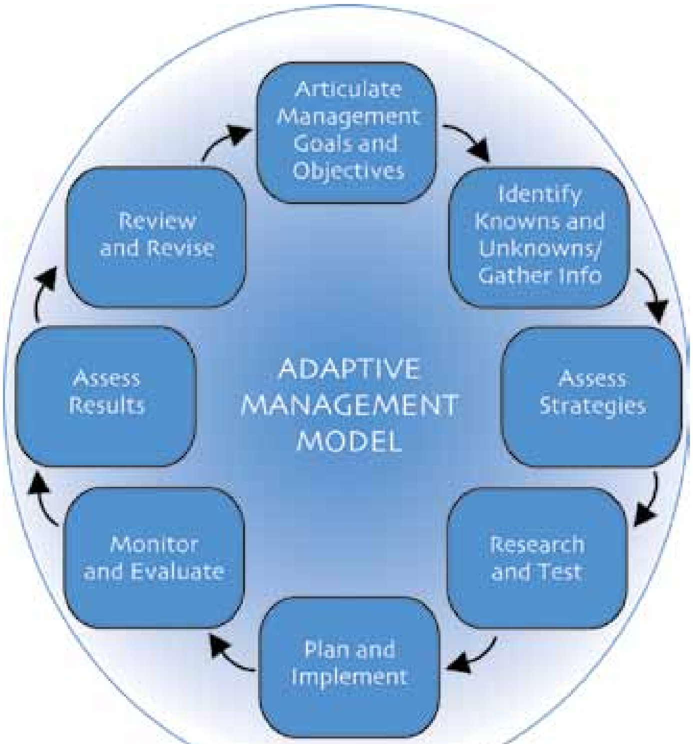


Figure 1. Illustration of the AM cycle as it may be applied to TMDL projects.

Nowhere is this observation truer than at Lake Tahoe, a subalpine lake whose basin straddles the border of California and Nevada in the Sierra Nevada. The lake is losing its famed clarity because of excess FSP and nutrient loading. Based on modeled estimates of historic lake loading rates, the NDEP and Lahontan Board have indicated that a 65% decrease in FSP loads will be needed to restore lake clarity (California Water Boards and Nevada Division of Environmental Protection, 2008). The Lake Tahoe TMDL program has also set an interim (20-year) transparency goal that will require a 32% reduction in FSP loads (California Water Boards and Nevada Division of Environmental Protection, 2010). We are in the process of evaluating critical assumptions about the sources and magnitudes of FSP loads and the load reduction effectiveness of various treatment approaches in the current TMDL program.

AM represents a promising framework for testing modeling assumptions and BMP effectiveness, addressing information gaps, and supporting effective TMDL implementation in conditions of substantial uncertainty, while simultaneously implementing these strategies to begin load reductions. The use of AM as a resource management technique began in the 1970s (Holling 1978), with various definitions evolving in the literature (e.g., Walters 1986; Parma et al. 1998; Shea et al. 1998; Callicott et al. 1999). Perhaps one of the most notable applications of AM was related to the successful maintenance of fisheries stocks in the Pacific Northwest (Gunderson, 1999).

Though definitions vary, the basic AM concepts remain simple and appealing (see Figure 1). AM begins with a clarification of goals and objectives, followed by the incorporation of all stakeholder and other available knowledge as well as the identification of knowledge gaps. Recognizing the information shortcomings, AM suggests the development of a project plan that includes monitoring designed to advance the information needed both to improve future modeling and implementation and to determine the relative success of the current implementation. Project goals and objectives (e.g., TMDL targets or fish stock quantities) are translated into measurable success criteria, which serve as triggers for possible corrective management actions (determined *a priori*) or project reevaluation. Success criteria and management responses are viewed not only as a means to achieve the initial objectives, but also as a process for learning more about the system(s) being managed and thereby improving future treatment efforts. Monitoring and development of applicable (quantitative) knowledge is included in project costs and is an inherent objective and foundational element of AM (Elzinga et al. 1998). In other words, the AM process represents a paradigm shift toward hypothesis-driven approaches in which initial outcomes affect future management actions and away from those that limit future inquiry by deploying unverified "solutions" on the basis of an assumed outcome.

To address the challenges inherent to both the determination and the implementation of sediment TMDLs, we advocate use of the AM model (see Hogan and Drake 2009, for sediment source control) for developing and evaluating load reduction methods at the project scale in the Tahoe basin. Herein, we follow the AM approach in describing two case studies, reflecting restoration projects currently underway, to discuss how monitoring can be used to help set TMDLs, evaluate relative success in achieving load reductions, and provide information that can guide the improvement of sediment reduction strategies and hydrologic model predictions.

Adaptive Management Case Studies: Modeling Approach and Linkage to Future Monitoring

Our objectives in this section are to: (a) demonstrate the use of a modeling approach that is based on several years of data collection to predict daily sediment loads and possible reductions from the Boulder Bay (BB) urban redevelopment area on Lake Tahoe's north shore and the Homewood Creek (HMR) watershed on the lake's west shore and (b) illustrate how AM can be applied on a site or program scale to measure, track, and support more effective implementation of sediment TMDLs. We will incorporate the modeling results from both projects into a field-based assessment whereby predictions are treated as hypotheses as well as targets for performance monitoring.

Part of the basic information needs in the AM process is the determination of existing and proposed land use type areas and related hydrologic conditions necessary for modeling. By way of example, Tables 1 and 2 summarize the pertinent land use information for the BB and HMR project areas, respectively. The largely forested HMR project involves the restoration of dirt roads and degraded ski runs, while the BB project involves the redevelopment and restoration of a combined impervious and degraded building site to be converted into a park area.

Table 1. Boulder Bay project area land uses (6.58 ha total on granitic soils)

LSPC Land Use	Area (m2)	Percentage of Project
Utility—Pervious	3,948	6.0
Utility— Impervious	30,270	46.0
Roads—Paved	9,344	14.2
Park	22,259	33.8

Note: LSPC, Loading Simulation Program in C++.

Table 2. Homewood Creek watershed characteristics and land uses (260.9 ha total, 89% volcanic soils).

Land Use Category	Area (m2)	Percentage of Basin	Slope (%)
Utility—Pervious	7,082	0.45	10.6
Utility—Impervious	4,768		17.9
Paved Roads	15,013	0.57	18.5
Dirt Roads	84,497	3.24	49.3
Ski Areas	439,173	21.2	49.6
Forests	19,130,000	73.3	47.3
Residential Areas	31,451	1.21	14.0

The modeling of watershed or stormwater runoff processes facilitates the organization of quantitative knowledge, the ready identification of information shortcomings, and the development of testable predictions. As suggested by Merritt et al. (2003), to inform land management decisions based on load (sediment and nutrient) allocations for the HMR watershed case study, we employed the US Environmental Protection Agency (USEPA) semi-distributed watershed model, Loading Simulation Program in C++ (LSPC; California Water Boards and Nevada Division of Environmental Protection 2008). Using annualized averaging from the 1994–2005 water year (WY) period, we first used LSPC to estimate appropriate TMDLs for each of the 182 catchments composing the Lake Tahoe basin. With precipitation (rain or snow) as the input driver and land use, soils, slope, and drainage channel network as the playing field, the model explicitly integrates the simulation of land and soil contaminant runoff with instream processes. That is, from the perspective of land allocation of sediment and nutrient loading, LSPC enables the linkage of instream water quality directly to point and nonpoint source loads.

We applied the LSPC model on a daily (rather than annualized) basis to determine the daily sediment loads for HMR based on the different land uses and associated runoff-dependent, upscaled sediment yield functions. These functions relate sediment load per unit runoff to soil type, slope, and FSP fraction at the 1-m^2 scale; we determined them from adaptively managed field rainfall simulation (RS) tests of progressively modified soil restoration strategies (Grismer and Hogan 2004, 2005a, 2005b; Grismer et al. 2008, 2009) across the basin. Use of the sediment yield functions reduced parameterization concerns because a daily time-step is deployed, upscaling factors were small, and plot-wise variability is averaged across the hillslope to watershed scales (Grismer, forthcoming [a]). For example, in the HMR watershed, the upscaling multiplier for 1 mm of runoff is 0.1917, indicating that RS plot-scale loads were approximately five times that needed to represent the watershed sediment loading.

A similar, though simpler, approach was used to model daily runoff and sediment loads from BB. For BB, the site drainage design routes all stormwater runoff after filling limited storage in low-impact development (LID) approaches, such as green roof and pervious pavement technologies, into tanks, infiltration galleries, and detention basins. In this case, the best available land use–dependent sediment yield information was determined from a recent stormwater runoff monitoring study (Heyvaert et al. 2008) at the existing site; we then used this information for the proposed BB project area.

Modeling uncertainties in both cases reflected a lack of field-derived knowledge of the actual performance of the various BMP, LID, or soil restoration strategies at the site or watershed scales. At HMR, uncertainty remains about the upscaling factors estimated from modeling comparisons with streamflow and loading data; these factors require further verification, which is currently underway. Similarly, at the BB site, factors that remain uncertain include the actual post-project BMP, LID, and soil restoration sediment yields as well as the performance parameters of the tanks, detention basins, and infiltration galleries with respect to sediment and FSP removal at the site scale.

AM Hypothesis Testing

Our approach to evaluating the successful achievement of TMDL targets (e.g., the overall 65% FSP load reduction at Tahoe) involves a determination of daily accumulated sediment loads from dry and wet year hydrology under existing and proposed project conditions followed by a reanalysis of this loading after project implementation (e.g., soil restoration and/or the installation of stormwater BMPs) and subsequent comparison. Though the original system designs were based in part on standard engineering design storms, the use of actual precipitation data to determine sediment loads enables (a) the incorporation of changing soil moisture conditions resulting from successive storms rather than a simple evaluation of possible loads from a single design storm, (b) load determination for actual runoff events that are likely to recur such that post-implementation performance can be evaluated, and (c) the determination of accumulated annual loading for the watershed or project area such that targeted reductions can be identified or determined for downstream water bodies.

Treating model predictions as hypotheses to be tested is a critical step toward developing an accurate understanding of actual treatment outcome

With the pre-project predicted and post-project measured accumulated load comparisons, we will test several hypotheses of concern to TMDL crediting; the specific hypotheses to be tested will continue to evolve as outlet (HMR, or BB site drainage culverts) monitoring data are developed. Possible hypotheses to be tested include the following:

- How critical is antecedent moisture (soil or rain) toward the evaluation of infiltration-type stormwater treatment performance?
- Must a minimum antecedent moisture threshold be exceeded prior to sediment discharge from infiltration-type systems?
- Are sediment and FSP removal rates in all systems rain intensity–dependent?
- Does upslope soil restoration actually increase site- or watershed-scale infiltration capacity and FSP capture while decreasing sediment yields from treated areas?

We underscore that the paradigm shift toward inquiry in the AM process is somewhat similar to the design, build, and testing process common to engineering practice. For stormwater runoff, real reductions in sediment, FSP, or nutrient loads from either the urban or forested land uses rely on a reduction in surface runoff (infiltration or capture), a reduction in sediment or nutrient yields per unit of runoff (soil restoration or stormwater treatment), or a combination thereof.

In both case studies here, we consider daily loading results in the context of accumulated sediment load (kg) for an example wet (1995 WY) and dry water year (1994 WY) to illustrate how the AM approach can be used both to refine project design and to inform future monitoring results. Considering pre- and post-project sediment loads first for the BB site, Figure 2 illustrates the accumulated sediment loads determined for pre-project installation of 20-year design storm BMPs only and proposed project conditions during the 1994 and 1995 (dry and wet, respectively) water years. Based on very limited stormwater sampling, we anticipate that the FSP fraction of the sediment load will be about 90% of the total sediment load from this urban setting. Note that in Figure 2(a), the predicted sediment load from the proposed project during the dry water year is zero with only two events leading to sediment discharge from the minimum 20-year design BMPs, but considerable sediment loads from the site under current conditions are predicted. In Figure 2(b), sediment loads from current conditions are not shown as they are only slightly greater than that from the 20-year BMP design (13,300 vs. 10,060 kg/year) and far greater than the predicted project load of 2,610 kg/year. Overall, model predictions suggest that proposed project storage will be capable of containing all stormwater during low-precipitation years, and that from all but six storm events during a very wet water year. Such a conclusion will be tested with post-project monitoring and, if it is not achieved, additional treatments or BMPs will be installed to ensure that no discharge occurs during similar dry water years. In contrast, considerable sediment loading occurs under current conditions in dry and wet water years but could be contained by the 20-year BMP design in dry years and only partially contained during a very wet water year. Thus, regulators and project designers should then convene to determine whether such a "20-year" design capacity is adequate for project implementation, TMDL targets, and sufficient TMDL credits to proceed with project permitting.

For the HMR watershed, we developed sediment load graphs similar to those outlined here for the BB site (not shown). In the HMR example, we considered levels of sustained restoration efforts for the more disturbed, erodible land uses (e.g., dirt roads and ski runs) such that watershed soil functionality was improved. The RS test plot data used to develop the plot-scale sediment yield functions indicated that the FSP fraction of the sediment loads from the slightly disturbed soils of HMR are expected to range from 40% to 55% of the total compared to 90% from urban areas. However in this case, hydrologic variability casts hypothesis testing in terms of confidence levels (single-tailed *t*-distribution tests) by which streamflow and load measurements can indicate successful improvements in soil functionality that were registered at the watershed scale (Grismer, forthcoming [b]). At this point, we are measuring HMR flows and sediment concentrations during the spring snowmelt periods in 2009 and 2010, following partial watershed restoration in 2008 and 2009, as a means of determining soil restoration impacts at the watershed scale prior to full project implementation.

> *For stormwater runoff, real reductions in sediment, FSP, or nutrient loads from either the urban or forested land uses rely on a reduction in surface runoff (infiltration or capture), a reduction in sediment or nutrient yields per unit of runoff (soil restoration or stormwater treatment), or a combination thereof.*

Importance of Monitoring and Results Assessment to the AM Process

As described above, the AM process requires project performance monitoring after installation to test hypotheses and improve model parameters and, we hope, future implementations. In the case of Lake Tahoe, monitoring costs are largely shouldered by the developer as they are built into the permit process. Using the data in Figure 2, regulators can advise the redevelopment project as to the design level sufficient to meet TMDL goals. Moreover, if pre-project TMDL crediting for the achievement of load reductions is considered part of project implementation, monitoring should be required to verify model-predicted loads as well as possible redesign and implementation to ensure the attainment of prescribed load reductions. Similarly, in the HMR watershed, though complicated by hydrologic variability, substantial dirt road restoration (50% by area, or 1.6% of the HMR catchment) results in model-predicted reductions of mean daily sediment loads by 12–30 kg for average daily flows of 99–804 L/second (3.5–28.4 ft^3/second) in the 1994–2005 water years. Such reductions require further verification with monitoring data that are currently being collected. Other model results suggest that monitoring for specific time periods (spring snowmelt) and flowrates may enable the detection of

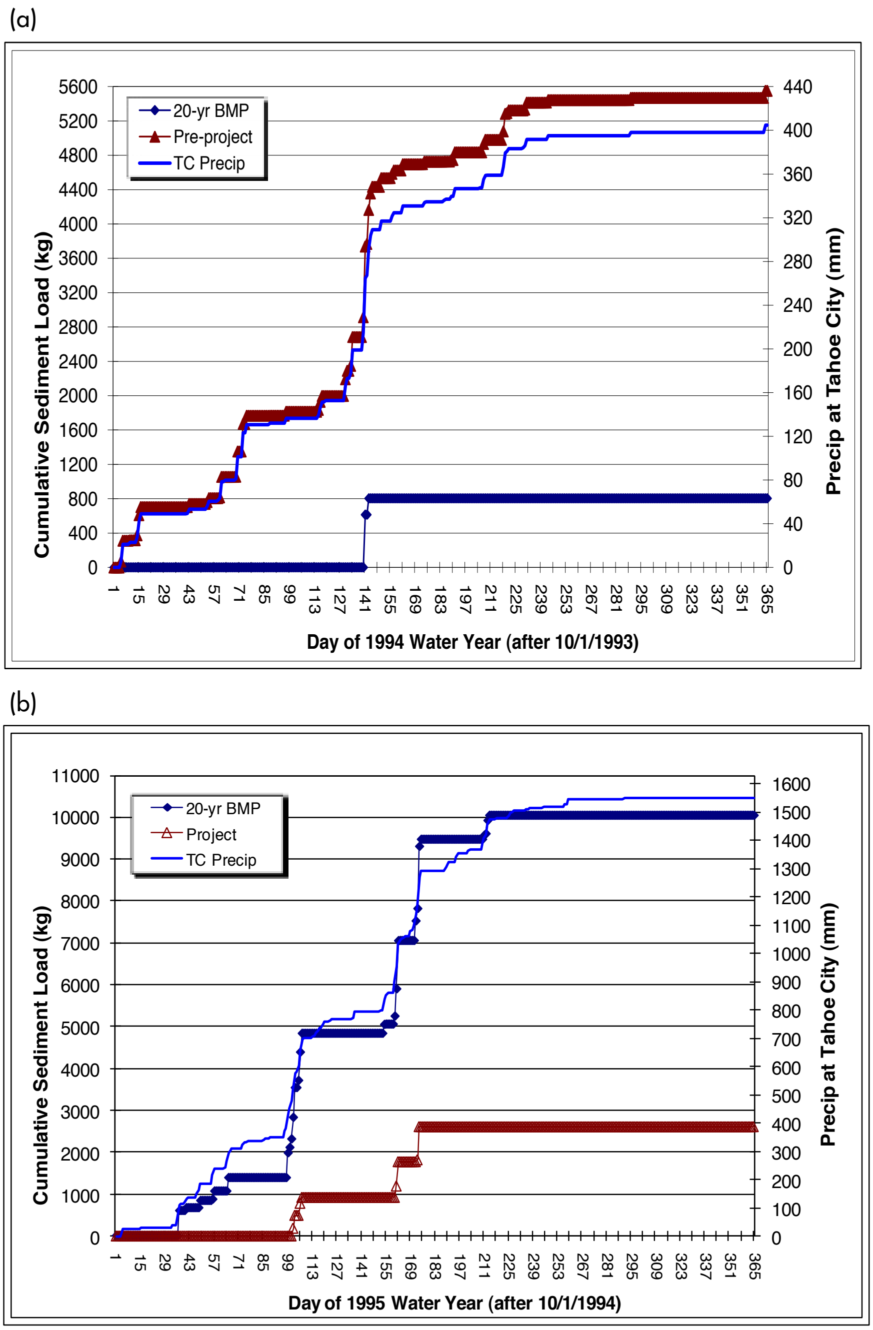


Figure 2. Predicted accumulated sediment loads from the Boulder Bay site under pre-project and 20-year BMP design (flow/load is zero under project design) in 1994 WY (a) and under 20-year BMP and project conditions in 1995 WY (b). TC, Tahoe City.

> *…predictions suggest that proposed project storage will be capable of containing all stormwater during low-precipitation years… in contrast, considerable sediment loading occurs under current conditions in dry and wet water years…*

load reductions associated with restoration in less than five years (Grismer, forthcoming [b]). At this time, proponents of both project (and local government entities, such as counties installing new stormwater treatment or BMP projects) will be committed to monitoring for several years so as to be able to include dry and wet year effects on system performance. Such monitoring information is necessary to (a) allow appropriate project crediting by the Tahoe Regional Planning Agency, the bi-state regulatory agency charged with TMDL implementation for the Lake Tahoe basin; (b) determine whether such predicted load reductions are even possible; and (c) improve the knowledge base needed for the site or watershed modeling required to estimate loads under the range of conditions found across the basin.

Closure

To effectively implement and accurately assess the progress and outcomes of TMDL efforts, we suggest that it is necessary to base initial modeling efforts on directly measured runoff, water quality, and climate data and to link modeling assumptions to a clearly articulated AM implementation process supported by this quantitative performance monitoring. Treating model predictions as hypotheses to be tested is a critical step toward developing an accurate understanding of actual treatment outcomes.

We have attempted to show how an AM approach and post-project performance monitoring can be used to assess actual project outcomes and refine treatment strategies. Employing such an approach provides a real-time feedback loop that will enable land managers, regulatory personnel, and other stakeholders to develop an increasing understanding of sediment and FSP reduction strategies related to TMDL crediting in the Tahoe basin. We suggest that the most cost-effective approach to TMDL implementation is based on the development of an accurate understanding of treatment and BMP effectiveness through field measurements at the project scale, rather than a reliance solely on modeled predictions. Those field measurements should be used to further calibrate and/or parameterize the models employed so that their predictive power is increased and load reduction technologies improved. This monitoring effort is included as part of the project permitting process to ensure that future monitoring costs are considered in the initial planning.

REFERENCES

California Water Boards and Nevada Division of Environmental Protection. 2010. Final Lake Tahoe total maximum daily load report. Draft, June 2010 California Water Boards and Nevada Division of Environmental Protection.

California Water Boards and Nevada Division of Environmental Protection. 2008. Lake Tahoe TMDL pollutant reduction opportunity report. v. 2.0, March. California Water Boards and Nevada Division of Environmental Protection.

Callicott, J. B., L. B. Crowder, and K. Mumford. 1999. Current normative concepts in conservation. Conservation Biology 13:22–35.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. Technical reference. 1730-1. Denver, CO: Bureau of Land Management.

Grismer, M. E. Forthcoming (a). Erosion modeling for land management in the Tahoe Basin—Scaling from plots to small forest catchments. Journal of Environmental Management (Submitted).

Grismer, M. E. Forthcoming (b). Erosion modeling for land management in the Tahoe Basin—Soil disturbance and restoration detection thresholds. Journal of Environmental Management (Submitted).

Grismer, M. E., A. L. Ellis, and A. Fristensky. 2008. Runoff sediment particle-sizes associated with soil erosion in the Lake Tahoe Basin. Land Degradation & Development 19:331–350.

Grismer, M. E., and M. P. Hogan. 2004. Evaluation of revegetation/mulch erosion control using simulated rainfall in the Lake Tahoe Basin: 1. Method assessment. Land Degradation & Development 15:573–588.

Grismer, M. E., and M. P. Hogan. 2005a. Evaluation of revegetation/mulch erosion control using simulated rainfall in the Lake Tahoe Basin: 2. Bare soil assessment. Land Degradation & Development 16:397–404.

Grismer, M. E., and M. P. Hogan. 2005b. Evaluation of revegetation/mulch erosion control using simulated rainfall in the Lake Tahoe Basin: 3. Treatment assessment. Land Degradation & Development 16:489–501.

Grismer, M. E., C. Shnurrenberger, R. Arst, and M. P. Hogan. 2009. Integrated monitoring and assessment of soil restoration treatments in the Lake Tahoe Basin. Environmental Monitoring & Assessment 150:365–383.

Gunderson, L. 1999. Resilience, flexibility and adaptive management–antidotes for spurious certitude? Conservation Ecology 3(1):7.

Heyvaert, A. C., A. T. Parra, C. C. Strasenburgh, and R. P. Townsend. 2008. Brockway project area stormwater runoff and characterization study. March. Reno, NV: Desert Research Institute.

Hogan, M. P., and K. M. Drake. 2009. Sediment source control handbook: An adaptive approach to restoration of disturbed areas. A Sierra Business Council publication. South Lake Tahoe, CA: Lahontan Regional Water Quality Control Board.

Holling, C. S. 1978. Adaptive environmental assessment and management. New York: John Wiley.

Merritt W. S, R. A. Letcher, and A. J. Jakeman. 2003. A review of erosion and sediment transport models. Environmental Modeling & Software 18:761–799.

Parma, A. M., and the NCEAS Working Group on Population Management. 1998. What can adaptive management do for our fish, forests, food, and biodiversity? Integrative Biology 1:16–26.

Shea, K., and the NCEAS Working Group on Population Management. 1998. Management of populations in conservation, harvesting, and control. Trends in Ecology & Evolution 13:371–375.

Walters, C. 1986. Adaptive management of renewable resources. New York: MacMillan.

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.

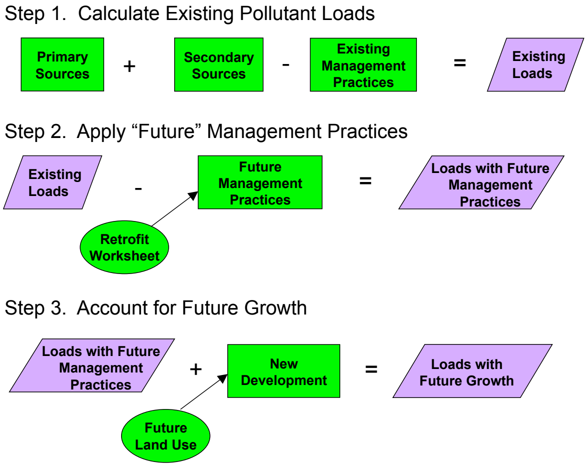


Figure 1. Model structure of the WTM. Note that the purple boxes refer to loads, including both pollutant loads and runoff volumes. The oval shapes are "support" worksheets of the WTM that provide input to another calculation sheet.

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.

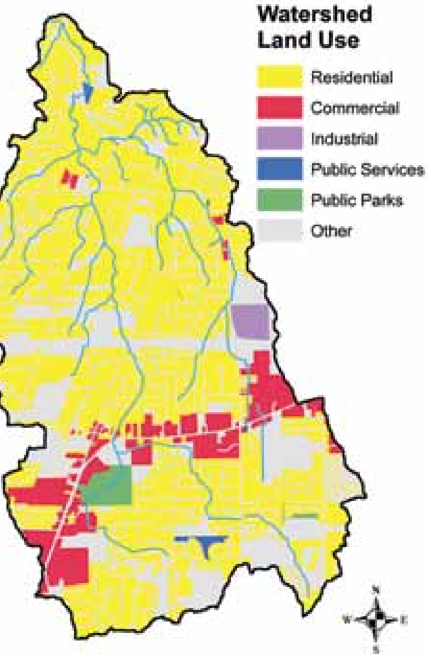


Figure 3. Land use data derived from Monroe County's parcel layer.

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%

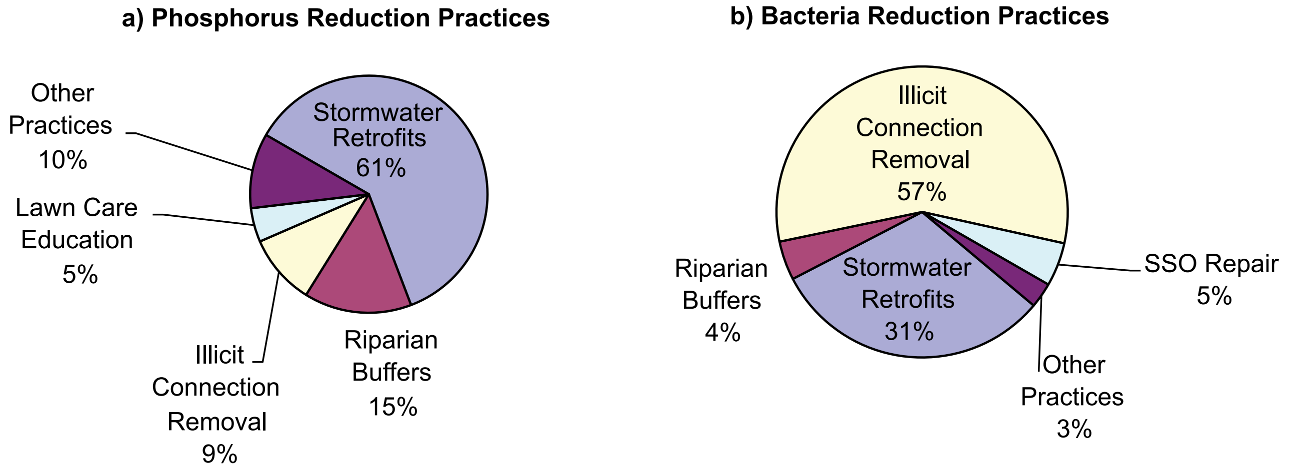


Figure 4. Estimated pollutant removal attributable to various management practices for phosphorus (a) and for bacteria (b).

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.

REFERENCES

Arnold, C. L., C. Bellucci, K. Collins, and R. Claytor. 2010. Responding to the first impervious cover-based TMDL in the nation. Watershed Science Bulletin Fall: 11-18

Caraco, D. 2002. Watershed Treatment Model—Version 3.1. Prepared for the US Environmental Protection Agency Region V and the Office of Wetlands, Oceans, and Watersheds. Ellicott City, MD: Center for Watershed Protection.

Hirschman, D., K. Collins, and T. Schueler. 2008. Technical memorandum: The runoff reduction method. Prepared for the US Environmental Protection Agency Office of Wastewater Management. Ellicott City, MD: Center for Watershed Protection and Chesapeake Stormwater Network.

Kitchell, A., and T. Schueler. 2005. Unified stream assessment: A user's manual. Urban subwatershed restoration manual no. 10. Ellicott City, MD: Center for Watershed Protection.

Wright, T., C. Swann, K. Cappiella, and T. Schueler. 2004. Unified site and subwatershed reconnaissance: A user's manual. Urban subwatershed restoration manual no. 11. Ellicott City, MD: Center for Watershed Protection.

New York State Department of Environmental Conservation. 2010. SPEDES General Permit for Stormwater Discharges from Municipal Separate Storm Sewer Systems; Permit No. GP-0-10-002. Part III.B, page 11

Reducing DDT and Sediment Loads in the Yakima River: A Success Story

The Yakima River valley in central Washington State is a major agricultural region producing corn, hops, orchard fruits, grapes, and mint. Fish sampled in this river in the 1980s had some of the nation's highest concentrations of DDT, a pesticide banned in 1972 because of its toxic effects on humans and wildlife. As a result, the Washington State Department of Health issued a fish consumption advisory for the river. In 1994, the Washington State Department of Ecology (Ecology) began work on a total maximum daily load (TMDL) for DDT in the lower Yakima River.

The Yakima River valley is one of the most intensively irrigated areas of the nation and, in the mid-1990s, many growers in the area used inefficient rill and furrow irrigation methods. Irrigation returns were laden with suspended eroded soil, and legacy pesticides, such as DDT from historic application, were attached to the soil particles.

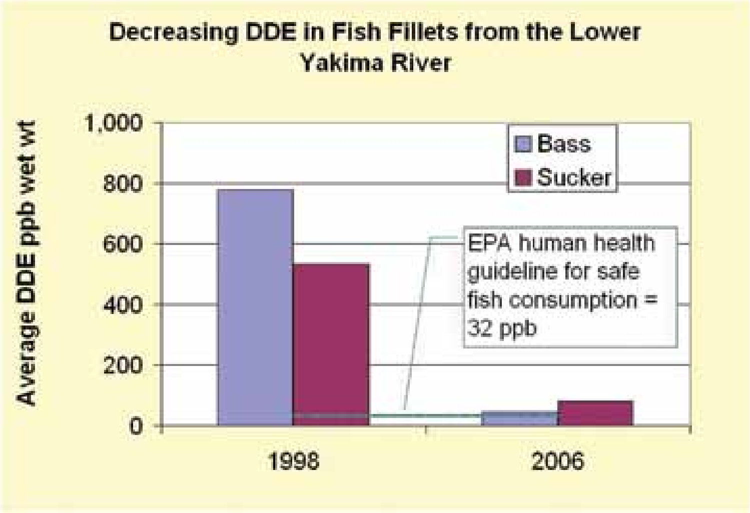


Figure 1. Decreasing DDE (the most persistent metabolite of DDT) in Fish Fillets from the Lower Yakima River

Because of the difficulty and expense of DDT analysis, Ecology found a surrogate contaminant that could be more easily monitored. Ecology scientists found strong correlations between DDT and total suspended sediment (TSS), and between TSS and turbidity. The 1998 TMDL set allocations for DDT, TSS, and turbidity, requiring TSS reductions of 89% to 98% within ten years. The numeric targets were a key component in the success of this reduction effort; earlier, less focused attempts to reduce DDT and sediment in the basin had failed.

Two of the valley's irrigation districts, the Roza and Sunnyside Valley Irrigation Districts, operating as the Roza Sunnyside Board of Joint Control, adopted policies requiring farmers to achieve turbidity goals, which became more stringent each year to meet the TMDL allocations' ten-year time frame. The districts established a laboratory to test irrigation return waters. Growers whose returns exceeded the turbidity goal were required to write short-term and long-term plans to address the problem to avoid the penalty of reduced irrigation flow.

Ecology provided the Roza and Sunnyside Valley Irrigation Districts with $10 million from the Clean Water State Revolving Fund for loans to upgrade irrigation systems. It also provided staff to the districts to assist with water quality sampling and to advise farmers in the selection of best management practices (BMPs) for remediation plans. The Natural Resources Conservation Service, Washington State University Extension Service, and the conservation districts were also key participants, providing outreach and education on the benefits of the BMPs.

The North Yakima Conservation District implemented a demonstration project with drip irrigation on hop fields in the Moxee Drain. The advantages and cost savings of this type of irrigation became apparent to area growers. As a result, 100% of the hop fields there were converted to permanent drip irrigation, leading to a 90% decrease in sediment loading to Moxee Drain recorded between 1998 and 2003.

In the first four years after the TMDL was adopted, the Roza and Sunnyside Valley Irrigation Districts recorded an 80% reduction in daily sediment loading. Ecology's fish tissue monitoring in 2006 showed a large reduction of DDT in fish tissue, allowing the Department of Health to lift the DDT fish consumption advisory (Figure 1). The Yakima River fish advisory for DDT is the first in the nation to be removed as a result of a TMDL and subsequent reduction measures.

All of this was done without shutting off a single farmer's water. Leadership on the part of the irrigation districts was crucial to success. The Yakima TMDL is a model for DDT reduction in areas where soil erosion from agriculture is a major source of DDT to streams.

List of Sources

Johnson, A., K. Carmack, B. Era-Miller, B. Lubliner, S. Golding, and R. Coots. 2010. Yakima River pesticides and PCBs total maximum daily load: Volume 1. Water quality study findings. Publication no. 10-03-018, April. Olympia, WA: Washington State Department of Ecology.

Joy, Joe, and Barbara Patterson. 1997. A suspended sediment and DDT total maximum daily load evaluation report for the Yakima River. Publication no. 97-321, July. Olympia, WA: Washington State Department of Ecology.

National Association of Conservation Districts. No date. TMDL case study: Washington. http://www.nacd.info/policy/environment/water/tmdl/casestudies/washington.phtml

Rinella, Joe F., Pixie A. Hamilton, and Stuart W. McKenzie. 1993. Persistence of the DDT pesticide in the Yakima River basin Washington. Circular 1090. Reston, VA: US Geological Survey.

Roza–Sunnyside Board of Joint Control. 2009. Water quality improvements in RSBOJC irrigation return waterways, 1997–2008. March. Sunnyside, WA: Roza–Sunnyside Board of Joint Control.

Washington State Department of Ecology. 2008. *Water Quality Program*. Publication no. 08-10-023, April. Olympia, WA: Washington State Department of Ecology.

For More Information

For more information, contact Ryan Anderson, Environmental Specialist, Washington State Department of Ecology, at rand461@ecy.wa.gov.

Case Study Contributors

Contributors to this case study include Helen Rueda, US Environmental Protection Agency Region 10; Ryan Anderson, Washington State Department of Ecology; Chris Coffin, Washington State Department of Ecology; Joe Joy, Washington State Department of Ecology; Mike Tobin, North Yakima Conservation District; Jim Trull, Sunnyside Irrigation District.

Thermal Load Trading in the Tualatin River Basin: A Watershed-based NPDES Permit

The low-gradient Tualatin River, located primarily in Washington County just west of Portland, Oregon, is part of the larger Willamette River basin. Roughly one-third of the watershed has been in agricultural use since the early 20th century, and the lower third of the watershed has been significantly impacted by urbanization. In particular, water temperatures have increased measurably over the past several decades. Warm rivers and streams constitute a major limiting factor for the recovery of salmonids, many species of which are listed in Oregon under the Endangered Species Act. In 2001, the Oregon Department of Environmental Quality (DEQ) issued a total maximum daily load (TMDL) for temperature in the Tualatin River, primarily to address salmonid recovery needs.

Clean Water Services (CWS), a special purpose district utility, provides wastewater collection and treatment and stormwater management services to over 500,000 residents in Washington County. The TMDL included a wasteload allocation to CWS wastewater treatment facilities that mandated a nearly 95% reduction in thermal loads (from 9×10^8 kcal/day down to 4.4×10^7 kcal/day), requiring the effluent temperature to decline from 72°F to nearly 62°F. During the summer months, discharged effluent from CWS facilities can make up over 50% of the flow in the river. The TMDL showed that approximately 40% of the thermal energy input into the Tualatin River comes from the sun's thermal energy reaching the river in altered urban and rural landscapes—essentially a loss of shade.

CWS estimated capital and operational costs of $150 million to install and operate chillers at its wastewater facilities to meet the TMDL requirement. At the same time, it recognized the opportunity to deliver greater ecological benefits by restoring streams and, with the cooperation of DEQ, chose to implement nonstructural methods by developing a thermal load trading program (shade credits) coupled with the release of stored water from two reservoirs to add cool water to the river.

The flexibility to take this approach was provided by CWS' 2004 watershed-based National Pollutant Discharge Elimination System (NPDES) permit, the first in the nation to allow temperature trading (point to nonpoint thermal load reduction credits) to comply with permit requirements. Key elements of the program include a capital improvement program, a Tree-For-All program for cities, and an Enhanced Conservation Reserve Program for rural areas. In the latter, CWS pays farmers with annual riparian land lease payments. This allows CWS, working through local soil and water conservation districts, to plant and maintain riparian areas on the enrolled land.

Since 2004, 63 urban and rural projects have planted over 1.6 million native trees and shrubs and have established 35 miles of riparian corridor; as of 2007, the riparian part of the trading option had cost $4.3 million. At the end of the five-year NPDES permit cycle, CWS had developed all of its needed credits for permit compliance plus a small surplus for future needs.

Several factors have contributed to the success of the program, including a focus on the highest priorities in the watershed for restoration and water quality improvement, regulatory flexibility, the development of important third-party partnerships, and the capacity to implement and maintain restoration on a large scale.

In response to the strong interest expressed by other utilities in the United States and abroad, Clean Water Services established the Clean Water Institute, a nonprofit 501 c3 organization, to aid other utilities in the development of water quality trading strategies and innovative approaches to watershed management.

For more information contact Bruce Roll, Director of Watershed Management, bruce@cleanwaterinstitute.org

List of Sources

Abdalla, C. 2008. Land use policy: Lessons from water *quality markets. Choices 23(4): 22–28.*

Clean Water Services. 2005. Healthy streams plan. Hillsboro, OR: Clean Water Services.

Clean Water Services. 2007. Tualatin River Flow Management Technical Committee: 2007 annual report. Hillsboro, OR: Clean Water Services.

Clean Water Services. 2009. Temperature management plan, credit trading activities, annual report. Hillsboro, OR: Clean Water Services.

Roll, B., B. Cordon, P. Guillozet, K. Petersen-Morgan, B. Vaughn, and K. Smith. 2008. Sustainable integrated watershed management in the Tualatin basin. Presented at Sustainability 2008: Green Practices for the Water Environment Conference, Washington DC.

For More Information

For more information, contact Bruce Roll, director of Watershed Management, Clean Water Services, at rollb@cleanwaterservices.org, or Bobby Cochran, executive director, Willamette Partnership, at cochran@willamette-partnership.org.

Case Study Contributors

Contributors to this case study included Tracie Nadeau, US Environmental Protection Agency Region 10, Oregon Operations Office; Bobby Cochran, Willamette Partnership; and Bruce Roll, Clean Water Services.

Optimizing Resources To Achieve Pollutant Reductions in Wisconsin

The ultimate goal for many total maximum daily loads (TMDLs) is to implement the load reduction practices and strategies that will achieve the TMDL restoration goal in a cost-effective manner, while sharing the burden of implementation equitably. This is easier said than done. However, the Wisconsin Department of Natural Resources (WDNR), along with its project partners, is steadfastly moving forward to implement such an approach to address total suspended solids (TSS) and total phosphorus (TP) in the Lower Fox River basin (LFRB) and Green Bay.

The TMDL is led by WDNR, which is working in partnership with The Cadmus Group, Inc., US Geological Survey, University of Wisconsin–Green Bay, University of Wisconsin–Milwaukee WATER Institute, University of Wisconsin Sea Grant, Green Bay Metropolitan Sewerage District, Brown County Land and Water Conservation Department, and the Oneida Tribe. As part of a pilot project sponsored by the US Environmental Protection Agency, The Cadmus Group, Inc., designed a watershed-based optimization modeling framework, shown in Figure 1. The modeling framework is intended to identify cost-effective combinations of best management practices (BMPs) to target both point and nonpoint source pollution and to achieve the load reduction goals set by the TMDL.

An initial pilot application of the optimization model (prior to TMDL development) compared agricultural BMPs, along with their implementation costs, and identified the optimal scenario—that is, the most cost-effective combination of BMPs that would achieve the TP load reduction. In addition, the pilot application estimated potential TP load reductions

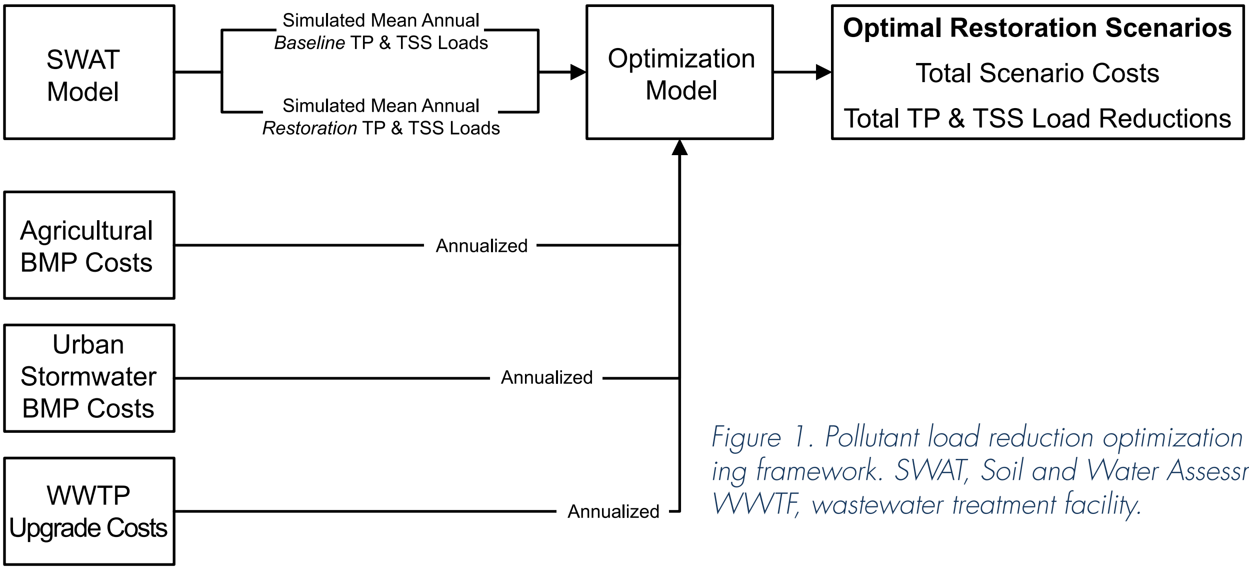


Figure 1. Pollutant load reduction optimization modeling framework. SWAT, Soil and Water Assessment Tool; WWTF, wastewater treatment facility.

and the costs associated with permitted point source facility upgrades.

The overall TP load reduction target was initially set at 50% for the pilot project. This target, which was not the final TMDL goal, was based on the targets defined as part of the 1993 Lower Green Bay Remedial Action Plan, a Great Lakes clean-up program. Modeling showed that implementation of the optimal scenario of agricultural BMPs in the LFRB would result in an estimated phosphorus load reduction of about 50,000 kg/year (21%). Point source facility upgrades in the LFRB would result in an estimated phosphorus load reduction of 45,045 kg/year (19%). Combined, these actions would result in an estimated 40% decrease in phosphorus loading to Lower Green Bay (from 238,912 to 143,700 kg/year). The cost estimates for the agricultural and point source facility upgrades were $138/kg TP and $240/kg TP, respectively. This approach fell short of the preliminary TMDL goal for TP by 10%, did not address urban areas, and did not accurately capture the true costs of point source upgrades.

The final TMDL-targeted load reductions for TP and TSS are 60% and 56%, respectively. During TMDL development, project partners ran the model a second time to identify a more cost-effective and equitable strategy by (a) identifying a more robust set of agricultural BMPs, (b) exploring a variety of treatment options for point source dischargers, and (c) determining costs for municipal separate storm sewer systems or regulated urban areas. The project partners will need to refine the model during TMDL implementation planning, possibly on a subwatershed scale, since the suite of agricultural BMPs could not meet the load allocations for the TMDL. Future model runs will incorporate programmatic costs and tailor treatment technologies to individual point source dischargers.

Optimization modeling has provided important information regarding the feasibility and costs of meeting the TMDL goals to guide local decisions about how to effectively target implementation funds. Getting the right combination of practices and costs, however, is only one part of the implementation equation. Achieving the restoration goals also requires a commitment by individuals and organizations to implement practices and change behaviors. The TMDL Outreach Team for the LFRB and Green Bay engages in extensive efforts to keep the community informed about the TMDL and to provide opportunities for input. Two mail-in surveys have helped focus outreach efforts by generating a greater understanding of pollutant sources and by developing messaging as part of implementation. The TMDL Outreach Team developed the two surveys and mailed them to 600 dairy farmers throughout the basin and 640 urban residents in the East River subwatershed. The response rate was 58% and 49% for the farming and urban surveys, respectively. The results informed the TMDL Outreach Team that, in general, extensive education and outreach is needed to better inform the public about the pollutants of concern, their contributing sources, and practices that could be implemented to improve water quality in the LFRB and Green Bay.

For More Information

For more information, visit http://dnr.wi.gov/org/water/wm/wqs/303d/FoxRiverTMDL/ or http://basineducation.uwex.edu/lowerfox/tmdl_outreach.html or contact Nicole Clayton, Water Quality Specialist, Wisconsin Department of Natural Resources, at nicole.clayton@wisconsin.gov, or Laura Blake, Senior Associate, The Cadmus Group, Inc. at lblake@cadmusgroup.com.

Case Study Contributors

Contributors to this case study include Neely Law, Center for Watershed Protection; Nicole Clayton, Wisconsin Department of Natural Resources; and Laura Blake, The Cadmus Group, Inc.

Lake Clarity Crediting Program for Lake Tahoe: An Adaptive Management Approach for Water Quality Crediting

Lake Tahoe is prized by both residents and visitors for its remarkably clear blue water. This famed lake clarity, however, has been in decline for decades. The Lake Tahoe total maximum daily load (TMDL) , currently being adopted, identifies urban stormwater as the source of 72% of fine sediment (the primary pollutant of concern), 38% of phosphorus, and 16% of nitrogen pollutant loading (California Water Boards and Nevada Division of Environmental Protection, 2010). However, after investing some $500 million in water quality restoration, stormwater managers and regulators do not have an understanding of the benefits from the pollutant controls implemented. The Tahoe basin is experiencing what a National Research Council (2008, 2) report, *Urban Stormwater in the United States*, had found across the nation: "the stormwater program has suffered from poor accountability and uncertain effectiveness at improving the quality of the nation's waters."

With this knowledge—and funding from a US Environmental Protection Agency Targeted Watershed Initiative Grant—the California Water Quality Control Board, Nevada Division of Environmental Protection, and Tahoe Regional Planning Agency focused on the development of a flexible stormwater program that rewards prioritization, innovation, and multijurisdictional cooperation. The Lake Clarity Crediting Program (Crediting Program) establishes the framework that connects on-the-ground actions to the goal of restoring Lake Tahoe clarity. It defines a comprehensive TMDL accounting system to track and report pollutant load reductions using Lake Clarity Credits that are a function of the impact of fine sediment, phosphorus, and nitrogen on clarity. Annually increasing credit targets in National Pollutant Discharge Elimination System stormwater permits and memoranda of agreement are used to define achievable goals and drive accountability.

Stormwater managers and maintenance personnel make the frontline decisions that prevent pollutants from entering the lake. Therefore, the Crediting Program puts an integrated set of modeling and condition assessment tools in the hands of engineers and field staff. The program awards credits to jurisdictions that implement and maintain structural and nonstructural pollutant controls where they are most effective. It also allows jurisdictions to distribute credits awarded for load reductions in specific urban catchments to any other jurisdiction in the Lake Tahoe basin, enabling cooperation and water quality trading.

Like typical ecosystem services accounting and water quality trading programs, the Crediting Program defines the credit by (1) using available scientific information to relate restoration actions to environmental goals and (2) embodying this scientific understanding in reasonably easy-to-use tools that generate consistent results. The resulting load reduction estimates provide an ideal hypothesis of expected environmental outcomes that can be tested by monitoring to improve the credit definition and the calibration of load reduction estimation tools.

In many programs, changing credit definitions and credit calculation tools can create regulatory compliance complications and financial ramifications for regulated entities. This uncertainty leads to a reluctance to invest resources in restoration actions and can stifle adaptive management. Without active adaptive management, the credit definition does not accurately reflect the best understanding of environmental reality over time; this ultimately undermines the program overall.

The Crediting Program enables adaptive management and continual improvement by employing a unique accounting and reporting structure and by establishing a transparent and predictable management system. A parallel load reduction and credit accounting structure creates a self-correcting mechanism whereby the credit definition and load reduction estimation tools can change without immediately changing the number of credits awarded for previously verified actions. The management system defines an annual schedule for reporting results, defining scientific and operational improvements, and updating tools and protocols. By eliminating uncertainty related to near-term regulatory compliance, stormwater managers and project developers can innovate and invest resources to achieve load reductions with confidence, and the Crediting Program can ensure that it is motivating effective actions to improve lake clarity over time.

The Crediting Program models critical features that should be included in any watershed-based ecosystem services or water quality accounting program in which (1) science and monitoring findings can improve restoration effectiveness, (2) significant public or private dollars are being invested, (3) innovation and flexibility can reduce costs, and (4) stakeholder attention requires clear reporting of results. The Lake Clarity Crediting Program ensures that credits can be trusted to reflect the best understanding of the environmental system and inspires conservation, innovation, and investment to achieve environmental goals.

List of Sources

California Water Boards and Nevada Division of Environmental Protection. 2010. Lake Tahoe total maximum daily load technical report. June 2010 California Water Boards and Nevada Division of Environmental Protection.

National Research Council. 2008. Urban stormwater management in the United States. Washington, DC: The National Academies Press.

For More Information

To find more information, including the Lake Clarity Crediting Program Handbook and associated tools, visit www.EnviroIncentives.com or contact Jeremy Sokulsky, PE, MBA, President, Environmental Incentives, LLC, at jsokulsky@enviroincentives.com or 530-541-2980.

Case Study Contributors

This case study was written by Jeremy Sokulsky of Environmental Incentives, LLC.

HAVE A QUESTION YOU'D LIKE US TO ASK OUR EXPERTS? *The upcoming Spring 2011 issue will focus on climate change and watersheds. AWSP members and Bulletin subscribers may email their questions to bulletin@awsps.org. The Bulletin features interviews with experts in the watershed and stormwater professions to discuss the topic of each issue. In this issue, three professionals weigh in with diverse perspectives on total maximum daily loads (TMDLs), sharing decades of experience with this complex process and providing suggestions for the future. Here is what our experts had to say….*

Talking Trash TMDLs with Xavier Swamikannu

Retired chief of the Stormwater Permitting Program for the Los Angeles Regional Water Board

About Xavier Swamikannu: Mr. Swamikannu is retired as chief of the Stormwater Permitting Program for the Los Angeles Regional Water Board and the California Environmental Protection Agency (CalEPA), where he developed the program over two decades. During that time, he worked extensively with municipal stormwater programs in Southern California. He also recently served as a member of the National Research Council's special committee on urban stormwater quality management in the United States.

Q: What was your role in the Los Angeles River and Ballona Creek trash TMDL process?

A: As chief of the Storm Water Permitting Program, I mainly worked with municipal separate storm sewer system (MS4) jurisdictions in the Los Angeles region. There had been a trash reduction component to the MS4 permits for a while before the trash TMDL for Los Angeles River and Ballona Creek was introduced. But many of the harbors were still filling with trash, and downstream jurisdictions, like the City of Long Beach, were having to spend a lot of money cleaning it up. In the late 1990s, both waterways were added to the 303(d) impaired waters list for their heavy trash content after storm events.

When the trash TMDLs were first developed in 2001, my role was to conform the new round of MS4 permits with the requirements of the TMDLs, so that the MS4 jurisdictions didn't have two different sets of standards to abide by. The target load in that first round of the trash TMDLs required the 42 regulated cities and the county in the Los Angeles River and Ballona Creek watersheds to achieve "zero trash" pollution in those waterways. That was seen by many as an unattainable goal. As a result, in 2003 several cities, including the City of Los Angeles, brought a lawsuit against CalEPA to have the structure of the TMDL changed. In response, a new technology-based criterion was set for localities to work toward achieving *full capture* of trash entering their storm drain systems by 2015. Our office worked with several other parties to define technical criteria that would be used to attain *full capture* of trash in storm drains. These criteria included design specifications on such things as the size of trash exclusion screening to be placed at storm drain openings and the design storm intensity that would determine trash capture device sizing. If localities install certified *full capture* devices in their catch basins, compliance with the TMDL is considered automatically achieved. Adding these specific technical criteria and connecting compliance directly to the implementation of management practices rather than to water quality monitoring results has brought the trash TMDLs into the realm of technical feasibility.

Q: What strategies seem to be working best for reducing trash loads in the watershed?

A: One approach that seems to be working well for many of the Los Angeles region jurisdictions is prioritizing those areas that are producing the most trash (like high-density residential and commercial areas) and focusing their catch basin retrofits there. It makes a lot of sense to catch and remove trash from those places that are contributing the largest mass of it.

Second, product substitution as a form of source control seems to be gaining ground and ultimately will provide the most significant reductions of harmful trash entering our waterways. Some of the major culprits that we see accumulating as trash in rivers, harbors, and beaches are being banned or restricted. For example, the City of Santa Monica passed an ordinance in 2007 banning restaurants from using styrofoam food containers. And this year, the California State Assembly passed a bill to prohibit stores across the state from giving out plastic bags to shoppers. These kinds of changes are not easy to come by—they take a long time to debate and turn into reality—but in the end, they are the changes with the broadest and most effective impact in reducing trash at the source.

Q: How do jurisdictions in the Los Angeles area track their improvements? Are reductions in trash quantities noticeable yet?

A: Each locality does it a little differently. Some quantify the amount of trash that they pull out of catch basins during their regular rounds, or after a rain event. The City of Long Beach, which sits at the mouth of the Los Angeles River, regularly removes trash from its harbor there. Since much of that trash washes down from Los Angeles County, Long Beach sends the county a bill to be reimbursed for the costs of that cleanup, based on the weight of trash removed. I do recall that Long Beach has reported a reduction in the amount of trash that the city staff have to scoop out of the harbor, so that's a good sign.

Others don't actually measure how much trash they remove, but rather keep track of the number of catch basin screens and retrofits that they install. Right now there is no standardized method for monitoring how much trash exists in the water, and there is no requirement to monitor trash that escapes. So most localities just track their progress toward retrofitting catch basins.

Q: So, how will these jurisdictions know when they have achieved the TMDL goals?

A: When they have met the goal of retrofitting 100% of their catch basins with trash screens or inserts (by 2015, hopefully). The target is based on how many practices are implemented, not on monitoring, because some trash will always get into the water.

Q: What is the attitude of local governments toward the trash TMDL?

A: As I mentioned earlier, most were opposed to the original target of achieving zero trash load, feeling that it was an unachievable goal. But they are all for reducing trash, and the public is in full support of that endeavor too. That is one of the unique aspects of a trash TMDL—it is easy to get public support for efforts to reduce such a visible and ugly pollutant. But, of course, the main concern for these local governments is cost. Despite this, it seems that city and county crews are keeping up well with maintenance. In one sense, you even have public enforcement of catch basin maintenance because if a street drain somewhere is clogged from trash and water is backing up, someone is likely to call the Public Works Department and complain.

Q: What lessons learned would you like to share with localities or regions with heavy trash loads that are considering a trash TMDL?

A: First, lay out technical standards (e.g., 5-mm screen openings to keep out cigarette butts), not just a vague goal that seems unachievable such as "zero trash." And those standards need to make sense for the landscape and for the situation in the watershed.

Second, provide some money for pilot projects in those localities that will be working toward meeting the TMDLs so they can start getting comfortable with the technologies out there. It takes some trial and error to figure out what products work best at catching trash and are easiest to maintain.

Finally, increase public awareness about the issues at hand. Citizens need to understand where the trash is coming from and what can be done about it, and they need to understand how their tax dollars are at work to help solve the problem.

Q: TMDLs have a reputation for not being implemented. What would you recommend to boost implementation?

A: We have to be able to go from identifying and assessing the pollutants we see in our receiving waters—whether they be high loads of phosphorus, sediment, or trash—to devising technologically feasible criteria for reducing those pollutants. This is what public agencies understand. Otherwise they will have no confidence in being able to achieve the TMDL. No confidence means no will or interest in putting money and energy into solving the problem at hand.

Q: What are your top two good and bad issues with TMDLs? Let's start with the good.

A: TMDLs help prioritize cleanup efforts and help create a plan for solving a real problem. Also, a TMDL creates a sense of urgency that may not exist otherwise.

Q: How about the bad issues?

A: Most TMDLs across the country take a pollutant-by-pollutant approach to solving water quality problems, rather than an integrated approach by which you tackle several pollutants in one plan. This becomes quite burdensome for communities. Regulatory agencies need to provide more flexibility for localities to integrate various TMDLs that may have many similar, overlapping solutions.

Also, TMDL numbers have a lot of uncertainty associated with them, which causes me heartache. Localities are told, "Here is your load allocation, now do something." Well, this allocation needs a planning target—some tangible goals. As I've said, communities are much more willing to invest in specific implementation actions that demonstrate progress than in some far-off objective way down the road. Unfortunately, I think that most TMDLs have been set up without integrating and emphasizing those intermediate tangible goals.

Q: Where do you think TMDLs are headed in the future?

A: I hope that we can move to a watershed-based integrated approach to developing TMDLs. Action-oriented implementation plans are a must. And finally, more research needs to be a part of TMDL plans so that communities can better understand how their management practices are affecting the health of the water bodies they are trying to improve.

–Interviewed by Laurel Woodworth,
Center for Watershed Protection

An Advocate's Perspective on TMDLs from Rick Parrish

Senior attorney at the Southern Environmental Law Center

About Rick Parrish: Mr. Parrish is a Senior Attorney at the Southern Environmental Law Center in Charlottesville, VA. He has worked on TMDL law and policy for over 20 years, including serving on the federal advisory committee on TMDLs in the late 1990s. At SELC, Rick works with national, state and local environmental groups on a wide range of water resource issues.

Q: How have you worked with TMDLs in the past?

A: My experience has been lengthy. I was introduced to TMDLs in the late 1980s as a board member for a nonprofit in Oregon. That organization was a plaintiff in one of the first successful cases against the US Environmental Protection Agency (USEPA) to get the TMDL program on track. Two years later, I came to work for the Southern Environmental Law Center (SELC). In the early 1990s, we were discussing how to move TMDLs forward in the south. SELC instigated some of the early lawsuits and later filed some ourselves. Eventually, there was a groundswell of litigation against USEPA. In the late 1990s, the director of USEPA's Office of Water assembled an advisory committee to straighten out the TMDL program, and I was one of the four representatives from environmental organizations to serve on that committee.

At about the same time, I was advising watershed advocates on the best way to participate to get state TMDL programs in the south up and running and was involved in lawsuits in Alabama and Tennessee. We found the program to be pretty frustrating, as the old rules never required the implementation of TMDLs, except perhaps through tighter National Pollutant Discharge Elimination System (NPDES) permits. As a result, most of the approved TMDLs are sitting on the shelf somewhere. More recently, I have been following the Chesapeake Bay TMDL very closely and I serve on Virginia's Watershed Implementation Plan Stakeholder Advisory Committee.

Q: What are your top two good and bad issues with TMDLs? Let's start with the good.

A: First, the TMDL program allows for a comprehensive look at water quality within a specific geographic area—not just from a single pipe, factory, industry, or farm. It allows us to look at all of these things in combination and figure out how to protect water quality.

The second good thing is that the program improved the assessment of water quality and, importantly, public awareness of that assessment. The early lawsuits came about because the states weren't even assembling the 303(d) lists of impaired waters, even though this was part of the original Clean Water Act (CWA) legislation in 1972. Now, these water quality assessments and listings are routine.

Q: How about the bad issues?

A: Well, one could argue that a lot of money has been spent on TMDLs that don't have a prayer of being implemented. In some regards, it has become a bean-counters problem. According to USEPA guidance, states are supposed to develop TMDLs within 10 to 12 years of a water body's listing, so most of the motivation to meet this deadline is to get the beans counted. In some cases, quality is sacrificed in the name of speed.

A related drawback is that TMDLs have heightened the public's expectations that water quality problems will be fixed. TMDLs do provide data and information, but fixing the problem will only occur if there is commitment and follow-up action, which require time and money.

Q: Where do you think TMDLs are headed in the future?

A: We need more implementation and more accountability. TMDLs have to become effective at restoring water quality, and two big components that are lacking are implementation and accountability. Without those, it is an academic exercise.

Q: How do you think that TMDLs should be linked with MS4 permits?

A: MS4s should comply with water quality standards; otherwise, they are a blanket exemption from the rules that govern all point source dischargers. However, it will be difficult, and the program needs to be realistic about timeframes—it won't happen overnight. For many local governments, these are new duties, and they need technical and financial assistance.

At the same time, we need to stop being afraid of requiring local constituencies to pay, at least in part, to correct local problems. In this regard, stormwater utilities are very positive. Passing the buck (to state or federal levels) or saying that we won't act until the state or federal government gives us money are weak excuses.

Q: What would you recommend to boost the implementation of TMDLs?

A: I would recommend detailed implementation plans (IPs) as part of each TMDL. The Chesapeake Bay TMDL will have IPs and measurable milestones in two-year increments; both concepts are from the 2000 rules. You have to be able to tell if you're making progress. Also, TMDLs need to account for and plan for growth. In jurisdictions where the population is growing, you can't assume that if you meet the loads, then you are done. This doesn't mean that growth should be stopped, but rather that it should be planned for in the TMDL process. This has never been a required component of a TMDL, though EPA does recommend it. Most TMDLs—if they are good ones—will have an allotment for future growth or will explain the requirement for future offsets.

Q: How do you think that USEPA and the states can or will enforce nonpermit (unregulated) pollution sources, such as agriculture and smaller municipalities? Do you think that agricultural sources should ever be regulated in the context of TMDLs?

A: Since USEPA has no regulatory authority over conventional agriculture, it's up to the states in the first instance to take the necessary steps to rein in runoff from nonpoint sources. Smaller municipalities can be designated as MS4s through USEPA's residual designation authority under the CWA if necessary findings are made about contributing to the Bay's impairments. But agriculture is a dilemma . . . I would love to see voluntary programs succeed, but I'm very skeptical. I think that ultimately we will need to impose some type of regulations on agricultural sources if we want the Bay TMDLs to succeed in restoring water quality. However, I suspect that many of the better farming operations are already meeting whatever requirements might have to be adopted, so the actual impact may not be as burdensome as feared.

Q: Anything else?

A: TMDLs are a simple concept, but not an easy one. It will continue to be a difficult challenge—one in which we all have to work together in pursuit of a common goal of restoring and protecting water quality.

–Interviewed by David Hirschman,
Center for Watershed Protection

Connecting the Dots between TMDLs and MS4s, a discussion with Michael Bateman

Deputy bureau chief, Resource Regulation, Northwest Florida Water Management District

About Michael Bateman: Michael Bateman has over 25 years of experience in environmental engineering, including over 13 years with the Florida Department of Environmental Protection. He has extensive experience in private practice working in land development, civil engineering, and environmental consulting. He is currently involved in the development of Florida's statewide stormwater rule. Mr. Bateman has served on the Florida Stormwater Association's Board of Directors since 2004 and is the current association president. He has also served as administrator of Florida's NPDES Stormwater Program. He is a registered Professional Engineer and a Certified Professional in Stormwater Quality.

Q: What are your top two good and bad issues with TMDLs? Let's start with the good.

A: On the positive side, TMDLs have helped focus attention on pollutants of concern and have forced us to quantify the effectiveness of the best management practices (BMPs) we're using. In the past, we have implemented BMPs without looking at their pollutant removal effectiveness.

Q: How about the bad issues?

A: Under the current system, there is an inequity among traditional *nonpoint* stormwater discharges stemming from the treatment of MS4 permits in the TMDL allocation. Other (non-MS4) nonpoint sources are accounted for in the *load* allocation, which typically brings a softer approach to meeting limits. However, MS4 stormwater discharges are treated as part of the *wasteload* allocation and are subject to the same numeric limits as traditional point sources in TMDL allocations. Therefore, MS4 permit holders are singled out among most other stormwater sources and are required to meet numeric limits.

Q: Where do you think TMDLs are headed in the future?

A: Lawsuits.

Q: What are major improvements that the state and federal government can make to improve TMDLs?

A: Allow for the use of an adaptive management strategy that first implements the stormwater management program, provides some time for the program to run its course, evaluates the program's effectiveness, and finally provides adjustments to improve the program. Also, regulators should provide consistent, reasonable tools for assessing program effectiveness. Currently, MS4s are generating their own methods of assessment that can result in inconsistent reporting and results. These MS4s need a broad assessment toolbox that each municipality in its district can rely on to improve reporting within the MS4 and among MS4s. USEPA is working on a tool that aims to meet this need.

Q: How do you think TMDLS should be linked with MS4 permits?

A: I'm not sure that they necessarily need to be directly linked, at least in terms of meeting numeric reduction goals. MS4s work to improve water quality using the maximum extent practical (MEP) standard (see 40 CFR Section 122.26), while most NPDES permitted discharges are directly linked to water quality standards. TMDLs, in effect, become a site-specific water quality standard. Therefore, a potential conflict is built into the rules if we are going to require an MS4 to meet water quality standards set forth in a TMDL, when in fact, the standard should be MEP. A soft link would be most appropriate for implementing TMDLs through MS4 permits.

Q: What would you do if you were in charge of making the rules for TMDLs in the United States?

A: Changing the TMDL equation to account for MS4 discharges under the load allocation instead of the wasteload allocation would be a really good start. This would level the playing field and would help put MS4s on par with other nonpoint source dischargers. It would also remove the apparent conflict of requiring municipal systems to meet numeric goals required for wasteload allocations under the TMDL program (see 40 CFR Section 130.7).

Q: **TMDLs have a reputation for not being implemented. What would you recommend to boost implementation?**

A: Implementing realistic schedules and realistic expectations through an adaptive management strategy is needed. If the MS4s are expected to meet overwhelming goals (e.g., zero discharge over the next permit cycle), then they may choose to do nothing. We need to better manage MS4s and improve water quality through improved goals and timetables. We have large systems that have big problems and we need to address these in a realistic manner.

–Interviewed by Sadie Drescher, Center for Watershed Protection

Nominate a "Watershed Superstar"

Do you know a watershed or stormwater professional who has demonstrated leadership and dedication to watershed protection? Consider recognizing that person's achievements by nominating him or her as a Watershed Superstar. The winner will be featured in the next issue of the *Watershed Science Bulletin*. To submit a nomination, please send an email to bulletin@awsps.org with "Watershed Superstar" as the subject line and include the following information:

- Nominee's full name
- Professional title
- Affiliation
- Short (½-page or less) description of why the nominee is a Watershed Superstar
- Name and contact information for the person submitting the nomination
- Name and contact information for two people we may contact as additional references

Nominations will be judged based on their accomplishments in the field of watershed and stormwater protection as well as the unique qualities that make up a Watershed Superstar, including ambition, innovation, collaboration, and dedication.

Nominations must be received by Friday, November 12, 2010.

AWSPs

ASSOCIATION OF WATERSHED &
STORMWATER PROFESSIONALS

Latest News from AWSPs

Membership Information

Enjoy reading the Watershed Science Bulletin? Consider joining the Association of Watershed and Stormwater Professionals (AWSPs).

Member benefits include:

- Two Issues of the Watershed Science Bulletin
- Substantial Webcast Discounts
- 50% Discount on Publications
- Subscription to the Quarterly e-newsletter, Runoff Rundown

Next Issue

Be on the lookout for the Spring 2011 issue of the Watershed Science Bulletin, which features articles on Watersheds and Climate Change. For additional information, visit www.awsps.org/watershed-science-bulletin.html.

Upcoming Events

- October 20, 12-2 pm, Webcast: Rooftop Disconnection, Filter Strips & Rainwater Harvesting
  www.awsps.org/training/webcasts.html
- December 15, 12-2 pm, Webcast: Better Site Design gets Better
  www.awsps.org/training/webcasts.html

Sponsorship

Sponsors of the Watershed Science Bulletin benefit from the Center for Watershed Protection's status among top decision-makers in the watershed and stormwater business. For additional information about sponsorship within the journal, please visit www.awsps.org/media-kit.html.

Sponsor Index

Kingfisher Sponsors	**URL**	**PAGE**
Michael Baker Corporation	www.mbakercorp.com	2
Stantec Inc	www.stantec.com	33
Straughan Environmental Services Inc	www.straughanenvironmental.com	18
Tetra Tech Inc.	www.tetratech.com	34
Water Penny Sponsors		
Imbrium Systems Inc	www.imbriumsystems.com	37
Johnson, Mirmiran & Thompson	www.jmt.com	24
Spatterdock Sponsors		
Constellation Energy Group Inc.	www.constellation.com	32
KCI Technologies Inc.	www.kci.com	60
Wetland Studies and Solutions Inc.	www.wetlandstudies.com	58

CENTER FOR WATERSHED PROTECTION

Solutions for clean water & healthy natural resources

The Center's clients and partners include municipal government staff from planning, engineering, public works, parks, utilities and other departments; private consultants in engineering, landscape architecture, forestry, and environmental science; community organizations working to implement on-the-ground restoration projects; state and federal government regulators and scientists; and University professors educating others about water issues.

We offer a wide range of services including…

- **Partnering with Watershed Groups** – Directly work with these small watershed organizations on the technical and organizational aspects of watershed management
- **Making Regulatory Updates** – Review development codes and evaluate local programs for communities
- **Providing Stormwater Services** – Update stormwater BMP manuals, do retrofit designs and develop programs for state & local government.
- **Distill Research into Practical Tools** – Translate research on the latest watershed technologies, trends, and successes into on-the-ground tools for practitionersd
- **Watershed Assessment and Planning** – Assist with mapping analysis, baseline characterizations, field assessments, regulatory audits, pollutant load modeling, and comprehensive watershed plan development
- **Training Others to Manage Watersheds** – Provide tailored workshops, weeklong Institutes, and speaking engagements designed to teach local planners, engineers, and watershed groups the technical skills they need to manage watersheds effectively

Learn more at www.cwp.org or contact us at 410-461-8323

Join the Center's Membership Program:
Association of Watershed and Stormwater Professionals (AWSPs)

Visit www.awsps.org for more information