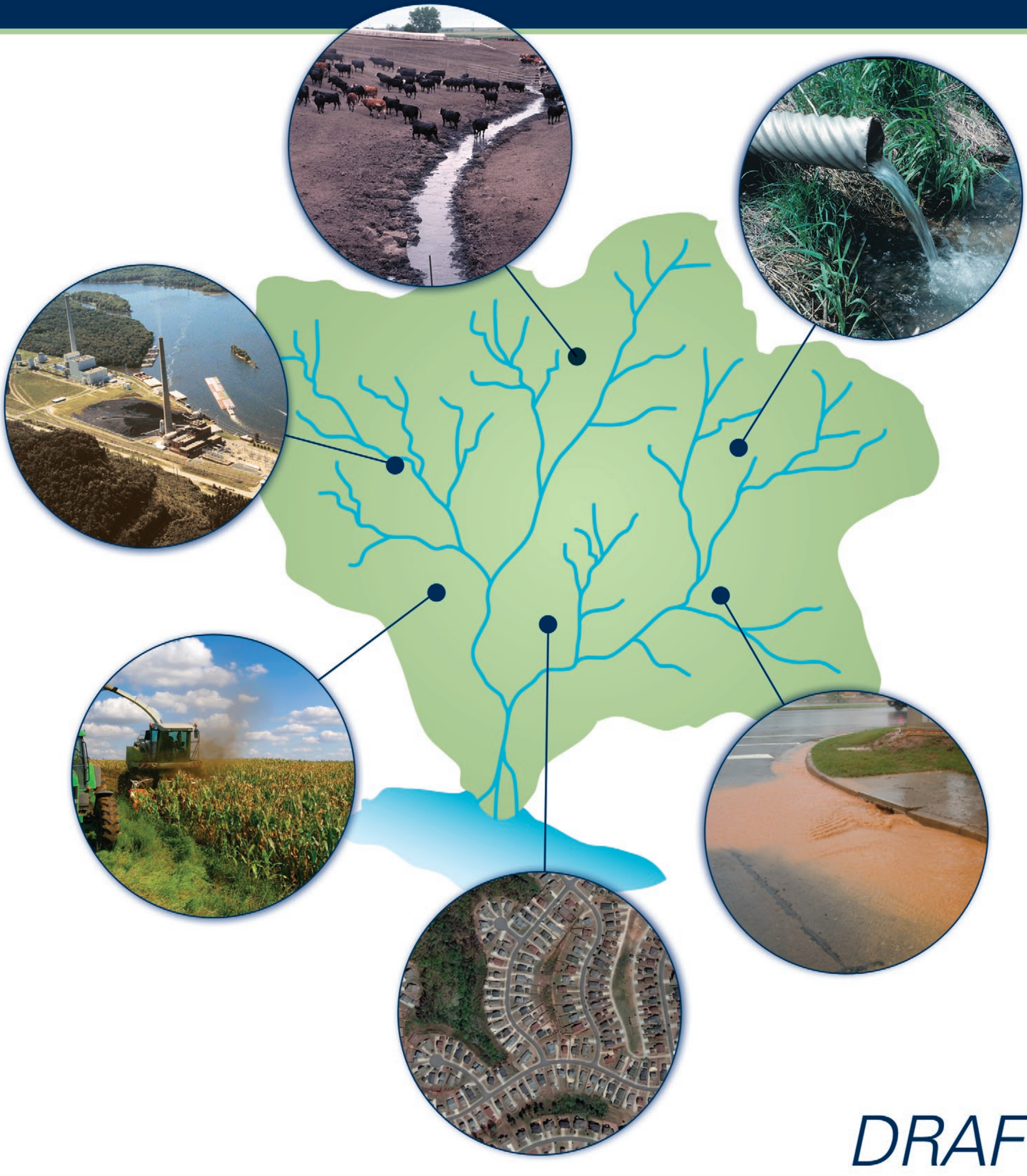
EPA United States Environmental Protection Agency

Office of Water
Office of Wetlands, Oceans, and Watersheds

Handbook for Developing Watershed TMDLs



DRAFT

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U.S. Environmental Protection Agency
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Disclaimer

This document provides technical information to TMDL practitioners who are familiar with the relevant technical approaches and legal requirements pertaining to developing TMDLs and refers to statutory and regulatory provisions that contain legally binding requirements. This document does not substitute for those provisions or regulations, nor is it a regulation itself. Thus, it does not impose legally binding requirements on EPA or States, who retain the discretion to adopt approaches on a case-by-case basis that differ from this information. Interested parties are free to raise questions about the appropriateness of the application of this information to a particular situation, and EPA will consider whether or not the technical approaches are appropriate in that situation.

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1. Introduction

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For more information on TMDLs visit EPA's TMDL Web site at www.epa.gov/owow/tmdl.

Section 303(d) of the 1972 Clean Water Act (CWA)[1] requires states, territories, and authorized tribes to develop lists of impaired waters. These impaired waters do not meet water quality standards that states, territories, and authorized tribes have set for them, even after point sources of pollution have installed the minimum required levels of pollution control technology. The law requires that these jurisdictions establish priority rankings and develop total maximum daily loads (TMDLs) for waters on the lists. A TMDL specifies the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards and allocates pollutant loadings among point and nonpoint pollutant sources. A TMDL is the sum of the individual wasteload allocations (WLAs) for point sources and load allocations (LAs) for nonpoint sources and natural background (40 CFR 130.2) with a margin of safety (CWA section 303(d)(1)(c)). The TMDL can be generically described by the following equation:

$$\text{TMDL} = \text{LC} = \sum \text{WLA} + \sum \text{LA} + \text{MOS}$$

where:

- LC = loading capacity or the greatest loading a waterbody can receive without exceeding water quality standards;
- WLA = wasteload allocation, or the portion of the TMDL allocated to existing or future point sources;
- LA = load allocation, or the portion of the TMDL allocated to existing or future nonpoint sources and natural background; and
- MOS = margin of safety, or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. The margin of safety can be provided implicitly through analytical assumptions or explicitly by reserving a portion of loading capacity.

The process of calculating and documenting a TMDL typically involves a number of tasks, including characterizing the impaired waterbody and its watershed, identifying sources, setting targets, calculating the loading capacity using some analysis to link loading to water quality, identifying source allocations, preparing TMDL reports and coordinating with stakeholders. EPA, states, tribes, and other TMDL practitioners have found that it can be advantageous to simultaneously complete the TMDL process and the associated tasks for multiple impaired waterbodies in a watershed. This process of developing *watershed TMDLs*—those that establish allocations for multiple impaired waterbodies in a watershed—is the focus of this document.

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[1] EPA's regulations for implementing section 303(d) are codified in the Water Quality Planning and Management Regulations at 40 CFR Part 130, specifically at sections 130.2, 130.7, and 130.10. The regulations define terms used in section 303(d) and otherwise interpret and expand upon the statutory requirements.

1.1. Rationale

Since 1995, more than 34,300 approved TMDLs have been developed by the states or established by U.S. Environmental Protection Agency (EPA), as shown in Figure 1-1, addressing more than 36,000 listed impairments. While this represents a significant number of TMDLs and a large effort by the states and EPA, states have identified nearly 70,000 TMDLs still to be developed in the next 8-13 years (one or more impairments affecting more than 41,500 waterbodies)[2]. This represents a pace of 5,300 to 8,700 TMDLs per year, nearly twice the average number of TMDLs developed per year during the last 10 years. As many states work to refine and implement more comprehensive monitoring and assessment strategies, it is likely that the number of additional impaired waterbodies requiring TMDLs will continue to increase in future 303(d) lists.

In a 2001 draft study conducted by EPA (USEPA 2001a, 2001b), it was estimated that "the national total undiscounted cost to develop 36,225 TMDLs for the pollutant causes of impairment identified in the 1998 303(d) lists is estimated to be about $1 billion, with a likely range of $0.97 to $1.06 billion." Using these figures, a conservative projection of the necessary funding to complete the remaining 70,000 TMDLs is between $1.86 and $2.04 billion.

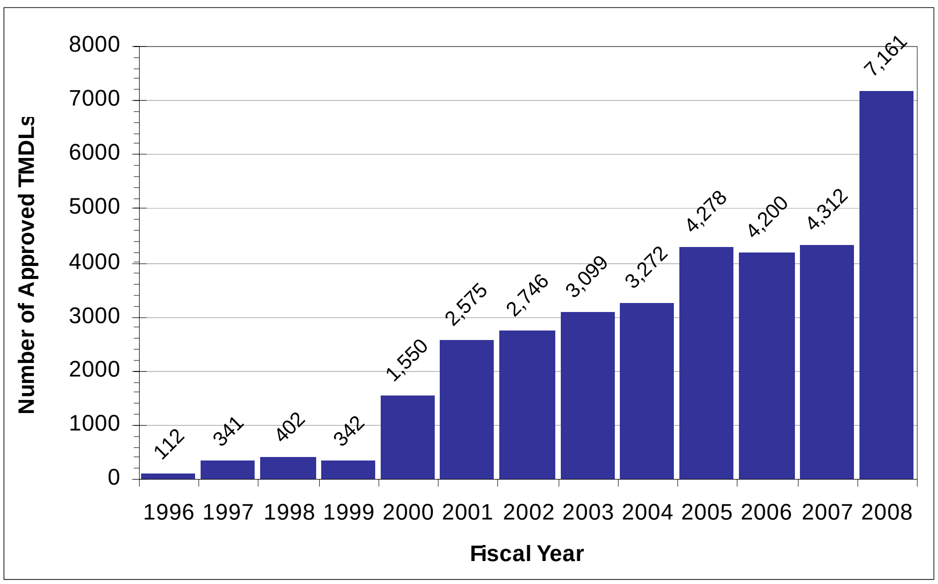

Figure 1-1. Number of TMDLs approved by fiscal year since October 1, 1995.

Adding to the expected demand on state resources, a recent survey of EPA regional TMDL programs indicated that efforts during previous years focused on many of the less complex TMDLs (Figure 1-2), leaving the more complex TMDLs in terms of waterbody type and pollutant kinetics still to be completed. Much of the TMDL efforts of states in the late 1990s focused on single-segment TMDLs, many representing single WLAs for point source-impaired waters. Into the early 2000s, some TMDL efforts began using/applying a watershed framework for developing multiple TMDLs; however, a majority of TMDLs were still being developed as single-segment TMDLs, guided by

[2] Based on EPA's National Section 303(d) Fact Sheet, http://iaspub.epa.gov/waters/national_rept.control, as of August 5, 2008.

pressures from court orders, limitations in available data, and activities to accommodate localized NPDES activities.

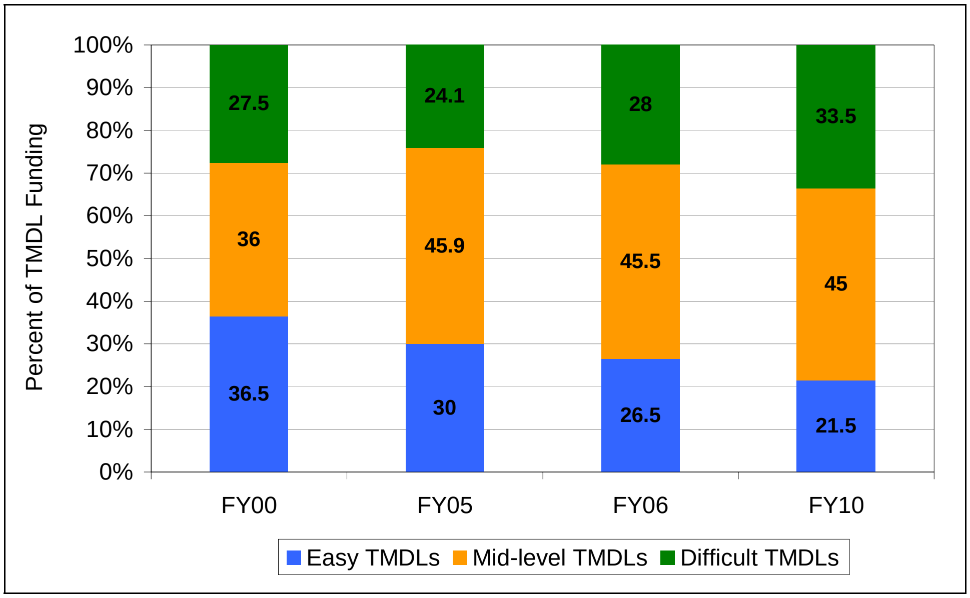

Figure 1-2. Complexity of TMDLs developed, as estimated by EPA Regions.

Based on these trends, states are facing a significant workload and associated financial responsibilities to develop the 65,000 TMDLs on current 303(d) lists. It is also expected that many of these TMDLs will require more complex analyses than the 34,300 TMDLs developed to date. While the workload and funding needs are increasing for TMDL development, the level of resources available to the states and to EPA are either declining or remaining unchanged. For all of these reasons, it is necessary for states to expedite TMDL development using an approach that will efficiently address the maximum number of impairments in a scientifically defensible manner. One strategy for doing this is to use a watershed framework for developing TMDLs. 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.

Definition:

Watershed TMDL vs. Single-segment TMDL

A ***watershed TMDL*** is the result of a holistic approach to the simultaneous development of multiple TMDLs for hydrologically linked impaired segments. A watershed TMDL will address one of the following:

- Same pollutant in multiple segments (e.g., fecal coliform bacteria)
- Different but similar pollutants in multiple segments (e.g., nitrogen and phosphorus)
- Different and unrelated pollutants in multiple segments (e.g., chromium and bacteria)

A ***single-segment TMDL*** is one that addresses only a single impaired waterbody, whether for a single or multiple impairments.

While a watershed TMDL evaluates multiple segments and impairments in an integrated analysis, a TMDL calculation with associated LAs and WLAs is needed for each waterbody-pollutant combination included on the 303(d) list.

1.2. Purpose

The purpose of this document is to promote the development of watershed TMDLs and to provide TMDL practitioners the information to move from concept to practice, making watershed TMDLs a standard approach in their programs. While the goal of this document is to support states in integrating a watershed approach to TMDL development into their overall programs, it focuses on the technical and programmatic information and considerations for developing and implementing watershed TMDLs primarily at the project level. A number of reference documents already exist to help states establish a program that uses the watershed as an operating framework for all of their statewide water programs.

This document outlines the basic technical issues related to watershed TMDLs, identifying the issues for practitioners to consider and tools and resources that can help them when planning for and developing watershed TMDLs. It also identifies the benefits of developing watershed TMDLs as well as the obstacles and ways to address them. Finally, this document highlights the connections between watershed TMDLs and other water programs, identifying opportunities for integrating watershed TMDLs into other watershed management efforts, such as watershed planning, permitting and water quality trading.

The overall message of this document is that TMDL practitioners should approach TMDL planning and development with the understanding that the watershed approach is a framework for coordination and development that can apply to a majority of TMDLs. During TMDL planning and scheduling, practitioners might find it necessary to identify those cases that do not fit or are not appropriate within the watershed framework and address those TMDLs separately.

1.3. Audience

The information in this document targets TMDL practitioners with an understanding of and experience with developing TMDLs. TMDL practitioners include those organizations actively developing TMDLs, including state and federal environmental agencies, third-party TMDL developers, and private consultants. To successfully develop TMDLs on a watershed basis, support and buy-in must occur at all levels of the TMDL program. This document presents information important for program managers as they outline the process and benefits of developing watershed TMDLs and make decisions about integrating the approach into their programs. While this document does discuss technical aspects of TMDL development for watershed TMDLs, it does not discuss in detail the overall TMDL development process or required TMDL elements. In this document, practitioners will find practical information related to commonly encountered technical and programmatic issues, available tools, and data and information sources to specifically support the development of watershed TMDLs.

> ***Program Notes:***
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> What Will You Get from this Document?
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> - **TMDL Practitioners—**get the information you need to decide when and how to develop watershed TMDLs
> - **Program Managers—**find out how watershed TMDLs will benefit your program and the issues you need to consider to successfully integrate a watershed approach into your TMDL program
> - **TMDL Implementation Partners—** understand how watershed TMDLs can more effectively support and coordinate implementation activities and can potentially support and reduce your ongoing efforts

In addition to TMDL practitioners, the information included in this document will be helpful to TMDL implementation partners. Implementation partners include National Pollutant Discharge Elimination System (NPDES) permitting authorities, municipalities responsible for implementing controls or subject to municipal separate storm sewer system (MS4) regulations, and watershed organizations working to coordinate and implement management efforts in the watershed.

1.4. Organization

To present the information necessary to support development of watershed TMDLs, the handbook is organized with the following sections:

- **Section 2: Understanding Watershed TMDLs.** This section defines a watershed TMDL and discusses the environmental, financial and programmatic benefits associated with watershed TMDLs.
- **Section 3: Identifying Candidates for Watershed TMDL Development.** This section discusses a series of criteria or factors that can be considered to define the scope of a watershed TMDL, whether on a project-specific basis or for a broader planning exercise (e.g., statewide).
- **Section 4: Developing Watershed TMDLs.** This section discusses the issues and considerations relevant to watershed TMDLs at each step of the TMDL development process, including stakeholder and public involvement, watershed characterization, linkage analysis, allocation analysis, and development and submittal of the TMDL report.
- S**ection 5: Supporting Implementation of Watershed TMDLs.** This section discusses a number of topics related to implementation, including coordination with related watershed programs (e.g., watershed-based permitting), follow-up monitoring, and financial resources for implementation.

There are a series of text boxes included throughout the document to highlight certain topics or provide specialized information related to development of watershed TMDLs. These boxes fall into the following categories:

- **Definition:** Defines key terms or concepts for better understanding of the respective discussion.
- **Example:** Provides real-world or hypothetical examples of watershed TMDL development and related programs to illustrate the benefits, technical issues or considerations associated with watershed TMDLs.
- **Process Tip:** Provides tips to focus efforts and successfully plan for and complete the steps to develop watershed TMDLs.
- **Program Notes:** Provides background on the TMDL or other watershed programs on topics relevant to watershed TMDL development.
- **Resources:** Identifies available resources to support completion of watershed TMDLs or to find further information on related topics.

1.5. Background

1.5.1. History of the TMDL Program

While the CWA has required TMDLs since 1972, the early focus was on developing WLAs for individual point sources. In the late 1990s, environmental groups began bringing legal actions against EPA seeking more accurate listing of waters and development of TMDLs. The litigation resulted in court-ordered schedules or consent decrees outlining TMDL development schedules in a number of states and requiring EPA to develop the TMDLs if the states do not. A significant effect of the litigation is that EPA and states began focusing TMDL efforts on waters impaired by not only point sources, but also by nonpoint sources as well as by a combination of point and nonpoint sources.

Since then states have strived to meet TMDL commitments in an effective and efficient manner. EPA has generated a number of guidance documents related to TMDL development, many providing recommendations for developing TMDLs on a watershed basis to provide both environmental and programmatic benefits. For example, EPA's first TMDL guidance document, *Guidance for Water-Quality-based Decisions: The TMDL Process*, states:

> *Many water pollution concerns are area-wide phenomena that are caused by multiple dischargers, multiple pollutants (with potential synergistic and additive effects), or nonpoint sources. Atmospheric deposition and ground water discharge may also result in significant pollutant loadings to surface waters. As a result, EPA recommends that States develop TMDLs on a geographical basis (e.g., by watershed) in order to efficiently and effectively manage the quality of surface waters. (USEPA 1991)*

At that time, the program began to move from a foundation of technology-based controls to one of water quality-based controls evaluated and implemented on a watershed scale. However, because of the workload demand and court-ordered schedules, many states continued to focus on developing "segment-by-segment" TMDLs. In following years, EPA policy memos reaffirmed their strategy to develop and implement TMDLs on a watershed basis. For example, in 1997, the EPA Assistant Administrator for Water issued a memo as a follow-up to the previously released *Healthy Watershed Strategy*, noting that a key component of the strategy was developing and implementing TMDLs to manage water quality on a watershed scale.

1.5.2. History of the Watershed Approach

The process for addressing water quality problems on a watershed basis is not a new idea. EPA has been promoting this idea for decades, solidifying their support in the early 1990s and continuing today through guidance, policy and training. EPA's Office of Water started The Watershed Academy in 1994 to provide training courses and educational materials on the basics of the watershed approach. The Watershed Academy has developed into one of the agency's key tools for educating and supporting agencies, stakeholders, and citizens working to protect water and watershed resources. In 1995, EPA released *Watershed Protection: A Project Focus* and *Watershed Protection: A Statewide Approach* to further the premise that many water quality and ecosystem problems are best solved at the watershed level rather than at the individual waterbody or discharger level. In June 1996, EPA's Office of Wetlands, Oceans and Watersheds (OWOW) released *The Watershed Approach Framework*, establishing guiding principals for watershed management. EPA has continued its efforts to promote implementation of clean water programs on a watershed basis with the development of additional guidance, watershed information tools (e.g., Watershed

> **Program Notes:**
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> *"Although ten years of effort have resulted in general awareness of the watershed approach within the Agency and at the State and local level, recent evaluations show substantial gaps in actual implementation. EPA believes that the watershed approach should not be seen as merely a special initiative, targeted at just a select number of places or involving a relatively small group of EPA or State staff. Rather, it should be the fulcrum of Federal and State restoration and protection efforts, and those of our many stakeholders, both private and public."* (USEPA 2002, 2005a)

Information Network, Surf Your Watershed), grants for watershed-based programs and projects, and a variety of training courses.

In 2002, the EPA Assistant Administrator for Water issued a memorandum "to reaffirm the Office of Water's commitment to advancing the watershed approach" (USEPA 2002). Subsequently, the Office of Water's *National Water Program Guidance* for Fiscal Years 2005, 2006, 2007, 2008, and 2009 all included goals to "restore and improve water quality on a watershed basis." As part of this goal, EPA encourages states "to organize schedules for TMDLs to address all pollutants on an impaired segment and to organize efforts so that segment level restorations are clustered together to provide improvements on a watershed basis" (www.epa.gov/water/waterplan/). To further define this goal, the FY2006 program guidance included a Subobjective Implementation Plan to describe strategies and performance targets for using the watershed approach for the implementation and integration of a number of core water programs, including water quality standards, monitoring, TMDLs, nonpoint source control, NPDES permitting, and wastewater infrastructure (USEPA 2005). Recognizing the potential benefits of managing water quality using a place based approach, the current EPA administration is continuing to promote and address issues on a watershed level and anticipates that these watershed-based strategies and performance targets will continue in 2009 and beyond.

1.5.3. Integration of Watershed Approach into Core Water Programs

Recently, EPA's Office of Water has supported their program goals by developing guidance for further integrating the watershed approach into their core water programs. For example, in July 2007, the Office of Wastewater Management (OWM) released the *Watershed-Based National Pollutant Discharge Elimination System (NPDES) Permitting Technical Guidance* (USEPA 2007a) as a follow up to the 2003 *Watershed-based National Pollutant Discharge Elimination System (NPDES) Permitting Implementation Guidance*. Watershed-based permitting emphasizes addressing all regulated stressors within a hydrologically defined drainage basin, rather than addressing individual pollutant sources on a discharge-by-discharge basis. The 2007 guidance provides greater detail on permit development and issuance and focuses on helping NPDES authorities develop and issue NPDES permits that fit into an overall watershed planning and management approach. Watershed-based permitting can encompass a variety of activities ranging from synchronizing permits within a basin to developing water quality-based effluent limits using a multiple discharger modeling analysis. The type of permitting activity will vary depending on the unique characteristics of the watershed and the sources of pollution.

In March 2008, OWOW released the *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (USEPA 2008) to help

Resources:

Recent EPA Watershed-based Initiatives

OWOW's Nonpoint Source Control Branch recently released the **"Watershed Handbook"** to support watershed managers in developing comprehensive watershed-based plans to restore and maintain water quality standards. The handbook focuses on developing plans that meet 319 requirements and focus on impaired and threatened waters. http://www.epa.gov/owow/nps/watershed_handbook/

OWM's Water Permits Division has developed a number of policy memos, programmatic and technical guidance, and case studies to further encourage the practice of **watershed-based permitting**. The ultimate goal of this effort is to develop and issue NPDES permits that better protect entire watersheds. http://cfpub.epa.gov/npdes/wqbasedpermitting/wspermitting.cfm

OWM's Water Permits Division recently released a toolkit to support permit writers' use of **water quality trading** in their watersheds. The toolkit builds on earlier policy and guidance that highlights the innovative approach that allows sources within a watershed to "trade" pollution reductions with other sources that can achieve the reductions at a lower cost. The approach encourages achieving water quality goals in the most cost effective and least burdensome manner. http://www.epa.gov/owow/watershed/trading.htm communities, watershed organizations, and local, state, tribal, and federal environmental agencies develop and implement watershed plans to meet water quality standards and protect water resources. The handbook is designed to aid in the development of a watershed plan that meets the minimum elements of a watershed plan as outlined in EPA's *Supplemental Guidelines for the Award of Section 319 Nonpoint Source Grants to States and Territories in FY 2003*. These guidelines called for an expansion of efforts to manage nonpoint pollution on a watershed basis through the development and implementation of watershed plans, with special emphasis on restoring impaired waters on a watershed basis.

Building on their *National Water Quality Trading Policy* issued in January 2003, OWM released the *Water Quality Trading Assessment Handbook* (USEPA 2004) in November 2004 to help water quality managers and watershed stakeholders determine if trading is a potential tool for use in their watershed to make cost-effective pollutant reductions that achieve water quality standards. The handbook helps users decide whether water quality trading will work in their watershed and when and where trading is likely to be the appropriate tool for achieving water quality goals. A framework for water quality trading is best built on a watershed approach to both permitting and TMDL development. In August 2007, OWM released *The Water Quality Trading Toolkit for Permit Writers* (USEPA 2007b) as the next step in EPA's support for trading. The Toolkit provides NPDES permitting authorities with the tools they need to incorporate trading provisions into permits. The Toolkit is the first "how-to" manual for designing and implementing trading programs consistent with EPA's 2003 *National Water Quality Trading Policy*.

As those documents have served their respective programs, this guidance document is intended to serve as a programmatic and technical resource for TMDL practitioners to develop watershed TMDLs, providing both environmental and programmatic benefits over single-segment TMDLs. Developing TMDLs on a watershed basis will also be consistent with and support the efforts of the other watershed-based initiatives in related water programs, such as those in permitting, monitoring and nonpoint source control. The programs overlap and can serve to support and enhance one another with the goal of restoring and protecting water quality watershed by watershed.

Program Notes:

Setting the Stage for Watershed TMDLs through Statewide Watershed Management

Can you organize your operations to do watershed-based TMDLs? Many states are doing just that through their statewide watershed management programs which coordinate efforts of their monitoring, assessment, NPDES permitting, habitat restoration, pollution prevention, TMDL development, nonpoint source grant allocation, and other resource management programs. States have found that benefits associated with watershed-based TMDLs—e.g. greater effectiveness and efficiency-- can accrue at a higher yield when implementing a TMDL program within a *statewide* watershed management framework.

If your state does not have a statewide watershed management framework, you can still begin developing TMDLs on a watershed basis, scheduling the TMDLs during your priority ranking and TMDL development scheduling. In addition, TMDL development can become a motivating factor for creating a statewide watershed management framework. EPA and its partners have written numerous documents on how to develop a statewide approach to watershed management (e.g., Watershed Protection: A Statewide Approach, USEPA 1995; Framework for a Watershed Management Program, Water Environment Research Foundation, 1996; Statewide Watershed Management Facilitation, USEPA, 1997). Based on states that have successfully organized statewide watershed management programs, there are four stages for developing a watershed management framework (WERF, 1996):

Stage 1: Organizing Statewide Framework Development
Stage 2: Tailoring Statewide Framework Elements
Stage 3: Making the Transition
Stage 4: Operating Under a Statewide Approach

<u>Stage 1. Organizing Statewide Framework Development</u>
This stage involves establishing leadership and vision for developing a statewide framework. A champion is needed to recruit partners from other programs and agencies, help achieve consensus on common goals and objectives, as well as establish ground rules and a workplan for developing the framework. This “champion” is typically from a state-level water quality program. Some states start small, with a framework built off the state’s NPDES permitting, water quality assessment, TMDL, and nonpoint source programs, while others reach out to more than 20 partners representing federal, state, and local agencies. To ensure the statewide framework addresses TMDL issues, a representative from the TMDL program should participate in framework development and serve as a champion of the process.

<u>Stage 2. Tailoring Statewide Framework Elements</u>
This stage is essential to ensure that the watershed framework supports the daily duties and leverages the resources of the programs being coordinated. Beginning with the end in mind, the first step is to decide the purpose of the framework—which programs will be coordinated within the framework and what are the resulting products (e.g., watershed plans, watershed TMDLs, rotating basin monitoring schedules). Next, and very key, is delineating watershed management units and subunits—these become the focus of monitoring, assessment, management and reporting. Next establish a watershed management cycle, and an associated gantt chart that shows how program activities can be synchronized.

<u>Stage 3: Making the Transition</u>
This stage involves establishing organizational structures and protocols for operating under a statewide watershed framework and synchronizing activities within the watershed management cycle. It also is the stage for addressing resource and technical support needs and staff training.

<u>Stage 4. Operating Under a Statewide Approach</u>
This includes monitoring progress of framework implementation, evaluating effectiveness, and modifying the framework as needed.

2. Understanding Watershed TMDLs

A watershed TMDL will vary in geographic scale and technical scope but it will generally involve a network consisting of multiple hydrologically connected waterbody segments, whether streams, rivers, lakes, estuaries or beaches. (Section 5 further discusses considerations and guidance for defining your watershed.) Within that watershed, a watershed TMDL will holistically consider multiple sources and impairments, evaluating the watershed as a whole rather than treating each waterbody and its impairment as separate analyses.

> **Definition:**
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> Watershed: Geographic Boundary vs. Conceptual Framework
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> Most TMDL analyses, whether single-segment or watershed, are defined by a watershed, evaluating all the sources within the drainage area of the impaired segment. However, for watershed TMDLs, *watershed* goes beyond the definition of a geographic boundary and represents also the conceptual scope of the TMDL—what segments and impairments are addressed. To be a watershed TMDL, the analyses would include and establish allocations for multiple impaired segments and possibly impairments within a common hydrological network and drainage area. A watershed TMDL can vary widely in size and does not have inherent size minimums or maximums to define it as a watershed TMDL. The geographic size of the watershed will be determined on a case-by-case basis, depending on such things as source/impairment type, data availability, available resources, and scheduling priorities.

Generally, the two types of watershed TMDLs are:

- **Intrastate Watershed TMDLs.** These are the most common type and represent the watershed TMDLs developed by a state (or EPA on behalf of the state) to address multiple impaired segments at varying geographic scales, but entirely within the jurisdiction of a single state. Many states currently develop TMDLs on a watershed basis, at least occasionally if not for the majority of their TMDLs. States might develop watershed TMDLs because of an established statewide watershed approach to TMDL development, or, states might still develop single-segment TMDLs the majority of the time and use watershed TMDLs to address special circumstances.
- **Multijurisdictional TMDLs.** Multijurisdictional TMDLs represent large-scale efforts that cross major jurisdictional borders and often encompass the entire drainage of a major regional waterbody (e.g., Chesapeake Bay, Ohio River, Klamath River). Whether led by EPA, an individual state or an interstate organization, these TMDLs typically involve coordinated participation from multiple states and tribes and sometimes EPA Regions to develop a comprehensive TMDL that addresses impaired segments throughout the multijurisdictional watershed. These TMDLs are often a larger geographic scope than the typical watershed TMDL.

Regardless of the type of watershed TMDL, the general approach and many of the benefits are the same. The overall benefit of watershed TMDLs is they provide the opportunity to use the TMDL as a tool for cost effectively identifying options for reducing point and nonpoint source loads to restore impaired waterbodies to water quality standards. By considering all sources impacting the watershed, watershed TMDLs provide the state with the greatest level of flexibility in allocating and subsequently controlling loads. For the watershed TMDL to be most effective, it is important to integrate all of the scientific, programmatic and social aspects of the TMDL within the watershed approach. Developing single-segment TMDLs might make it more difficult in many cases to efficiently use a program's resources as well as organize and target projects, engage related program representatives and maximize stakeholder participation.

> ***Definition:***
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> Third-party TMDLs
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> A third-party TMDL is one developed by an organization other than the one with TMDL development responsibility (i.e., state water quality agency or EPA). A third-party can be a watershed group volunteering to lead the TMDL to integrate it into their watershed management efforts. It can also be another government agency, whether local municipality, county, city or other federal entity (U.S. Geological Survey, U.S. Forest Service). Third-party TMDLs are emerging as an alternative approach in watersheds where complex issues (e.g., stormwater management, CSO control, interstate systems) are prevalent. The technical process to develop third-party TMDLs will not differ from that for traditional TMDLs, and they are subject to the same requirements. Therefore, third-party TMDLs can also use the watershed framework and can realize many of the same benefits of traditional watershed TMDLs. Regardless of how they are developed, third-party TMDLs must be submitted by states and approved by EPA.

2.1. Environmental Benefits

Many of the environmental benefits of watershed TMDLs are a result of evaluating and managing the watershed holistically, allowing for an integrated and comprehensive analysis of sources, impairments, and management options. The environmental benefits are also closely tied to a variety of programmatic benefits (discussed in Section 2.2). For example, most of the environmental benefits that result from watershed TMDLs also result in cost savings when compared to developing the same TMDLs as single-segment TMDLs. The following are the primary environmental benefits resulting from watershed TMDLs.

Includes a Broader Source Assessment. Developing TMDLs on a watershed basis allows the practitioner to evaluate all the sources in a watershed and identify their relative impacts on water quality. By focusing only on single-segment TMDLs, a practitioner might miss a source that is outside the immediate drainage area but contributes a significant pollutant load that influences the segment's water quality. In addition, a watershed TMDL can optimize allocations and target those sources that will most efficiently and effectively result in attainment of standards. When addressing multiple pollutants that might be contributed by common sources, a watershed TMDL can target a source that will result in improvements for multiple pollutants, maximizing the potential for source controls. For example, some agricultural sources (e.g., livestock-related sources) and residential sources (e.g., septic systems) can be significant sources of both bacteria and nutrients. By simultaneously developing TMDLs for both pollutants, the allocations can target those sources that control both bacteria and nutrients. If the TMDLs were developed separately, unnecessary and duplicative reductions might be allocated to watershed sources.

Captures the Interaction Between Upstream and Downstream Sources and Impacts. Closely related to the benefit of more broadly evaluating sources, this benefit of watershed TMDLs allows a practitioner to fully understand the interactions of watershed sources and their cumulative effects on impaired waterbodies. Water quality is the result of a variety of load inputs, in-stream conditions, and physical, chemical and biological processes. Load inputs can come from sources in the immediate drainage of a waterbody or from upstream areas through tributary inflows, both of which are accounted for in a watershed TMDL. Alternatively, a watershed TMDL also considers the impact of *reductions* in the loads from upstream sources. Considering the cumulative impact of all

> ***Program Notes:***
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> Benefits vs. Challenges of Watershed TMDLs
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> While watershed TMDLs provide the potential for a number of benefits, they are not without their challenges. Challenges related to developing watershed TMDLs and how to address them are discussed throughout the document in the relevant sections. For example, challenges in data analysis are discussed in Section 4.2.1, Data Analysis for Problem Identification. Some of the typical challenges include the potential for increased complexity in the analysis; dealing with more data, sources and stakeholders; and the difficulty of evaluating the multiple impairments at an appropriate scale.

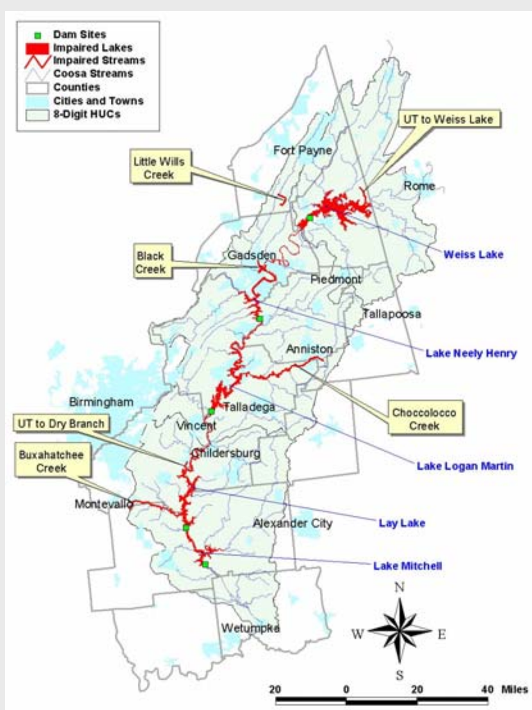
sources allows TMDL practitioners to optimize and maximize source reductions in the allocation process. Downstream impaired segments might require less stringent reductions to meet water quality standards because of reductions required for upstream impaired segments. Developing single-segment TMDLs might ignore the cumulative impacts and interactions of watershed sources and processes, potentially resulting in overly stringent and inappropriate load reductions and subsequent ineffective use of resources.

Reduces the Potential Need for Future TMDLs. Because the watershed approach to TMDL development evaluates source inputs and water quality impacts throughout the entire system, it can protect threatened or unimpaired segments in the watershed. A goal of the watershed approach is to holistically evaluate sources and target controls to protect the watershed as a whole, rather than narrowly focusing on portions of the watershed. This provides water quality benefits throughout the watershed rather than just in the impaired segments or only for the listed pollutants. This can prevent the need for future TMDLs, and the associated expenditures, by protecting waters that might have otherwise

Example:

Watershed TMDL Development Identifies Main Source Impairing Coosa Chain of Lakes, Alabama

A watershed TMDL was developed to address organic enrichment, low dissolved oxygen and nutrients for four reservoirs located on the Coosa River in Alabama as well as a number of tributaries to the reservoirs. In downstream order the lakes are Lake Neely Henry, Logan Martin Lake, Lay Lake and Lake Mitchell. A watershed model (LSPC) for the Coosa River Basin and a 3-dimensional hydrodynamic (EFDC) and water quality (WASP) model for each lake in the Coosa Chain of Lakes provided a framework to evaluate multiple sources, pollutants and waterbodies. During the TMDL scenario runs, it was determined that the primary source of nutrients, namely phosphorus, was coming from Weiss Lake, located upstream on the Georgia-Alabama border. Therefore, it was determined that if the phosphorus were reduced from the various point and non-point sources contributing loads to Weiss Lake that the four downstream reservoirs would be able to meet established nutrient criteria.



The Coosa Chain of Lakes TMDL can be found at:
http://www.adem.state.al.us/WaterDivision/WQuality/TMDL/WQTMDLInfo.htm.

been listed in future cycles. Developing single-segment TMDLs does not capitalize on the added benefit of protecting good quality waters while also restoring impaired waters. This also represents a financial and programmatic benefit by potentially reducing future workloads associated with additional TMDLs.

2.2. Financial and Programmatic Benefits

The financial and programmatic benefits of developing TMDLs on a watershed basis rather than as single-segment TMDLs are primarily recognized through decreased total time spent on developing TMDLs and the resulting cost savings. Advantages also include a variety of programmatic benefits resulting from coordinated, more efficient completion of TMDL tasks. The following are the primary financial and programmatic benefits resulting from watershed TMDLs.

Result in Lower Per-TMDL Development Costs. Because a program's ability to develop TMDLs is often dictated by the amount of funding and staff resources available, it is important to consider the potential savings from developing watershed TMDLs. While single-segment TMDLs might require a lower initial cost to complete the project, the cumulative savings from developing TMDLs on a watershed basis can be significant. While a watershed TMDL might take longer to develop than a single-segment TMDL, the per-TMDL cost and level of effort is typically lower for watershed TMDLs. The demand for TMDL development is still substantial for many states as they work to meet TMDL schedules. However, funding for TMDL development is remaining fairly constant or even decreasing. By using the watershed approach to TMDL development, states can maximize their funding and staff resources to more efficiently meet their TMDL commitments.

Address Greater Number of TMDL Pollutant-Waterbody Combinations. Because the per-TMDL cost is lower when developing TMDLs on a watershed basis, they provide the opportunity to address a greater number of pollutant-waterbody combinations at a lower cost than if they were done separately, providing an *economy of scale* to TMDL development. This allows practitioners to more expeditiously meet their TMDL development schedules, especially useful when working under a consent decree or court-ordered schedule.

> **Program Notes:**
>
> TMDL Accounting
>
> While a watershed TMDL evaluates multiple segments and impairments in an integrated analysis, a TMDL calculation with associated LAs and WLAs is still needed for each waterbody-pollutant combination included on the 303(d) list. Therefore a "watershed TMDL" can count as multiple TMDLs toward a state's commitments.

Encourages Efficient Use of Resources and Completion of Tasks. Developing TMDLs on a watershed basis maximizes resources and avoids duplication of effort in completing a number of activities related to TMDL development. Efficiencies are most easily illustrated in the public participation activities because these activities are relatively similar across TMDLs. For a watershed that contains six impaired waterbody segments, the state would traditionally conduct six separate public meetings and address feedback from six separate comment periods when using single-segment TMDLs. Under a watershed TMDL approach, the state can conduct one public meeting and have one public comment period for the comprehensive watershed TMDL. The separate public involvement activities would not only result in an inefficient use of resources, but would likely ask similar sets of stakeholders to participate in multiple activities – not an effective way to engage stakeholders.

Program Notes:

What Are the Potential Cost Savings of Developing Watershed-based TMDLs?

In 2001, EPA completed a draft study to estimate the cost to develop all of the required TMDLs associated with states' 1998 303(d) lists (USEPA 2001a, 2001b). In doing so, the study also estimated potential cost savings associated with different approaches to TMDL development and implementation. One of the key findings is that there can be significant cost savings in TMDL development and implementation when "clustering" TMDLs through a watershed approach. The following table summarizes the efficiencies estimated for the major TMDL tasks, recognizing that developing multiple TMDLs within a watershed can result in efficiencies for every step of the TMDL process (USEPA 2001b):

Tasks	% of Unit Effort of Initial Full-cost TMDL		
	Type A TMDL (no efficiencies)	Type B TMDL	Type C TMDL
1. Watershed characterization	100%	25%	25%
2. Modeling and analysis	100%	100%	25%
3. Allocation analysis	100%	100%	25%
4. Develop TMDL document	100%	25%	25%
5. Public outreach	100%	25%	25%
6. Formal public participation	100%	25%	25%
7. Tracking, planning, legal support	100%	25%	25%
8. Implementation plan	100%	50%	15%

Type A TMDLs = Full cost; address single waterbody and single pollutant
Type B TMDLs = Standard efficiencies; subsequent pollutants in single waterbody or clustered waters
Type C TMDLs = Additional modeling-related efficiencies; multiple clustered waterbodies; one or more related pollutants

Translating these efficiencies to level of effort (LOE) and costs to develop TMDLs, the draft study identified the following average hour and cost burdens for the different levels of efficiencies:

Type of Efficiencies	Average Unit Burden to Develop TMDL by Level of Analysis					
	Level 1		Level 2		Level 3	
	LOE (hours)	Cost (2000 $)	LOE (hours)	Cost (2000 $)	LOE (hours)	Cost (2000 $)
Type A TMDLs	933	$36,284	1,798	$69,924	3,175	$123,476
Type B TMDLs	308	$11,978	740	$28,779	1,459	$56,741
Type C TMDLs	226	$8,789	436	$16,956	774	$30,101

Type A TMDLs = Full cost; address single waterbody and single pollutant
Type B TMDLs = Standard efficiencies; subsequent pollutants in single waterbody or clustered waters
Type C TMDLs = Additional modeling-related efficiencies; multiple clustered waterbodies; one or more related pollutants
Level 1 analysis = Simplified TMDL analysis using spreadsheet calculations
Level 2 analysis = Mid-range analysis (e.g., QUAL2E, GWLF, BATHTUB)
Level 3 analysis = Detailed analysis (e.g., HSPF, SWMM, WASP)

Similarly, technical analysis tasks such as data analysis and modeling also can experience more streamlined efforts and avoid duplication when conducted for an entire watershed rather than a series of single-segment TMDLs. For example, when compiling and analyzing data for the watershed TMDL, a practitioner will conduct related activities only once, rather than multiple times—activities such as extracting data from the applicable databases, compiling water quality data, performing statistical summaries, and extracting and compiling GIS data. For single-segment TMDLs, the practitioner would often compile and analyze some (but not all) of the same data for each of the projects. So, for each project there would be an overlap in data sets that would cumulatively result in duplication of efforts for data analysis and inefficient use of staff time and resources. Similarly, in modeling activities there are clear advantages to completing TMDLs on a watershed basis rather than as single segments. When setting up a model for the watershed, the modeler would use much of the same data and parameters if setting up a model for each individual segment, but develop the model once rather than six times. This can also ensure consistent assumptions when representing the waterbodies and sources in the analysis.

Facilitates More Effective Use of Public Participation and Stakeholder Involvement. Developing watershed TMDLs is more likely to engage stakeholders. Similar to the example above, multiple public meetings held for single-segment TMDLs will likely generate less participation from stakeholders versus one meeting representing a more comprehensive watershed TMDL. It is likely that some of the TMDLs would share common stakeholders, and engaging stakeholders watershed-wide would streamline participation for stakeholders with an interest in several impaired waterbodies within the watershed. As a result, this approach has a better likelihood of avoiding stakeholder participation “burn-out” and of gaining meaningful input. In addition, stakeholders participating on a watershed-basis might reveal useful monitoring data (e.g., local jurisdiction, volunteer monitoring, discharger data) that are not available from the state or public databases to support the TMDL analysis. In addition, coordinating the public participation activities on a broader watershed level will likely provide benefits when implementing the TMDL as well. When the stakeholders are involved in the process, and all of the stakeholders have been introduced to the problem and each other, they are more likely to actively participate in development and support implementation of the TMDL.

Example:

Understanding Sources and Educating Stakeholders in the Beaver Creek and Grand Lake St. Marys Watershed

The Beaver Creek and Grand Lake St. Marys Watershed drains approximately 171 mi^2 in west-central Ohio near the Ohio-Indiana border. Many of the streams in the watershed are impaired due to bacteria and nutrients, as is Grand Lake St. Marys, an important local recreational resource and drinking water supply. The watershed’s primary land cover is row crops and pasture/hay (more than 80 percent of the total watershed area), and it contains an estimated 4 million animals at numerous animal feeding operations. Several wastewater treatment plants and unsewered residential areas in the watershed are additional sources of nutrients and pathogens.

Opinions on major causes and sources varied among the stakeholders, including farmers, lakeshore residents and recreational users. Development of the watershed TMDL, including modeling the relative magnitude and impact of watershed sources, helped to reduce uncertainty as to the most significant pollutant sources, allowing the local stakeholders to focus their attention on solutions. Modeling scenarios were also run to illustrate the potential impact to Grand Lake St. Marys of implementing the TMDL.

The TMDL public meeting was attended by more than 50 stakeholders including representatives from EPA, Ohio EPA, Ohio Department of Natural Resources, U.S. Fish and Wildlife Service, The Grand Lake/Wabash Watershed Alliance, and The Lake Improvement Association and local politicians, numerous local farmers and sportsmen, and members of the community. Ohio EPA facilitated discussion among these diverse and passionate stakeholders to communicate the findings of the TMDL and to discuss options for implementation. Current efforts in the watershed are now focused on implementing projects to reduce nutrient and pathogen loading (e.g., manure dewatering, septic system replacement) and continuing to monitor water quality in the watershed.

In February 2008, Congressman John Boehner (R-West Chester) and Senator Sherrod Brown (D-Ohio) together with the NRCS announced that $1 million will be available through the USDA to help improve the water quality of Ohio watersheds. The bulk of the money will be used for the creation of buffer strips along tributaries to Grand Lake St. Marys and for the planting of cover crops. The government will provide incentive payments to cover a portion of the planting costs, with the rest covered by participating farmers, who must meet eligibility requirements established by the NRCS’s Environmental Quality Incentives Program (EQIP).

Avoids Potential for Having to "Redo" TMDLs. Without using a watershed approach, a practitioner might face the need to reopen and recalculate previously completed TMDLs. For example, TMDLs completed for smaller headwater streams might contain allocations that are not stringent enough to support TMDLs for downstream impaired segments. A practitioner might also have to recalculate upstream TMDLs upon completion of downstream TMDLs, resulting in unexpected costs as well as potentially undermining the defensibility of the TMDLs.

Encourages More Comprehensive and Targeted Monitoring Programs. Through an evaluation of all sources in a watershed and consideration of the water quality throughout the entire system, the results of a watershed TMDL can support more effective monitoring program design and implementation. For example, through the watershed TMDL process, the practitioner can identify data gaps and areas to monitor for better evaluating source impacts, sites to monitor to gauge progress in achieving load reductions and water quality improvements, and recommended schedules considering the critical conditions and potential implementation schedules. In addition, because a watershed TMDL encourages the participation of multiple stakeholders there is the potential for leveraging on the resources and involvement of other entities (e.g., local jurisdictions, watershed groups) to extend monitoring resources.

Provides Opportunity to Integrate TMDL with Other Watershed Programs. Another benefit of watershed TMDLs is the potential to couple the TMDL with other watershed-based programs. Integrating watershed TMDLs with other water programs, such as monitoring, permitting, and nonpoint source control projects (i.e., Section 319 funded projects), provides the opportunity to more efficiently prioritize and target areas for monitoring and restoration. Coordinating with programs that rely on similar analyses can avoid duplicative efforts while also resulting in a more effective plan. For example, watershed planning projects are beginning to conduct more quantitative analyses of existing and acceptable levels of pollutant loading, similar to analyses conducted for a TMDL. Coordinating the related efforts maximizes the cross-program resources to coordinate and target related, yet often separate, activities. (This concept as related to implementation of the TMDL is further discussed in Section 5.)

Example:

Evolution of a Successful Watershed-based TMDL Program

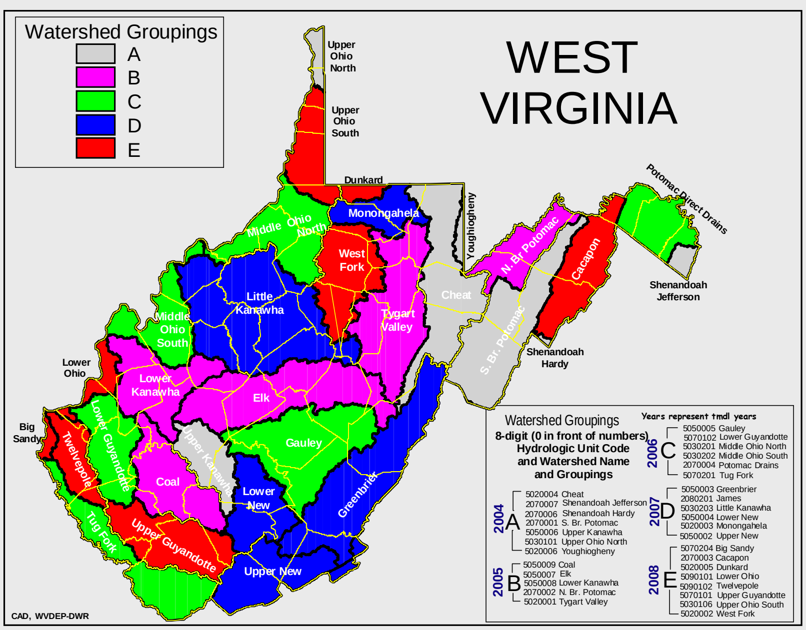
West Virginia provides an example of a state TMDL program that embraced the watershed TMDL concept and integrated it successfully into their standard procedures and related water programs. When faced with daunting consent decree schedules, West Virginia used the watershed TMDL approach to not only more efficiently meet their commitments but also to build their TMDL program into an effective program that goes beyond legal requirements and uses the watershed approach to identify sources, monitor water quality, develop TMDLs, and issue consistent permits.

West Virginia Department of Environmental Protection (WVDEP) is committed to implementing a comprehensive watershed based TMDL process that reflects the requirements of the TMDL regulations, provides for the achievement of water quality standards, and ensures that ample stakeholder participation is achieved in the development and implementation of TMDLs.

From 1997 through September 2003, EPA Region 3 developed West Virginia TMDLs, under the settlement of a 1995 lawsuit, Ohio Valley Environmental Coalition, Inc., West Virginia Highlands et al. v. Browner et al. The lawsuit resulted in a consent decree between the plaintiffs and EPA that established a rigorous schedule for TMDL development for the impaired waters on West Virginia's 1996 Section 303(d) list. While EPA was working on developing TMDLs, WVDEP concentrated on building its own TMDL program. With the help of a TMDL stakeholder committee, the agency secured funding from the state legislature and created the TMDL section within the Division of Water and Waste Management.

The TMDL stakeholder committee consisted of 22 members with balanced interests among extractive and manufacturing industry, environmental advocates, agriculture, forestry, state and federal government, sportsmen associations, and municipalities. The committee made recommendations for WVDEP TMDL development and supported general revenue funding.

Since October 2003, West Virginia's TMDLs were and continue to be developed by WVDEP. While accommodating the remaining TMDLs required by the consent decree, WVDEP's TMDL program generates numerous other TMDLs under a comprehensive watershed based approach. WVDEP develops TMDLs according to the Watershed Management Framework cycle. The framework divides the state into five hydrologic groups (groups A - E) with 32 major watersheds and operates on a 5-year rotation process.



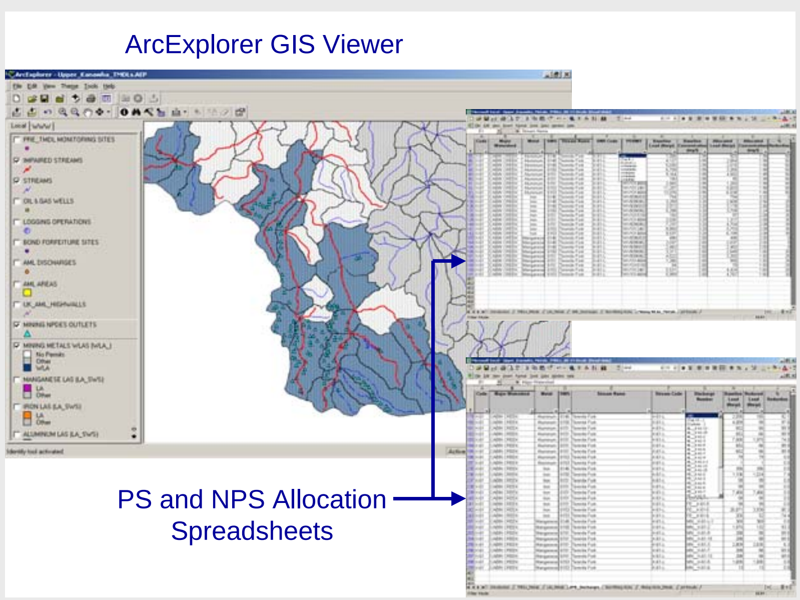
Prior to the existence of the TMDL Program, WVDEP stream monitoring and NPDES permit reissuance activities were organized in accordance with the Framework. The TMDL program was then designed to be synchronized with the monitoring and implementation schedule of the Framework creating a fully integrated watershed based program.

The TMDL development process begins with pre-TMDL water quality monitoring and source identification and characterization. Informational public meetings are held in the affected watersheds. Data obtained from pre-TMDL efforts are compiled, and the impaired waters are modeled to determine baseline conditions and the gross pollutant reductions needed to achieve water quality standards. WVDEP then presents its allocation strategies in a second public meeting, after which Final TMDL reports are developed. The draft TMDL is advertised for public review and comment, and a third informational meeting is held during the public comment period. Public comments are addressed, and the draft TMDL is submitted to EPA for approval.

WVDEP's 48-month development process enables the agency to carry out an extensive data generation and gathering effort to produce scientifically defensible TMDLs. WVDEP strategically plans water quality monitoring prior to TMDL development where numerous monitoring locations are established and a comprehensive suite of analytes are sampled. This fine scale monitoring resolution coupled with identification and characterization of problematic sources through field-based source tracking activities provides a sound basis for assessment and TMDL development for all streams and impairments within the watershed.

In addition, WVDEP has created unique ways to integrate large-scale, watershed-based TMDLs with fine-scale, highly technical methodologies that produce "implementable" TMDLs in a cost-effective manner. The comprehensive watershed based approach typically includes all known impairments in the watershed and involves a multi-faceted modeling approach to address total recoverable metals, dissolved metals, acidity (pH), bacteria, and biological impairments. This watershed-based approach allows WVDEP to maximize efficiency throughout all phases of TMDL development and thereby minimizing funding requirements of their TMDL program. Since 2003, WVDEP's TMDL program has completed more than 1,300 EPA approved TMDLs (428 streams) with another 675 (250 streams) currently under development.

WVDEP also has designed a "TMDL on CD" concept where all relevant TMDL information (TMDL Reports and Appendices, Technical documentation, and supporting data) is included on a CD-ROM. To further improve the usability of the TMDLs, WVDEP developed a series of interactive tools to provide TMDL implementation guidance. These tools are designed to simplify and assist "implementers" (nonpoint source staff and permit writers) in using the TMDLs to develop watershed plans and issue/renew permits. An interactive ArcExplorer geographic information system (GIS) project allows the user to explore the spatial relationships of the source assessment data, as well as further details related to the data. Users are also able to "zoom in" on streams and other features of interest. In addition, spreadsheet tools (in Microsoft Excel format) were developed to provide the data used during the TMDL development process and the detailed source allocations associated with successful TMDL scenarios. These tools provide guidance for selection of implementation projects as well as for permit issuance and are also included on the TMDL Project CD.



2.3. Implementation Benefits

While many of the benefits of watershed TMDLs are realized during the development stages, there are several additional benefits realized during TMDL implementation. Many of these benefits also present financial, programmatic and environmental benefits but are included here to highlight the separate step of implementation, which often involves its own set of unique issues and considerations compared to TMDL development. The following are the primary benefits of watershed TMDLs as related to TMDL implementation.

Provides a Framework for More Effective Implementation. Building on the organizational and environmental benefits from the TMDL development stage (e.g., source assessment, upstream-downstream impacts), watershed TMDLs can more effectively target source controls and allow for better implementation planning. The implementation plans developed based on watershed TMDL analyses and allocations are likely to be more equitable and effective than those developed for single-segment TMDLs because they consider the relative magnitude and influence of all sources. A watershed TMDL can also provide the necessary information to meet Section 319 requirements to receive funding for implementation of watershed management projects. For example, TMDLs quantify source loads and identify the necessary load reductions needed to meet water quality standards, important elements of a watershed plan required by Section 319 supplemental guidance. In addition, a watershed TMDL is more likely to parallel the geographic scope of a watershed management planning effort than is a single-segment TMDL.

Facilitates Watershed-wide Planning. Applying a watershed approach to TMDLs allows for easier integration with the overall watershed management approach. As recently promoted in EPA's *Handbook for Developing Watershed-based Plans to Protect and Restore our Waters* (USEPA 2008), TMDLs developed within a watershed management framework can provide the quantitative link between on-the-ground actions and the attainment of water quality standards. The TMDLs can serve as a tool to quantify necessary load reductions and guide nonpoint source controls within the watershed planning process. Similarly, as discussed below, a watershed TMDL can provide a framework for implementing other watershed-based source controls, such as watershed-based permitting and water quality trading.

Promotes "Equal Representation" Among Sources. Because watershed TMDLs evaluate source, whether nonpoint or point, impacts across an entire watershed, they evaluate the sources at the same time and with comparable analyses and approaches. Sources can be represented using the same assumptions and within the same context. This can make stakeholders representing pollutant sources feel more comfortable that they are receiving the same treatment and representation as other sources in the watershed. This process can help to avoid "finger-pointing" at sources that would have otherwise been excluded from the analysis. It can also avoid the worries of stakeholders concerning new or additional allocations that would have been developed in the future in TMDLs developed for nearby waters or for similar pollutants.

Facilitates Use of Innovative Implementation Options. Watershed TMDLs provide an organizational and quantitative framework for innovative approaches to point source control such as watershed-based permitting and water quality trading. WLAs in watershed TMDLs are developed with consideration of the cumulative effects of all the nonpoint and point sources in the watershed; this facilitates the effective use of watershed-based permitting and water quality trading. Because a watershed permitting approach needs to consider all sources in the watershed when determining permit provisions, an existing TMDL can save a great deal of time and effort if it has already considered all of the sources to identify necessary WLAs. Similarly, developing TMDLs on a watershed basis maximizes opportunities for implementing WLAs through water quality trading programs. The larger geographic area for which WLAs are established in a watershed TMDL combined with the more extensive pollutant fate and transport analyses provide some of the needed information and drivers for water quality trading programs to be successful. Water quality trading programs allow for those point sources with higher pollutant control costs to achieve their WLA in a more cost effective manner by paying another pollutant source, whose control costs are lower, to make pollutant reductions needed to meet the WLA or the new water quality-based effluent limitation (WQBEL) that is derived from the WLA.

More Easily Addresses Non-traditional Point Sources. A watershed TMDL provides a tool for more effectively integrating and addressing non-traditional point sources, such as CAFOs and Phase II stormwater communities, in the allocation process. *Non-traditional* point sources are those sources that are regulated and subject to NPDES permits yet behave like a nonpoint source, primarily delivering land-based loads in response to precipitation runoff events. These sources present a challenge to TMDL practitioners and regulators because of the difficulty of identifying appropriate WLAs for sources that do not have discrete discharge points or operate under a controlled set of conditions as do traditional permitted facilities. The watershed TMDL provides an opportunity to evaluate these sources in the context of the larger watershed and to most appropriately account for their behavior and response. Particularly with permitted stormwater, a watershed TMDL can better evaluate the stormwater inputs and influence on in-stream water quality. Because the watershed TMDL considers the entire watershed, likely evaluating various subwatershed and land use types, it can provide flexibility in how to express stormwater WLAs (e.g., for entire MS4 area, by subarea, by impervious land uses) and construction stormwater future growth provisions.

3. Identifying Candidates for Watershed TMDL Development

> **Process Tip:**
>
> What is the Scope of a Watershed TMDL?
>
> This section provides a series of criteria to evaluate 303(d) listings in a defined geographic area (e.g., statewide, specific basin) to narrow the larger area into multiple "bundles" of waterbodies and impairments to be addressed in watershed TMDLs. This process defines the ***scope*** of the respective watershed TMDLs—both the geographic extent of the watershed and also the individual pollutant-waterbody combinations that will be addressed in the analysis.

The first step in developing watershed TMDLs is identifying and evaluating the opportunities for and defining the scope of the TMDLs. Ideally, a state can identify those waters and impairments that are appropriate for a watershed TMDL framework as they are developing their TMDL schedules based on current 303(d) lists. While it would be ideal for all state TMDL programs to operate on a watershed framework, that is not necessarily the reality. Assuming that the majority of a state's list can be addressed through the use of watershed TMDLs, one of the goals of this document is to encourage states to coordinate their TMDL development on a watershed basis to more efficiently and effectively tackle their TMDL development commitments. Planning for watershed TMDLs should be approached with the idea that most waterbody-impairment combinations can be addressed as part of a larger watershed TMDL; however, there will be some instances that are more appropriate as single-segment TMDLs.

The decision to develop a watershed TMDL will be guided by multiple factors that will usually serve to determine the actual scope of the TMDL—how large is the geographic area and what range of pollutants and sources should be addressed? If a waterbody segment is impaired by one pollutant originating from a unique, localized source, a watershed TMDL might not be necessary because the impairment and source activity might not impact other segments within the larger watershed. However, many impairments and impaired segments within a watershed can be "bundled" and addressed through a broader watershed TMDL. There is no set size for the geographic area of a watershed TMDL and no rules on the number of waterbodies or impairments addressed. Watershed TMDLs have addressed areas ranging in size from a few square miles to thousands of square miles and scopes of two impaired segments for the same pollutant to thousands of waterbody-pollutant combinations. Ultimately, the scope of the TMDL depends on a variety of project- and watershed-specific factors that must be considered in the planning stages. This section addresses the various factors to consider in determining whether a watershed TMDL is appropriate and the scope of the TMDL or whether a single-segment analysis is best.

Figure 3-1 illustrates the typical screening criteria for identifying candidate groupings for, and ultimately defining the scope of, watershed TMDLs. Starting with the 303(d) listings within the area of concern, whether statewide or for a specific region or basin, evaluating these criteria should help identify candidate groupings or "bundles" of waterbodies and related impairments for watershed TMDL development. This process should also identify those listings that are appropriate for single-segment TMDL development.

As shown in Figure 3-1, the first, and most important, screening criterion, is related to the listing—the impairment, waterbody type, and sources. The next screening level evaluates program commitments such as consent decrees and available resources to further narrow the scope or prioritize the watershed candidates. The final screening is based on evaluating the existence of ongoing watershed-based efforts that can define or guide the scope of a watershed TMDL.

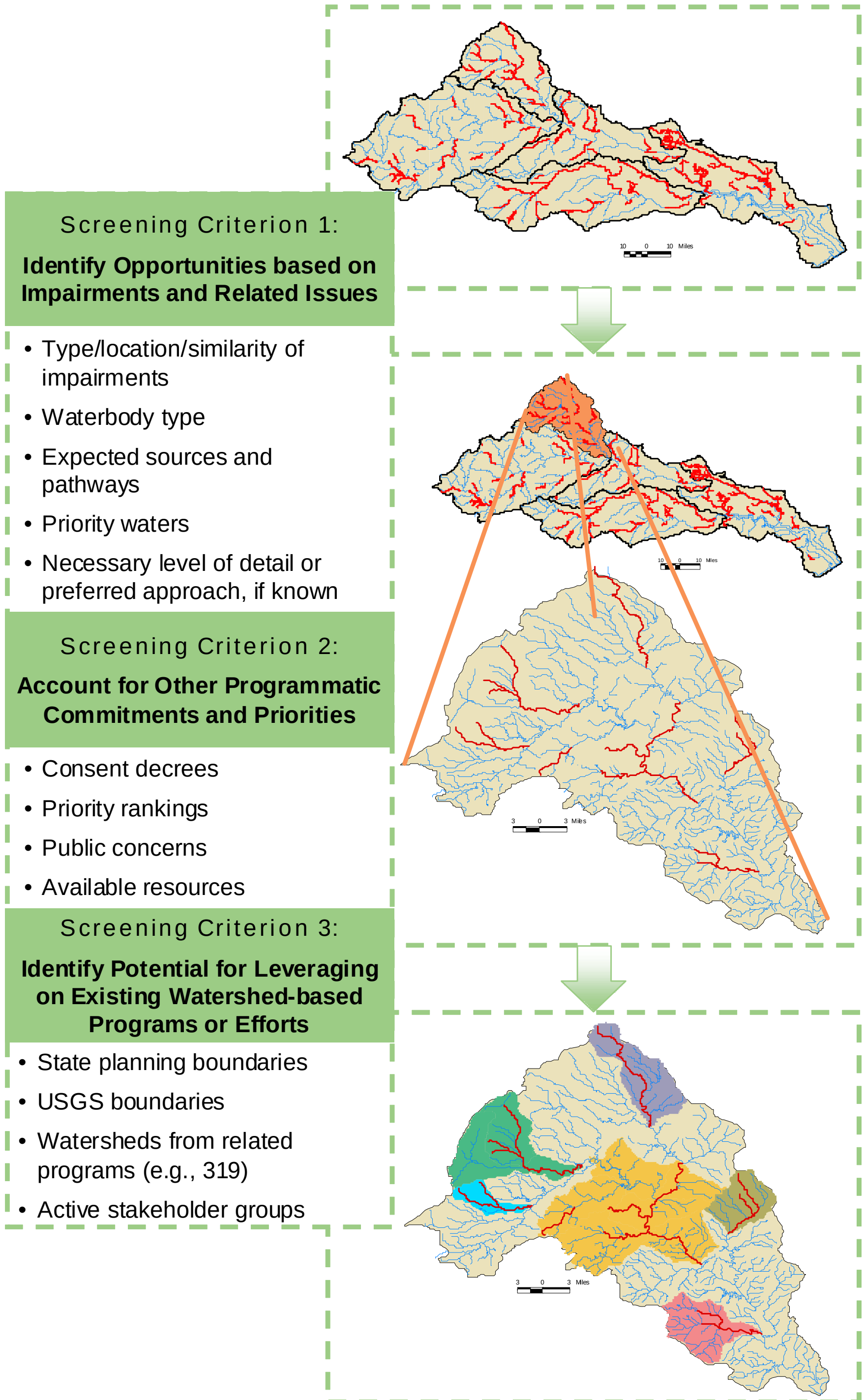


Figure 3-1. Process for identifying the scope of a watershed TMDL.

While these screening criteria are presented in a priority order for evaluation, they are not steps that are dependent on one another. Practitioners can independently evaluate each criterion and, in some areas, not all of the considerations will be relevant or necessary for identifying groupings for watershed TMDLs. For example, the first criterion is applicable to any exercise to identify candidates for watershed TMDLs, using information contained on a state's 303(d) list. Alternatively, the final screening criterion based on existing watershed efforts might not be relevant to many watersheds. Either there are no existing watershed efforts with which to coordinate or information on their existence is not readily available or known to the state. However, a few quick inquiries to representatives from related programs (e.g., Section 319 nonpoint source program, permitting, monitoring) can hopefully identify any efforts worth considering in identifying watershed TMDL candidates. All of the screening criteria discussed in this section serve to work in concert to collectively narrow the starting scale (e.g., state, basin) down to several manageable and logical groupings for watershed TMDL development, as well as identify those listings to address in single-segment TMDLs.

> **Process Tip:**
>
> Where to Start in Identifying Watersheds for TMDL Development
>
> Even if a state doesn't currently schedule TMDLs as watershed groupings, impaired segments are typically identified and organized on a watershed basis. State 303(d) lists might organize the listed segments according to 8-digit hydrologic unit, even if not by smaller subbasins. These basins are a logical place to start in identifying the watershed groupings for TMDLs. By looking at the listings within an 8-digit basin, it will be easier to identify the logical combinations of segments and impairments for smaller watersheds.

3.1. Identifying Opportunities based on Impairment and Related Issues

The first screening criterion for identifying opportunities for developing watershed TMDLs is based on evaluation of the 303(d) listings, including the impairment type, waterbody type, and the associated sources, as well as what implications these factors might have on the TMDL approach. Of these, the impairment and waterbody type are readily available from all 303(d) lists. They provide the most basic of filters in identifying potential groupings for watershed TMDL development. Source type is helpful for further grouping waters and impairments; however, expected sources are not included on all 303(d) lists and also are not always known. The final factor in this category is considerations related to the eventual TMDL technical approach. This can include critical conditions or a preferred approach. For example, some programs have standard TMDL development approaches or tools. Using this as a screening tool for grouping watershed TMDLs can identify those waterbody-impairment combinations for which that approach is appropriate. As with all of the screening criteria discussed in this section, all of these factors might not be relevant or even known for the area of concern.

> **Process Tip:**
>
> Impairment-related Issues to Consider when Grouping Watershed TMDLS
>
> - Impairment type or pollutant
> - Source dynamics (pollutants delivered, delivery mechanisms, characteristics)
> - Source type (point, nonpoint)
> - Waterbody type and characteristics
> - Critical conditions
> - Required level of detail or preferred approach, if known

3.1.1. Impairment and Source Type

Impairment(s) or the source(s) of the impairment can determine the groupings addressed through a watershed TMDL. Bundling together multiple segments with the same or related impairments for TMDL analysis can create economies of scale in data collection, technical analysis, and report development. Impairments due to "eutrophication" or "nutrients," for example, often require analysis of multiple processes and parameters including dissolved oxygen levels, nutrient cycling, pH, and even sedimentation. For watersheds with multiple segments listed for the same impairments, it is more efficient to evaluate the interrelated processes and sources on the watershed scale to most efficiently develop allocations. Grouping impairments that are "similar"—meaning those that are likely to originate from common sources, are delivered through common pathways, or impair the waterbody under similar conditions—provides the same benefits.

Similarly, the expected sources or delivery pathways of the impairing pollutants can help to define the scope of a watershed TMDL. One of the greatest benefits of a watershed TMDL is the opportunity to evaluate multiple sources impacting a watershed, thereby evaluating their relative magnitude and maximizing the load reductions to get the most water quality improvement with the smallest, but targeted, load controls. This can impact multiple sources and multiple impairments. A watershed might have a number of sources contributing to multiple impairments. While some of those sources might exclusively contribute to single impairments, there is likely a subset of sources that generate a variety of pollutants and contribute to more than one impairment. Considering the sources occurring in a watershed, whether known or expected based on the impairments and general knowledge of the area, can help to identify combinations of waterbodies and impairments amenable to watershed TMDL development.

Table 3-1 provides the most commonly listed impairments and some of their typically associated sources. This illustrates the potential overlap in sources and related impairments. For example, agricultural areas are typically sources of pollutants such as nutrients, sediment, pesticides, and bacteria; these areas are not usually associated with metals or toxic pollutants. In addition, sediment and nutrients are often associated with shared sources because nutrients can be sorbed to sediments and delivered to receiving waters through erosion and runoff processes. While this type of information can provide a general understanding of the common impairments and their associated sources, practitioners should base candidates for watershed TMDL development on site-specific knowledge of expected sources of the pollutants of concern whenever possible.

Table 3-1. Summary of Common Pollutants and Sources

Pollutant	Potential Point Sources	Potential Nonpoint Sources
Pathogens	▪ WWTPs ▪ CSOs/SSOs ▪ Permitted CAFOs ▪ Discharges from meat processing facilities ▪ Landfills	▪ Animals (domestic, wildlife, livestock) ▪ Malfunctioning septic systems ▪ Pastures ▪ Boat pumpout facilities ▪ Land application of manure ▪ Land application of wastewater
Metals	▪ Urban runoff/permitted stormwater ▪ WWTPs ▪ CSO/SSOs ▪ Landfills ▪ Industrial facilities ▪ Mine discharges	▪ Abandoned mine drainage ▪ Hazardous waste sites (unknown or partially treated sources) ▪ Marinas ▪ Atmospheric deposition
Nutrients	▪ WWTPs ▪ CSOs/SSOs ▪ CAFOs ▪ Discharge from food-processing facilities ▪ Landfills	▪ Cropland (fertilizer application) ▪ Landscaped spaces in developed areas (e.g., lawns, golf courses) ▪ Animals (domestic, wildlife, livestock) ▪ Malfunctioning septic systems ▪ Pastures ▪ Boat pumpout ▪ Land application of manure or wastewater ▪ Atmospheric deposition

Pollutant	Potential Point Sources	Potential Nonpoint Sources
Sediment	▪ WWTPs ▪ Urban stormwater systems ▪ Construction ▪ CAFOs	▪ Agriculture (cropland and pastureland erosion) ▪ Silviculture and timber harvesting ▪ Livestock (rangeland erosion, streambank erosion) ▪ Excessive streambank erosion ▪ Construction ▪ Roads ▪ Urban runoff ▪ Landslides ▪ Abandoned mine drainage ▪ Stream channel modification
Temperature	▪ WWTPs ▪ Cooling water discharges (power plants and other industrial sources) ▪ Urban stormwater systems	▪ Lack of riparian shading ▪ Shallow or wide channels (due to hydrologic modification) ▪ Hydroelectric dams ▪ Urban runoff (warmer runoff from impervious surfaces) ▪ Sediment (cloudy water absorbs more heat than clear water) ▪ Abandoned mine drainage

The types of sources (point source, nonpoint source or mixed) can also be a factor in evaluating how to define the scope of a watershed TMDL. The types of sources can influence what approaches are feasible and how much detail will be necessary for the TMDL analyses. For example, an analysis accounting for both point and nonpoint sources might require more data and a more detailed analysis to evaluate the varying critical conditions and types of loading. However, a watershed scale analysis for areas with mixed sources (point and nonpoint) helps to ensure an adequate assessment of the problems and maximize the potential for controls. It is necessary to consider the benefits of evaluating multiple types of sources versus the need for a more rigorous analysis and therefore a likely increase in time and resources needed for the analysis. In addition, the coverage or extent of some sources might guide the definition of a watershed for TMDL development. For example, the regulated areas of Phase I or Phase II MS4s might fall within targeted watersheds and addressing associated TMDLs within the larger watershed context can facilitate better representation and inclusion of the MS4 loadings.

3.1.2. Waterbody Type

Evaluating multiple types of waterbodies (e.g., lakes and rivers) within a watershed TMDL sometimes adds a layer of complexity depending on how detailed an analysis is required. In the context of a watershed TMDL, the goal is to include upstream tributaries contributing loads to the multiple waterbodies of concern. Although the analysis might take all waterbodies into consideration, the resulting allocations might solely focus on one type of waterbody. For example, when dealing with a large lake that exhibits impairments impacted by internal lake processes and conditions in addition to the amount and timing of incoming watershed loads, a detailed analysis of the lake is typically used to fully understand the lake dynamics and capture spatial differences. The lake-specific analysis coupled with a comparably detailed watershed analysis to evaluate the loads originating throughout the watershed can provide the ability to also develop TMDLs for impaired tributaries. However, the analysis can focus only on identifying the TMDL for the lake with the watershed loads more simply represented in the analysis as a cumulative load entering the lake. The location and interaction of impaired tributaries in a lake's watershed can influence whether the lake's TMDL is developed as a single-segment or watershed TMDL. Similar situations can exist when dealing with combinations of other types of waterbodies, such as rivers, controlled impoundments, and estuaries.

3.1.3. Technical Approach Considerations

Although not always known prior to TMDL development, the preferred technical approach or the level of detail required for a TMDL might affect how practitioners choose to group waterbodies and impairments for watershed TMDL development. There are instances where it is generally understood how much detail or the types or approaches that are appropriate given the waterbodies of concern and the associated impairments and sources. For example, in a watershed where sources are fairly well understood, a more diagnostic approach that evaluates source- or site-level impacts is not likely necessary. In this case, it might be feasible to develop TMDLs for a larger watershed area, using a simpler approach and encompassing more segments given the available resources and time. Alternatively, a complex system that has a number of sources that are not well-defined might require a more detailed analysis involving additional monitoring and field surveys and comprehensive modeling to understand the conditions and identify necessary allocations. In this case, it would likely be more effective to focus the watershed at a smaller scale around that system to allow for detailed analyses with the available resources.

In addition, states sometimes have preferred approaches or tools that they apply for TMDL development in an effort to promote consistency among projects and manage the resources and effort required to develop TMDLs. In this case, practitioners can consider the approach when identifying candidate groupings for watershed TMDL development. It would be necessary to evaluate the listings and identify those that are appropriate for the approach and evaluate whether grouping them together for a larger analysis makes sense.

Example:

Grouping Waters and Impairments for TMDL Development to Maximize
Use of a Proven, Consistent Approach in Southern California

EPA and California worked together to identify listings that could be grouped together to use a uniform approach for calculating TMDLs. EPA and the state assessed listings in the region and identified many of the coastal lagoons that are impaired by nutrients, bacteria, and sedimentation as candidates. Although the lagoons are not a traditional watershed in the sense that they are hydrologically connected, grouping them utilizes the same principals of a watershed TMDL—grouping similar listings and waterbodies to more effectively develop TMDLs. Using a consistent and proven approach for multiple listings and watersheds has resulted in a significant reduction in the costs to develop the TMDLs and buy-in from stakeholders. Facilitated by the use of a consistent approach across the region, stakeholders have led an effort to develop a comprehensive regional monitoring strategy to both inform the technical analyses and support tracking progress in meeting water quality standards.

3.2. Accounting for Programmatic Commitments and Priorities

The second screening criterion for determining the scope of watershed TMDLs is programmatic commitments and priorities, as shown previously in Figure 3-1. Most TMDL programs have existing commitments or priorities that can affect TMDL grouping, prioritization, and development. These commitments and priorities can include existing consent decrees that establish TMDL schedules, priority rankings identified in 303(d) lists or TMDL schedules, public concerns or priorities and the availability of program resources to support TMDL development.

3.2.1. Consent Decrees and Settlement Agreements

Program priorities set by consent decrees or settlement agreements can often drive the schedule of TMDL development. Depending on the type of priorities influencing the program, they can either facilitate or hinder development of TMDLs on a watershed basis. Many consent decrees establish TMDL schedules or commitments for states, but do not specifically identify the waters that the state must address in the timeframe. In this situation, the states can establish their own schedules and target specific waters as long as they meet the court-ordered deadlines and commitments for developing a minimum number of TMDLs. Alternatively, some states do have specific waters that the TMDL program must address in a set timeframe, forcing the state to prioritize those waters over others. Because those waters might not relate in terms of pollutants or sources, or share the same geographic boundaries, practitioners might find it difficult to plan for a watershed TMDL when operating under this type of court-mandated schedule.

For states that can establish their own TMDL schedules, using watershed TMDLs might help to more efficiently meet TMDL development commitments. When dealing with commitments for specific waters that are not identified based on geographic region, impairment type or other connecting factor this might be more difficult. However, specific waters identified in consent decrees can still be grouped with other waters (not included in the consent decree) as part of a watershed TMDL. States can integrate the required TMDLs into broader TMDL projects to meet their commitments while implementing a watershed approach and more holistically and efficiently addressing their water quality impairments.

3.2.2. Priority Rankings

States identify the priority rankings for waters included on their 303(d) lists. Similar to having a consent decree specify TMDL development for certain waters, priority rankings might dictate development schedules that hamper addressing the prioritized waters as part of a comprehensive watershed TMDL. Watersheds that contain waters with varying priority levels might lead the state to focus on the "high" priority waters before addressing the "low" priority waters in the same watershed – resulting in a missed opportunity for a comprehensive, integrated watershed TMDL project. If the impaired waters in a watershed have varied rankings, practitioners might consider using the first screening criterion to evaluate whether these waters have other shared factors that are appropriate for a watershed TMDL process (e.g., have similar impairments and sources). If so, the state could proceed with grouping the waters as part of a watershed TMDL, regardless of the "low" rankings of some of the segments. If the lower rankings are appropriate to address separately from the high-priority waters (e.g., unique impairment, localized sources, not impacted by upstream sources), it makes sense for the state to continue with scheduling the TMDLs separately according to their original priority rankings.

> ***Process Tip:***
>
> Low vs. High Priority Waters
>
> Because waters have different priority rankings on a state's 303(d) list does not mean they cannot be addressed at the same time as part of a watershed TMDL. If waters of varying priority are hydrologically connected, experience similar impairments, and have similar sources, a state should consider grouping the waters for a watershed TMDL, despite the varying priorities.
>
> This approach might add waters to their current workload since they will be addressed sooner than they are scheduled. However, in the long run, developing the watershed TMDL will provide cost savings over addressing the waters individually and will result in a **more scientifically defensible and implementable TMDL**.

3.2.3. Availability of Resources

While technical considerations can determine the scope of a TMDL, practical considerations such as available budget and schedule can also be important factors in deciding how to approach a watershed TMDL. Whether single-segment or watershed, the cost and time associated with developing TMDLs can vary widely. Therefore, it is often necessary to consider the expected resources needed to complete a TMDL when deciding on its scope. The available timeframe and budget for developing TMDLs can be considered along with the expected complexity of the analysis to find the most beneficial scale and scope—one at which the analysis can be completed within the available resources while still meeting the project goals in an appropriate and scientifically defensible manner.

The perception of the funding or technical resources necessary to develop watershed TMDLs might discourage practitioners and serve as an obstacle to initiating a watershed TMDL process. However, as discussed in Section 3, a watershed TMDL can result in cost savings to a TMDL program by more efficiently using the available resources and reducing the per-TMDL costs. Due to the potential time-savings associated with a watershed TMDL process, the project might have a shorter lifespan with a larger upfront budget—a budget that will likely be less than the combined budget of the corresponding single-segment TMDLs. Developing TMDLs on a watershed basis ultimately saves money and maximizes resources. They also provide the state with maximum flexibility in setting allocations, thereby providing more opportunities for optimizing the cost of implementation.

The availability or experience of staff to complete TMDLs can also influence the decisions regarding scope of a TMDL. Watershed TMDLs might require more complex approaches (e.g., dynamic modeling) and can present difficulties for inexperienced practitioners. However, most TMDL practitioners have access to technical support staff, technical training or qualified consultants to support more detailed analyses, if necessary. In addition, having limited technical expertise or resources should not preclude practitioners from choosing to develop watershed TMDLs. Watershed TMDLs can accommodate a variety of technical approaches and still accomplish many of the benefits of the most detailed, complex watershed TMDLs. For example, a watershed TMDL might use a load duration or other statistically based TMDL approach and apply that approach at various locations throughout the watershed to address impaired segments. Although this approach does not quantitatively account for upstream-to-downstream effects and the cumulative impact of watershed sources, it still evaluates the watershed as a whole. It allows the practitioner to identify major sources throughout the watershed, evaluate spatial variations in water quality and source activity, and target controls more efficiently.

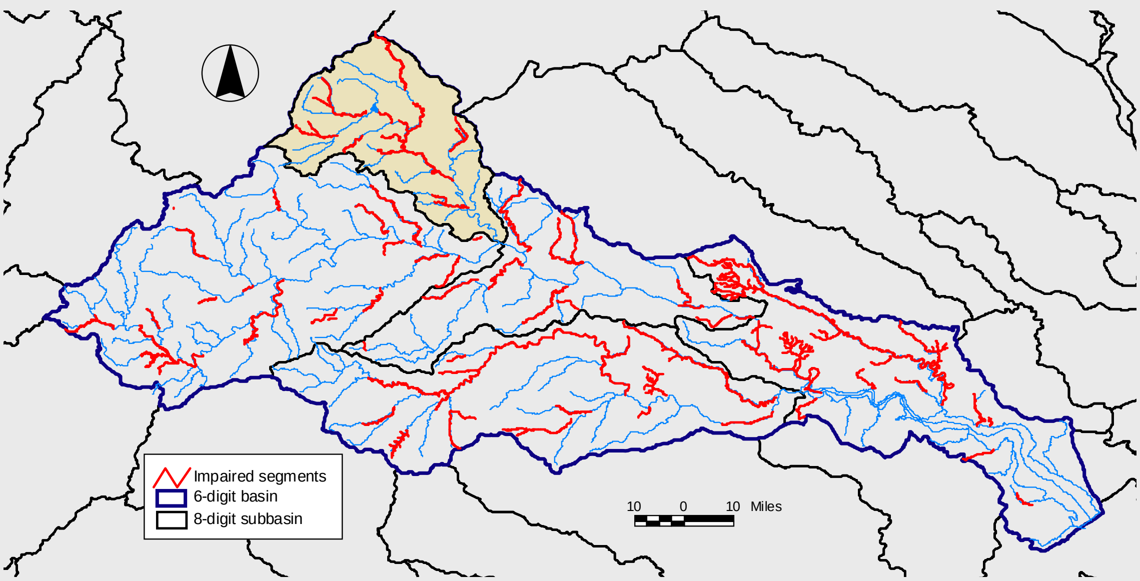
Planning for TMDLs should consider the expected level of resources and time needed to address a particular waterbody or impairment when deciding how to group watershed TMDLs. Waterbodies with impairments and sources that are fairly well understood will likely have more straightforward approaches and predictable resource needs. However, some TMDLs might appear to require more analyses, resources and time to adequately address, such as impairments that are impacted by a number of varying pollutants and sources; loads contributed by multiple permitted and unpermitted sources; and complex physical, biological and chemical dynamics and processes. Anticipated costs and complex technical considerations might indicate the need to consider a more focused single-segment TMDL rather than a watershed TMDL.

Example:

Example Analysis to Identify Groupings for Watershed TMDL Development

This example identifies potential watershed TMDL groupings based on listed impairments and related issues (i.e., Screening Criterion 1 in Figure 3-1). Because most of this information is readily available on a state's 303(d) list or the supporting assessment documentation, it will be the first and most commonly applied criterion for identifying groupings. The remaining criteria (i.e., programmatic commitments, existing watershed-based efforts) are likely to be more site-specific in their availability and usefulness. They should be considered when identifying groupings, when available and relevant, but are not explicitly illustrated in this example. The goal of this grouping exercise is to review available listing and assessment information for similarities in type/location/behavior of impairments, waterbody type, expected sources and pathways, priority waters, level of detail/approach.

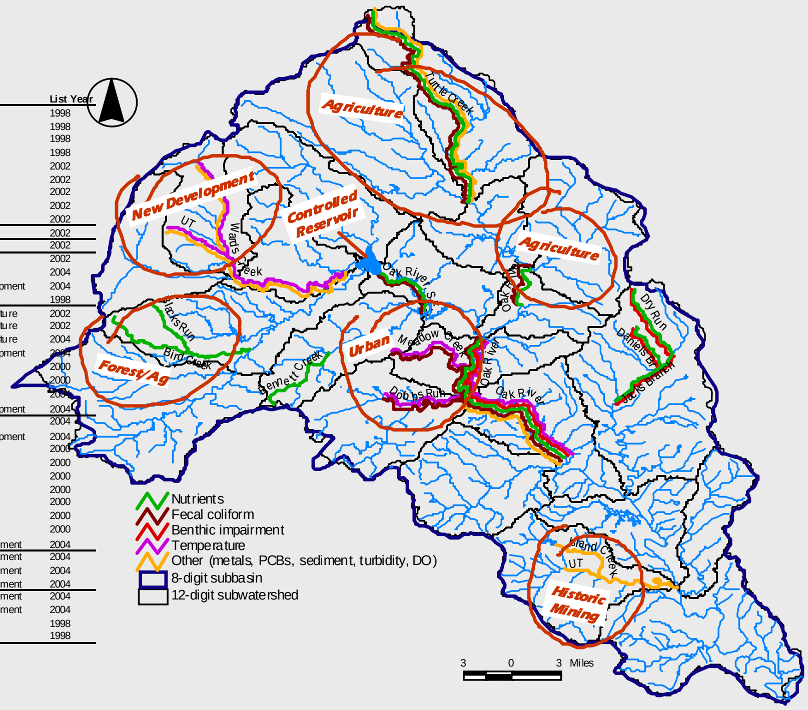
The evaluation for identifying watershed TMDL groupings can be conducted at any geographic scale, whether statewide or within a specific watershed of concern. If dealing with the listings for an entire state it will be useful to approach the listings for smaller divisions. For example, most state lists are organized according to 8-digit subbasins or other state planning watersheds. This can be a logical scale at which to begin. In some states, watershed TMDLs are developed at the 8-digit watershed scale. However, available resources, schedule and priorities cannot always accommodate that approach. For this example, listings are evaluated for an 8-digit watershed, highlighted in the following figure, to identify smaller groupings appropriate for watershed TMDLs, as well as those impairments that are better addressed using an individual TMDL analysis.



The following figure presents the hypothetical 303(d) listings for the fictional 8-digit Oak River subbasin. The impairments listed in the table are presented on a map of the subbasin to illustrate the distribution and location of similar impairments. As shown in the table and map, there are multiple impaired waters in the subbasin, many with multiple impairments. The 303(d) list also identifies expected sources of the impairments, including agriculture and urban runoff. These sources have been labeled on the map to illustrate the distribution of sources in relation to impaired segments. Also included on the map are the boundaries of the state's existing planning level subwatersheds (12-digit) that can help to identify the associated watersheds of the identified groupings.

Example Analysis to Identify Groupings for Watershed TMDL Development (continued)

List ID	Waterbody Name	Size	Impairment	Source	List Year
ABC-1234	Island Creek	7.5 mi	Iron	Point source	1998
			Aluminum	Point source	1998
ABC-1238	Unnamed Trib to Island Creek	1.8 mi	Iron	Point source	1998
			Aluminum	Point source	1998
ABC-1242	Jacks Branch	4.2 mi	Nutrients	Unknown NPS	2002
			Benthic Impairments	Unknown NPS	2002
ABC-1243	Daniels Branch	2.5 mi	Nutrients	Unknown NPS	2002
			Benthic Impairments	Unknown NPS	2002
ABC-1244	Dry Run	4.3 mi	Nutrients	Unknown NPS	2002
			Benthic Impairments	Unknown NPS	2002
ABC-1247-03	Oak River	6.8 mi	Fecal Coliform	Urban Runoff	2002
			Nutrients	Urban Runoff	2002
			Benthic Impairments	Urban Runoff	2004
			Temperature	Urban Runoff/Development	2004
			PCBs	Unknown	1998
ABC-1247-04	Oak River	7.1 mi	Fecal Coliform	Urban Runoff, Agriculture	2002
			Nutrients	Urban Runoff, Agriculture	2002
			Benthic Impairments	Urban Runoff, Agriculture	2004
			Temperature	Urban Runoff/Development	2004
ABC-1247-06	Oak River	2.9 mi	Fecal Coliform	Agriculture	2000
			Nutrients	Agriculture	2000
ABC-1248	Meadow Creek	5.3 mi	Fecal Coliform	Urban Runoff	2004
			Temperature	Urban Runoff/Development	2004
ABC-1249	Dobbs Run	5.2 mi	Fecal Coliform	Urban Runoff	2004
			Temperature	Urban Runoff/Development	2004
ABC-1256	Turtle Creek	14.5 mi	Nutrients	Agriculture	2000
			Fecal Coliform	Agriculture	2000
			Dissolved Oxygen	Nutrient Enrichment	2000
			Turbidity	Agriculture/Grazing	2000
ABC-1260	Oak River, S.F.	4.1 mi	Fecal Coliform	Agriculture	2000
			Nutrients	Agriculture	2000
ABC-1262	Bennett Creek		Nutrients	Agriculture	2000
ABC-1265-01	Wards Creek	7.7 mi	Sediment	Construction/Development	2004
			Temperature	Construction/Development	2004
ABC-1265-02	Wards Creek	6.3 mi	Sediment	Construction/Development	2004
			Temperature	Construction/Development	2004
ABC-1266	Unnamed Trib to Wards Creek	3.4 mi	Sediment	Construction/Development	2004
			Temperature	Construction/Development	2004
ABC-1272	Bird Creek	7.6 mi	Nutrients	Agriculture	1998
ABC-1273	Blacks Run	3.4 mi	Nutrients	Agriculture	1998



As shown in the above table and map, there are a number of waterbodies that share common impairments and/or sources. Visually evaluating the location and connection of these impairments and sources can help in identifying potential groupings for watershed TMDL development. For example, many of the segments are listed as impaired by fecal coliform and nutrients from either agriculture or urban runoff. The shared pollutants can provide a basis for grouping, but different sources can sometimes require different analyses to account for varying delivery pathways and source behavior. Many of the segments in the middle of the watershed (e.g., Oak River, Meadow Creek, Dobbs Run) seem to be impacted by urban runoff while those in the northern part of the watershed (Turtle Creek) are impaired by agriculture. However, the watershed seems to transition from agriculture uses to urban uses as evidenced by the most upstream segment of Oak River, which is identified as impaired by both agricultural and urban runoff. This apparent transitioning of land uses provides some guidance for how to group many of these segments for analysis to evaluate the separate and also cumulative effect of the different sources on the connected segments. Within this grouping Turtle Creek also is impaired for low dissolved oxygen and elevated turbidity. While these listings are not the same as the other similar fecal coliform, nutrients and benthic impairments, they will likely involve many of the same analyses. Dissolved oxygen is likely linked to the nutrient impairments and the turbidity impairment can be caused by many of the same sources (e.g., runoff from agriculture or algal growth from excessive nutrients).

Alternatively, there are some impairments or waters that can merit smaller groupings/watersheds or even individual analysis either because of the nature of their impairment or the location of the waterbodies. For example, within the Oak River grouping, there are some impairments listed for temperature and PCBs. The temperature listings might share a source (urban runoff) with the nutrient and fecal coliform impairments, but the dynamics and behavior of the source and resulting impairment are often different. Because of the unique nature of temperature impacts and impairments, the data analysis, source assessment, TMDL calculation approach and even the identification and expression of allocations will likely be very different from those conducted for other pollutants. For this reason, it would be appropriate to address the temperature listings separately from other impairments; however the temperature-impaired segments can be grouped together for analysis to evaluate the common sources and causes, more efficiently analyze the data and apply a common technical approach. Also within this grouping, PCBs are listed as an impairment for only one segment in the subbasin. PCBs are typically related to legacy sources and might be the result of highly localized issues. These issues and other unique characteristics (environmental persistence, unknown sources) provide an ideal justification for addressing the PCB impairment as an individual TMDL.

Example Analysis to Identify Groupings for Watershed TMDL Development (continued)

In addition, while Dry Run, Daniels Branch and Jacks Branch experience similar impairments as the Oak River grouping, they are not hydrologically connected to those impaired segments, and any water quality improvement or impairment would not have an impact on the Oak River segments and vice versa. Therefore, it makes sense to group the three segments in the eastern portion (Jacks Branch, etc.) together for analysis. Their impairments of nutrients and benthic impacts can feasibly be analyzed together because of likely common sources (although unknown at listing) as well as shared data analyses. Benthic impairments are usually linked to sources of excessive sediment or nutrients, and the analysis to identify the stressors often involves evaluation of much of the same data as would be analyzed for a nutrient impairment. In addition, sources targeted for control of nutrients loads would often be the same as those impacting the benthic community.

Island Creek also represents isolated segments that are not hydrologically impacted by other impaired segments. In addition, they are listed for metals, an impairment that is not associated with any other segment in the subbasin. The list indicates the impairment is due to historical mining activities. Because of the location and the localized impairment, these segments and their associated metals impairments can be grouped for TMDL development.

While the upstream segments in the northwestern portion of the watershed (Wards Creek, Blacks Run, Bird Creek) are hydrologically connected to downstream impaired segments, they are located upstream of a controlled reservoir that can act as a divide for the watershed. The reservoir can serve as an upstream boundary for the watershed of the Oak River grouping and allow for the upstream segments to be analyzed separately from downstream segements. These upstream segments experience a variety of impairments, including sediment, temperature and nutrients. While these impairments are not the same and they might not share sources (temperature and sediment impacts from construction vs. nutrients from agriculture), the stream segments (Wards Creek, Bird Creek, Blacks Run) could still be grouped together for a larger watershed TMDL. Sediment and nutrients often require similar analyses and although impairments are not the same, there will likely be efficiencies in data analysis and other TMDL activities. On the other hand, it would also be appropriate to break these upstream segments into groupings based on their impairment and associated sources. For example, Wards Creek and its impaired tributary would be grouped to address their multiple impairments for temperature and sediment, while Bird Creek and Blacks Run would be grouped together to address their nutrient impairments. This decision would likely be based on program-specific factors such as available resources (funding and staff time) and existing studies or activities for the area.

The following table and map illustrate the resulting groupings based on the above evaluation, with each color grouping representing a separate watershed TMDL and the corresponding impaired segments and impairments.

List ID	Waterbody Name	Size	Impairment	Source	List Year
ABC-1234	Island Creek	7.5 mi	Iron	Point source	1998
			Aluminum	Point source	1998
ABC-1238	Unnamed Trib to Island Creek	1.8 mi	Iron	Point source	1998
			Aluminum	Point source	1998
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			Benthic Impairments	Unknown NPS	2002
ABC-1243	Daniels Branch	2.5 mi	Nutrients	Unknown NPS	2002
			Benthic Impairments	Unknown NPS	2002
ABC-1244	Dry Run	4.3 mi	Nutrients	Unknown NPS	2002
			Benthic Impairments	Unknown NPS	2002
ABC-1247-03	Oak River	6.8 mi	Fecal Coliform	Urban Runoff	2002
			Nutrients	Urban Runoff	2002
			Benthic Impairments	Urban Runoff	2004
			Temperature	Urban Runoff/Development	2004
			PCBs	Unknown	1998
ABC-1247-04	Oak River	7.1 mi	Fecal Coliform	Urban Runoff, Agriculture	2002
			Nutrients	Urban Runoff, Agriculture	2002
			Benthic Impairments	Urban Runoff, Agriculture	2004
			Temperature	Urban Runoff/Development	2004
ABC-1247-06	Oak River	2.9 mi	Fecal Coliform	Agriculture	2000
			Nutrients	Agriculture	2000
ABC-1248	Meadow Creek	5.3 mi	Fecal Coliform	Urban Runoff	2004
			Temperature	Urban Runoff/Development	2004
ABC-1249	Dobbs Run	5.2 mi	Fecal Coliform	Urban Runoff	2004
			Temperature	Urban Runoff/Development	2004
ABC-1256	Turtle Creek	14.5 mi	Nutrients	Agriculture	2000
			Fecal Coliform	Agriculture	2000
			Dissolved Oxygen	Nutrient Enrichment	2000
			Turbidity	Agriculture/Grazing	2000
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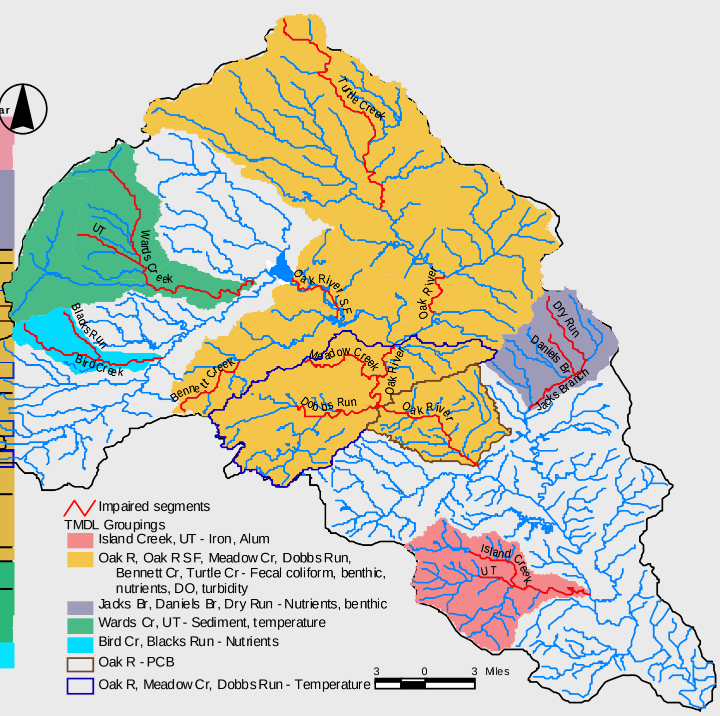
ABC-1265-02	Wards Creek	6.3 mi	Sediment	Construction/Development	2004
			Temperature	Construction/Development	2004
ABC-1266	Unnamed Trib to Wards Creek	3.4 mi	Sediment	Construction/Development	2004
			Temperature	Construction/Development	2004
ABC-1272	Bird Creek	7.6 mi	Nutrients	Agriculture	1998
ABC-1273	Blacks Run	3.4 mi	Nutrients	Agriculture	1998



3.2.4. Public Concerns

Sometimes the level of detail used in an analysis is influenced by the political or social concern over the waterbody. For example, a waterbody that is a “special resource” to the region, perhaps providing important recreational or economic opportunities, might merit a more detailed analysis because of the increased public interest and also the potential economic impact to the area if the water is not restored. When deciding how to group watershed TMDLs, it might be important to define the scope of a TMDL to allow the necessary level of detail and focus for these special waters.

3.3. Leveraging Existing Watershed-based Programs or Efforts

In some cases, ongoing and related watershed-based programs might facilitate identifying waterbodies and impairments to group in a watershed TMDL. Considering these existing watershed-based efforts represents the third screening criterion for determining the scope of watershed TMDLs, as shown previously in Figure 3-1. Many states coordinate some, if not all, of their water programs on a rotating basin or watershed framework. Whether or not this is the case for TMDLs, the existing planning structure can guide watershed TMDL planning. For example, planning basins used to coordinate monitoring schedules often serve as a good template for defining the geographic boundary of the TMDL. Established planning basins and associated schedules can also help to schedule the timing of watershed TMDL development. For example, if a basin is scheduled to undergo its 5-year cycle of monitoring in the next year, it might be helpful to evaluate the TMDLs that fall within that basin and schedule the TMDLs for a year following the monitoring and in groupings that correspond to monitoring schedules and station locations. Similarly, NPDES permits are sometimes reviewed and issued by basin on a set interval (e.g., every 5 years). Where this is the case, a practitioner can consider grouping TMDLs using a similar geographic organization and schedule TMDL development to precede permitting activities to ensure permit writers can incorporate relevant WLAs during the issuance or reissuance process.

Another consideration in identifying and grouping potential watershed TMDLs is the activities of existing stakeholder groups. Stakeholder groups have the potential to play an important role in TMDL development by providing data and information, identifying potential sources, providing historical and local perspective, and identifying opportunities for implementation activities. Some watersheds have active watershed groups that conduct a range of activities, from promotion of basic education and awareness to large-scale volunteer monitoring and cleanup activities to development of comprehensive watershed management plans. Large watersheds that have active watershed or stakeholder groups can be targeted for TMDL development to capitalize on the ongoing efforts and participation of the groups that already have a defined geographic focus.

Related to existing watershed groups and activities, ongoing watershed planning efforts under the Section 319 nonpoint source control program might also serve to guide identification of watershed TMDLs and their scope. While some Section 319 efforts focus on small, site-scale projects, others focus on wider watershed efforts for implementing BMPs or conducting monitoring. An existing 319 project can support watershed TMDL planning and development by helping to define the geographic scope of the analysis and providing a basis for the TMDL analysis. Recently EPA developed *Handbook for Developing Watershed Plans to Restore and Protect or Waters* (USEPA 2008) to encourage the development of comprehensive watershed-based plans to meet 319 requirements. These plans are typically more quantitative than historical 319 plans in

Example:

Guiding Watershed TMDL Development based on Related Previous, Ongoing or Planned Efforts

Sometimes the scope of a watershed TMDL can be defined to either build upon related previous or ongoing watershed-based efforts or similarly to facilitate planned efforts. The following are examples of how watershed TMDLs were chosen for development based on the goals or efforts of related watershed-based programs:

- **Simpson Northwest Timberlands Sediment and Temperature TMDLs:** The TMDLs for waters included in Simpson Timber Company land were developed concurrently with an aquatic Habitat Conservation Plan (HCP) developed under the Endangered Species Act (ESA) for the same geographic area. The HCP describes a suite of management prescriptions, assessment, and monitoring actions, with Simpson's conservation program emphasizing the protection of riparian forests and erosion control to satisfy the requirements of ESA §10. The TMDL provided the analytical framework to support the necessary riparian and sediment management practices identified in the HCP and provided needed technical information to guide monitoring efforts that satisfy the adaptive management aspects of the HCP. This unique coordination of two federal programs relied on cooperative input from the core group of Simpson, National Marine Fisheries Service, U.S. Fish and Wildlife Service, Washington Department of Ecology, and EPA. To read the Simpson TMDLs, please visit www.ecy.wa.gov/pubs/9956.pdf and www.ecy.wa.gov/biblio/0010047.html.
- **Long Island Sound Nitrogen TMDL:** Beginning in 1985, New York, Connecticut and the EPA formed the Long Island Sound Study (LISS) to promote measurable improvements to the water quality of the Sound. In 1994, the LISS completed a Comprehensive Conservation and Management Plan (CCMP) under EPA's National Estuary Program. The CCMP identified seven priority issues, the highest of which was low dissolved oxygen levels in the Sound. By 1998, the LISS CCMP adopted a 58.5 percent reduction target for nitrogen loads and specified in its implementation plan that a TMDL for nitrogen be adopted with LAs and WLAs for all sources in the watershed. As a result, the states of New York and Connecticut jointly developed and submitted a TMDL for nitrogen, which was approved by EPA in 2001.

their analysis of sources and linkage to water quality. Any existing or planned 319 watershed planning efforts provide an ideal basis for integrating and developing watershed TMDLs.

In addition, it is helpful to consider other existing state and federal programs that might impact TMDL development either through the provision of data for developing the TMDL or through their potential for leveraging implementation funds. How many NPDES facilities are contributing to the impaired segments? Are there areas in the contributing drainage that are covered by Phase II stormwater permits? What pollutant parameters are being discharged and are they related to the TMDL?

The NPDES program and permittees can provide data for the source characterization and analysis. In addition, these key stakeholders also serve as critical implementation partners for the TMDL. Any NPDES watershed-based permitting effort involves a TMDL-like analysis of pollutant fate and transport in a watershed; therefore, TMDL practitioners should investigate if such an effort is underway in the watershed and what type of information is available from the permitting activity for use in the watershed TMDL.

4. Developing Watershed TMDLs

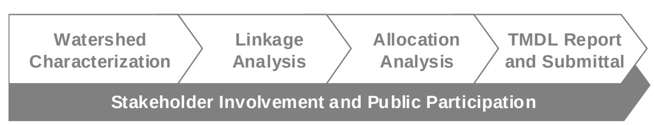
The general process for developing watershed TMDLs is much the same as that for developing single-segment TMDLs. Figure 4-1 illustrates the typical steps for developing a TMDL, including:

- Stakeholder involvement and public participation to engage affected parties and solicit input, feedback and buy-in for a successful TMDL. This process should occur throughout the TMDL development (and implementation) process.
- Watershed characterization to identify the watershed, waterbody and impairment conditions; TMDL targets; and potential sources.
- Linkage analysis to calculate the loading capacity.
- Allocation analysis to evaluate and assign WLAs to point sources and LAs to nonpoint sources.
- Development of the TMDL report and administrative record for submittal to EPA.

> ***Resources:***
>
> Guidance on Developing TMDLs
>
> For more information on the general TMDL development process, refer to the following EPA references:
>
> *Guidance for Water Quality-based Decisions: The TMDL Process* (USEPA 1991): www.epa.gov/OWOW/tmdl/decisions/
>
> *Protocol for Developing Nutrient TMDLs* (USEPA 1999a) www.epa.gov/owow/tmdl/nutrient/pdf/nutrient.pdf
>
> *Protocol for Developing Sediment TMDLs* (USEPA 1999b): www.epa.gov/owow/tmdl/sediment/pdf/sediment.pdf
>
> *Protocol for Developing Pathogen TMDLs* (USEPA 2000): www.epa.gov/owow/tmdl/pathogen_all.pdf
>
> More technical and policy support documents are available on EPA's TMDL Program Web site at www.epa.gov/owow/tmdl.

While these steps are common to all TMDL development projects, there are a number of considerations for each step when developing multiple TMDLs within a watershed framework. This section highlights the critical issues for each step as related to developing watershed TMDLs.

4.1. Stakeholder and Public Involvement



In any TMDL process, practitioners should engage stakeholders early with activities such as project scoping and data collection and continue throughout the allocation and implementation phases. Stakeholders to involve in TMDL development can include partner state and federal agencies; pollutant sources, such as permitted facilities or landowners that are likely to receive WLAs or LAs; and citizen groups, watershed organizations, and other interested parties in the watershed that might provide assistance in TMDL implementation. Depending on the complexity of the TMDL, stakeholders can participate in a variety of capacities ranging from attending public information meetings to supporting selection of technical approaches and contributing data to participating in implementation decisions. For a watershed TMDL, stakeholder and public involvement is likely to expand due to the larger geographic area and increased number of sources addressed through the watershed TMDL process. Practitioners should anticipate more stakeholders involved in the development process and anticipate stakeholders to bring to the table watershed concerns and issues that transcend the scope of the watershed TMDL. The stakeholder engagement phase is critical because there are likely to be more potential stakeholders than those involved in a single-segment TMDL.

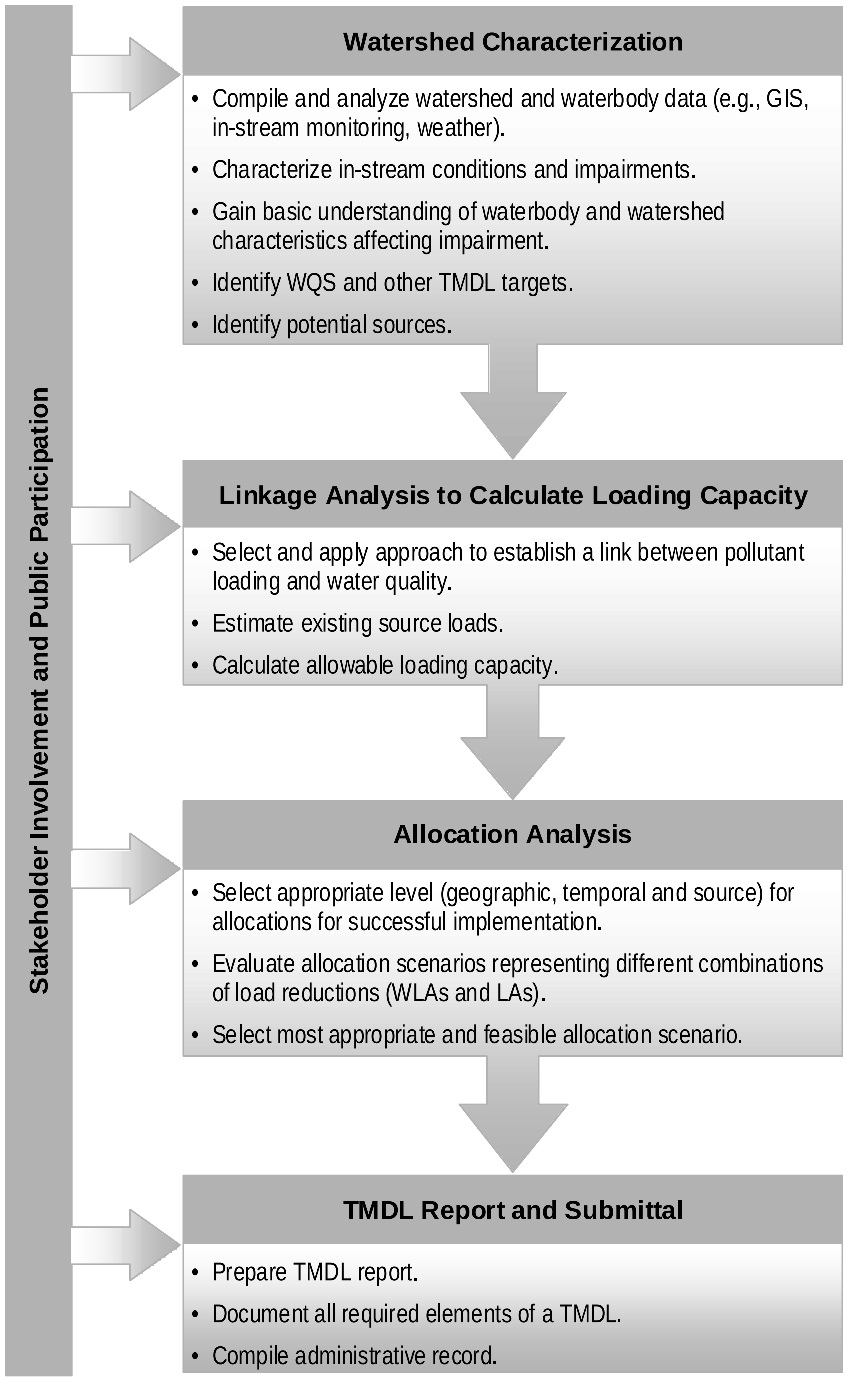


Figure 4-1. General steps in developing a TMDL.

In watersheds, engaging stakeholders early in the TMDL development process often results in better integration of stakeholder data, more buy-in and acceptance of the process and resulting allocations, and fewer “surprises” during the later public comment stages. A watershed TMDL provides an opportunity to engage all of the stakeholders in the same process at the same time, using the TMDL as a unifying goal and focal point for discussion and involvement. This helps to raise awareness about the stakeholders’ priorities and concerns and avoid potential delays caused by having to revisit decisions and previously conducted analyses because of new information or issues introduced by stakeholders who were not engaged in the early stages of the process. Stakeholders can also be important sources of data (e.g., volunteer monitoring data, knowledge of key watershed characteristics, facility discharge data) and can provide information on the existence and locations of critical sources that might otherwise have been unaccounted for (e.g., historical land uses). Broad-based stakeholder involvement also feeds into implementation phases of the TMDL since many stakeholders are also key implementation partners that will perform the on-the-ground work necessary to reduce loading by upgrading treatment processes, installing BMPs, and acquiring funding for necessary implementation activities.

Some watershed TMDL projects cross jurisdictional boundaries, including county, city and sometimes even state boundaries and federal jurisdictions, introducing a number of regulatory agencies into the TMDL development process, as well as implementation efforts. Watershed TMDLs that move into the category of multijurisdictional TMDLs (those involving multiple states or tribes) can present a unique set of challenges to TMDL development, including varying water quality standards, TMDL schedules and implementation goals. The approach for planning and completing a multijurisdictional watershed TMDL is generally the same as any other TMDL. However, the process should include increased attention to and coordination with the other affected groups so that all parties involved are included in all communications and at critical decision points and have a thorough understanding of the expectations, legal requirements, priorities and needs of each entity. The TMDL should be developed with an active stakeholder process to ensure all agencies are informed and that any issues requiring decisions (e.g., approach to maintaining varying water quality standards) are introduced early in the process. Open communication and consensus-based decision-making are essential for the successful completion of multijurisdictional TMDLs.

Example:

Maximizing the Benefits of Stakeholder Involvement in the San Jacinto Watershed, California

The Santa Ana Watershed Project Authority (SAWPA) developed TMDLs for Lake Elsinore and Canyon Lake as part of development of a nutrient management plan for the San Jacinto Watershed. During the effort, SAWPA engaged the active stakeholder community and relied heavily on its participation to provide data, previously developed tools, historical knowledge, and review of potential management options.

The effort involved application of a watershed and lake modeling system to evaluate nutrient sources and transport in the 780-mi^2 watershed under a range of hydrologic regimes. The modeling system was also used, through consultation with the stakeholder group, to identify and test potential BMP strategies to meet lake water quality goals. The results of an analysis of relative impacts of alternative management solutions were used as decision support for development of the final nutrient management plan and placement of an appropriate suite of BMPs.

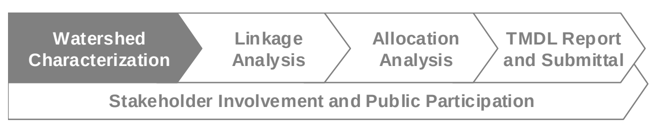
Following adoption of the nutrient TMDL, stakeholders were tasked with developing a monitoring plan to address data gaps and provide data for evaluating compliance to TMDLs. SAWPA and the TMDL Task Force evaluated the ongoing and planned monitoring programs of multiple stakeholders to develop a single monitoring plan. The resulting plan provided significant cost savings (phased monitoring approach with reduced costs ranging from $20,000 to over $200,000 per year) to stakeholders. SAWPA worked closely with stakeholders to reach an agreement regarding priorities, schedule, data gaps, and requirements for measuring compliance to the TMDL.

The increased stakeholder participation fostered by SAWPA led to greater acceptance of the management strategies and increased the likelihood of implementation and success. Because the stakeholders were actively involved in the decision-making process they were more confident in the resulting allocations and therefore more willing to expend resources to implement them. The TMDL allocations not only provided a framework for distributing load reductions but also associated funding responsibilities among the stakeholders.

The San Jacinto watershed provides an example of a watershed TMDL facilitating increased stakeholder participation, which then led to benefits from greater accessibility to watershed data and tools, consensus-based decisions, increased acceptance and ownership of allocations, and maximizing of resources and coordination for implementation and follow-up monitoring.

To read the plans developed for the San Jacinto watershed, please visit www.sawpa.org/tmdl/Lake_elsinore_Canyon_lake.html.

4.2. Watershed Characterization



The TMDL process requires a thorough understanding of the watershed characteristics, available data, causes of impairment, sources, water quality standards, and potential targets. Some of this information will be available through a state's 303(d) list and waterbody assessment documentation, but much of the information will have to be gathered and summarized while completing the TMDL. Collectively, this is referred to here as the *watershed characterization* component of the TMDL. Watershed characterization serves as the foundation of the TMDL analysis, providing a basic understanding of the impairments of concern, the desired levels for restoration (e.g., water quality standards and TMDL targets) and the likely sources contributing to the impairment. Characterizing the watershed, as well as the waterbody and the associated impairments and sources, provides the necessary background information to support decisions regarding the approach used for calculating the TMDL, the level of detail or focus of the analysis and ultimately TMDL implementation. The following sections describe the major elements of the watershed characterization, including:

- Data analysis for problem identification
- Identification of TMDL targets

- Identification and assessment of potential sources

4.2.1. Data Analysis for Problem Identification

The objective of problem identification in the TMDL process is to identify the nature of the impairment(s) being addressed by the TMDL. In many cases, the listing itself is not enough to fully inform the problem identification process. A state or tribe's 303(d) list identifies the basic information regarding the impaired waterbody and the observed impairment, usually including the waterbody characteristics (e.g., name, location, size), the water quality standard that was violated, the pollutant of concern, and the suspected causes and sources of impairment. Additional information, however, is often desired for the TMDL process. For example, a TMDL practitioner might want to know:

> ***Process Tip:***
>
> What is the Problem?
>
> The problem identification step is likely the most important in the TMDL process. This step determines how subsequent steps are conducted and focused. This is especially true with watershed TMDLs. The problem identification identifies the areas/segments, pollutants, sources and conditions of concern, which in turn help to focus source characterization, determine technical approaches, and identify allocations.

- How does the available water quality data vary over space and time?
- How are the water quality data and impairments in a watershed related?
- Did the 303(d) process correctly identify the causes and sources of impairment in the waterbody?
- Have new data been collected since the initial 303(d) listing, and what additional information do those data provide?

The data analysis activity of a TMDL serves to answer these questions and support problem identification. It involves a review of the 303(d) listings, a thorough inventory of watershed conditions and systems, and the mapping of the spatial distribution of pollutant sources as they relate to the water quality impairment. Critical issues are identified by developing a preliminary description of water quality problems and basic interactions (when, where, under what conditions is problem evident?) through the analysis of in-stream monitoring data (e.g., flow, water quality, bioassessment). The answers to these questions help to define many of the technical aspects of the TMDL, including what sources are quantified, what approaches can be used, how allocations are determined, and on what time and spatial scale the analysis is conducted.

> ***Resources:***
>
> Online Sources of Physical, Chemical and Biological Monitoring Data
>
> **STORET** is EPA's database for the storage and retrieval of ground water and surface water quality data. In addition to holding chemical and physical data, STORET supports a variety of types of biomonitoring data on fish, benthic macroinvertebrates, and habitats. STORET data can be downloaded from www.epa.gov/STORET/index.html.
>
> The **National Water Information System Web site (NWISWeb)** is the USGS's online database for surface water and ground water flow and water quality data. The NWISWeb database provides access to water resources data collected by USGS at approximately 1.5 million sites in all 50 states, the District of Columbia, and Puerto Rico. Data can be downloaded at http://waterdata.usgs.gov/nwis.
>
> State and local environmental agencies might have additional data that are not yet included in STORET or other available databases.

Because a watershed TMDL can include multiple subwatersheds, impaired segments, pollutants of concern, expected sources and critical conditions affecting impairment, the problem identification stage is critical to effectively focus the analysis to identify and address the critical issues and also maximize the resources available to develop a watershed TMDL. For this reason, it is important to carefully analyze available monitoring data to identify any patterns or trends that can highlight important sources, connect multiple impairments, and describe critical conditions or important watershed processes affecting impairment. Important aspects of the data analysis to support problem identification for the watershed TMDL include:

- Spatial analysis to identify spatial variations in waterbody and watershed conditions to identify sources and understand the relationship among impaired segments
- Temporal analysis to evaluate the timing of impairment and potential source loading or other conditions contributing to impairment
- Analysis of the relationships among multiple parameters or in-stream measures (e.g., pollutant concentration and flow) to understand critical conditions and identify potential sources

Because watershed TMDLs are often developed for a broader geographic scale than single-segment TMDLs, it is desirable to have sufficient data to characterize the water quality and sources throughout the watershed and at key locations (e.g., tributary confluences, upstream/downstream of major sources). With the larger area, there is more potential for variations in the amount, type, and quality of data throughout the watershed. Incomparable data can create difficulties in conducting meaningful statistical or modeling analyses. However, data limitations and variations among datasets can be an issue with any TMDL, whether single-segment or watershed. TMDLs are sometimes developed with less than desirable amount, period and spatial distribution of data. Existing TMDL program guidance (USEPA 1991) suggests that having limited data is not a sufficient reason for *not* developing a TMDL and recommends that TMDLs be developed with the best available data. If data are limited the TMDL should be developed, recognizing that additional data and information could be used in the future to revise the TMDL as necessary.

Alternatively, although a larger watershed can mean data from a greater number of agencies and of varying types, it also provides more opportunity to extrapolate an understanding of conditions throughout a watershed. When focusing on a single-segment TMDL with insufficient data to characterize the watershed, it might be necessary to evaluate data outside of the study area to make assumptions about the area without a real understanding of how the areas are related or similar. However, developing a watershed TMDL encourages evaluating data for a larger area and the relationships among that data. It provides a stronger foundation for any assumptions about conditions in data-poor areas.

The following sections provide more details on the common types of data analyses conducted for a watershed TMDL to understand impairment conditions and identify sources.

Spatial Analysis

TMDL practitioners often times want to know how watershed characteristics (e.g., land use, water quality, soils/geology) vary throughout their watershed. A spatial analysis of these characteristics can help to inform multiple steps of the TMDL process. For example, a spatial analysis of water quality data can help to identify the location and distribution of areas that exhibit increased pollutant levels. Through additional analysis of land use and other waterbody

> **Process Tip:**
>
> Bigger Watershed = More Data
>
> When conducting a watershed TMDL, there will be more data and information to organize and analyze. It is important to establish an effective and consistent way of organizing data, including in-stream flow and water quality data, GIS coverages and watershed reports.
>
> EPA’s Watershed Handbook (USEPA 2008) includes tips on gathering and organizing data from disparate sources on a watershed scale.

information, a TMDL practitioner can begin to understand what sources might be contributing to impairment and the conditions or processes that might be exacerbating impairment in the watershed. Regardless of the type of TMDL (single-segment or watershed), a spatial analysis of the available data is a critical step in understanding the linkage between sources, causes of impairment, and waterbody response.

When completing a watershed TMDL, the spatial analysis step can be more important because the larger land areas, multiple tributaries, and multiple sources might require more careful evaluation to fully understand the relationship between sources and waterbody impairment. For example, a downstream waterbody might be impaired because of a number of upstream tributaries and sources. A spatial analysis of the available water quality data would help to identify and locate the sources, including any potential unknown sources, and would inform future steps in the TMDL process including target setting, source assessments, and load allocations. Understanding the spatial variation in water quality levels can also help to determine how to subdivide the watershed for subsequent analyses (e.g., watershed modeling) by isolating areas of increased loadings or unique characteristics.

When completing a watershed TMDL, spatial analyses can be used to look at trends throughout the entire watershed or more specifically evaluate data bracketing areas of concern or of expected source activity. For example, Figure 4-2 presents a map generated using GIS coverages of monitoring station locations on impaired segments in a watershed and corresponding statistics for water quality data. The map can be used to generally identify areas exhibiting higher TDS concentrations. Similarly, Figure 4-3 shows statistics for data collected at a number of stations located along the length of a river. Understanding the increases and decreases in pollutant concentrations can help to identify types and locations of sources in the watershed. Alternatively, spatial analyses can also be used to evaluate specific sources. Figure 4-4 presents a graph showing matching data collected upstream and downstream of an expected source to evaluate the potential impact of the source on downstream water quality. Plotting the upstream data versus the downstream data can examine whether upstream and downstream concentrations differ and indicate whether a source discharging to the impaired stream between the stations is contributing to the impairment. As shown in the figure, the downstream (Station 4) TSS values are consistently higher than those measured at the upstream site, indicating that there is some loading input between the stations. Figure 4-5 presents an alternative representation of the data in Figure 4-4, simply plotting the data chronologically at the two stations to visually determine whether upstream and downstream stations are comparable and follow similar patterns. This type of analysis can be effective for evaluating the influence of tributary inputs as well. Reviewing data collected upstream and downstream of a tributary confluence can provide insight into whether the tributary subwatershed is contributing elevated levels of pollutants and affecting downstream water quality. This can be especially useful when developing watershed TMDLs and evaluating multiple subwatersheds of impaired segments.

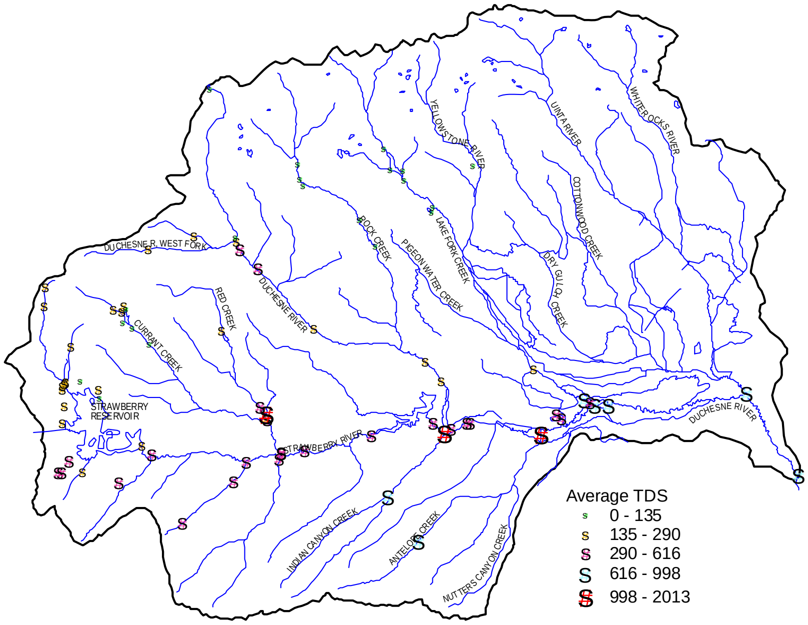


Figure 4-2. Example map showing average TDS concentrations throughout a watershed.

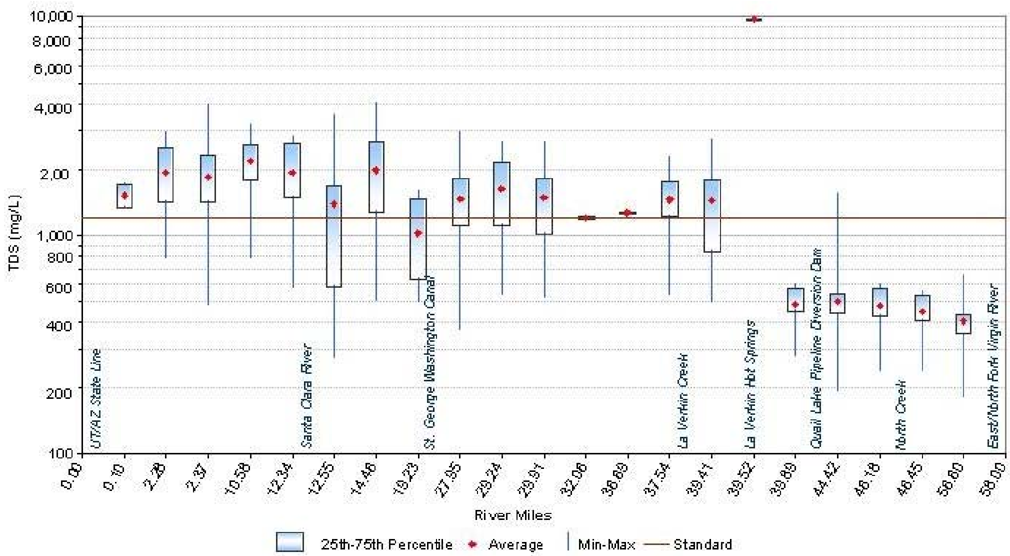


Figure 4-3. Example graph showing summary statistics in measured TDS concentrations along the length of an impaired river.

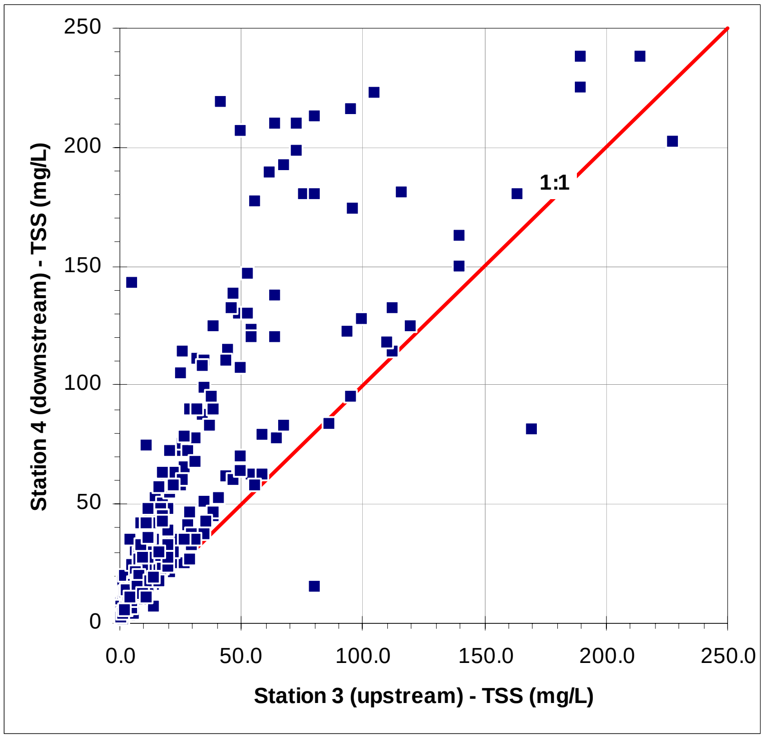


Figure 4-4. Example graph showing relationship between upstream and downstream data to evaluate potential impact of an expected source.

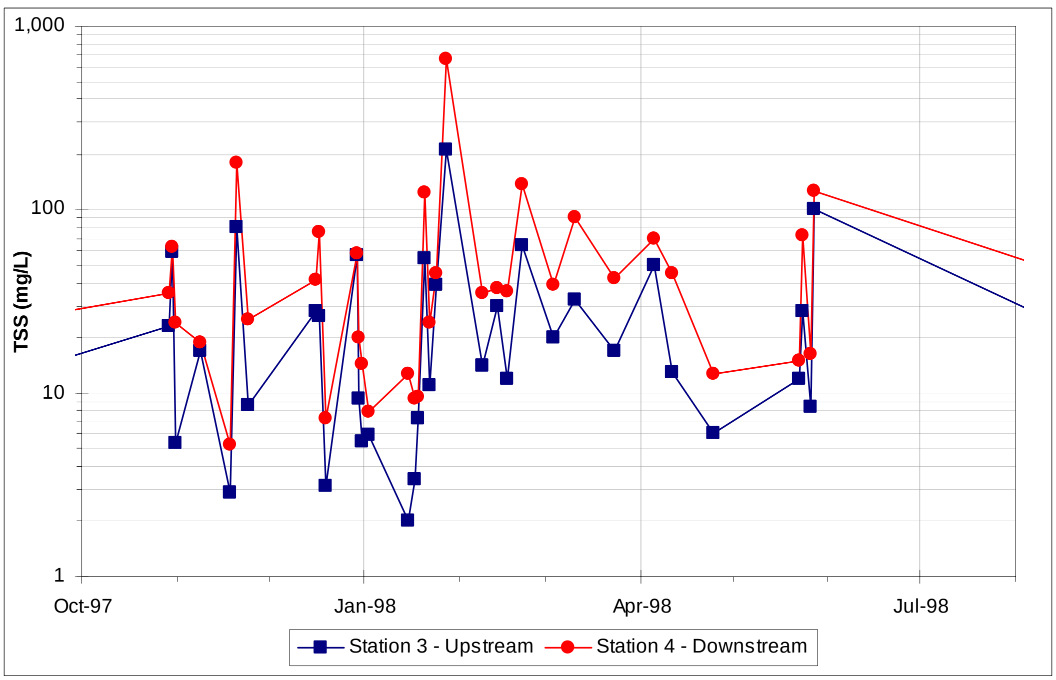


Figure 4-5. Example graph showing data collected upstream and downstream of an expected source.

Example:

Using Spatial Analyses to Identify Sources in the Big Spring Creek Watershed, Montana

PCB sampling in the lower reach of Big Spring Creek, Montana, (Waterbody ID MT41S004_020) found elevated levels in fish tissues, and the segment was placed on Montana's 2004 303(d) list. The suspected source of the impairment was the "Brewery Flats" industrial area in Lewistown, Montana. Instead of focusing on a single-segment TMDL for Big Spring Creek and the Brewery Flats area, Montana DEQ initiated a watershed TMDL for the entire Big Spring Creek watershed. As part of this effort, DEQ collected additional PCB data and conducted a watershed-scale spatial analysis of the concentrations. The spatial analysis showed that PCB concentrations were highest in the headwaters of the watershed (in Waterbody Segment MT41S004_010) and then declined in a downstream direction past the Brewery Flats industrial area. Further investigations found that the source of the PCBs was contaminated paint from the Big Spring Creek fish hatchery's raceways and not the Brewery Flats industrial area. Completion of the watershed scale spatial analysis identified a previously unknown source of PCBs and identified a new waterbody segment as impaired because of PCBs.

Temporal Analysis

As with any TMDL, evaluating the temporal patterns in water quality data can lead to an understanding of how source behavior, weather patterns, and waterbody conditions relate to resulting impairment. Evaluating these factors in the context of a watershed TMDL can identify important issues to be addressed in the technical approach. A temporal analysis of water quality data can help to identify seasonal sources and associated loads (e.g., grazing, seasonal residents, and recreational uses), identify new sources, and compare pre- and post-source water quality data. Understanding the different sources and their times of loading and influence can guide the selection of a technical approach and help to better maximize the watershed-wide benefits of load reductions during the allocation analysis.

While temporal variations in water quality can be affected by source activity, they are more often related to environmental conditions such as weather and resulting flow patterns. Evaluating the relationship between water quality, flow and seasonality can be done using a variety of techniques including simple visual comparison of graphed time-series data, regression analyses, or the use of flow duration curves. Figure 4-6 includes examples of each of these types of data representation using the same dataset. As shown in the figure, all of the figures can be used to show the relationship between bacteria and flow. While the regression plot does not show a strong correlation between flow and bacteria, the chronological and flow duration graphs show that they do tend to follow similar patterns, with elevated bacteria typically occurring during higher flows. Because discharges from certain types of sources are typically observed during particular flow conditions, evaluations of flow and corresponding water quality can be a helpful tool in identifying potential sources of impairment in a watershed and also understanding waterbody and impairment conditions for selection of an appropriate technical approach.

The evaluation of temporal variations in water quality for watershed TMDLs will not likely be different than for single-segment TMDLs. However, as with many of the data analysis activities, the analysis has the potential for evaluating multiple pollutants and impairment types and the effects of multiple sources. This can result in the identification of varying temporal trends (e.g., depending on varying source behavior or pollutant fate or behavior) that can affect what approach is selected for TMDL development.

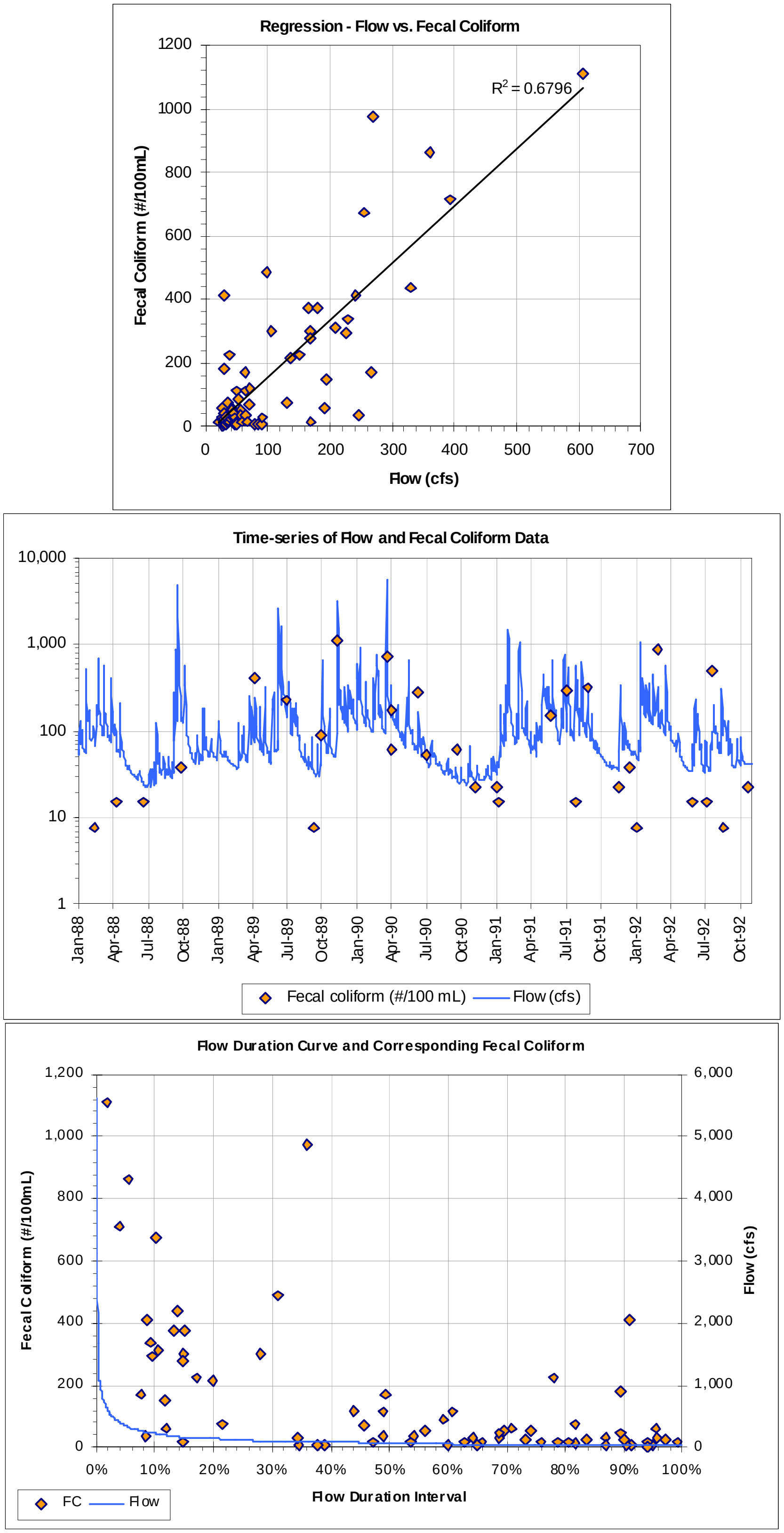


Figure 4-6. Examples of different data representations to evaluate the relationship between flow and water quality

Evaluation of Multiple Parameters

Many pollutants causing impairments throughout a watershed can originate from a common source(s). For example, nutrients and bacteria often are associated with the same types of sources, such as failing septic systems, wildlife populations, and agricultural livestock uses. Evaluating the correlation among multiple pollutants can help to understand the types of sources in the watershed and better focus subsequent assessment and allocation. In addition, some pollutants might in fact be dependent on other pollutants. For example, some pollutants (e.g., nutrients, metals) can be delivered to receiving waters adsorbed to sediment particles. In agricultural areas that have experienced fertilizer application, areas of increased erosion (e.g., degraded cropland, overgrazed areas, areas experience streambank erosion) can deliver significant amounts of nutrients that have attached to watershed soils. Similarly, some waterbodies experienced historical accumulation of pollutants, such as metals or pesticides, that adsorb to sediments but do not die-off. These pollutants can remain in bottom sediments but can also be resuspended during increased flows or other disturbances. Identifying a relationship between increased sediment concentrations and other pollutants can help to identify these situations to better target source assessment.

4.2.2. TMDL Target Identification

All TMDLs require a target or indicator that can be used to evaluate attainment of water quality standards in the listed waterbody. Often, the numeric target value for the TMDL pollutant will be the numeric water quality criterion for the pollutant of concern. In some cases, however, TMDLs must be developed for pollutants that do not have numeric water quality criteria. When numeric water quality criteria do not exist, impairment is determined on the basis of narrative water quality criteria or identifiable degradation of designated uses (e.g., impaired fishery). The narrative criterion is then interpreted to develop a numeric TMDL target that represents attainment of the water quality standards.

One of the benefits of completing a watershed TMDL is that the TMDL targets can be set based on an understanding of upstream and downstream conditions. For example, when interpreting narrative criteria for single-segment TMDLs, it is possible to set a target that is not protective of the upstream or downstream beneficial uses. The single-segment target (and the associated TMDL) could be set, only to be revisited later when another segment's TMDL requires more stringent targets. The watershed TMDL process allows the practitioner to consider multiple upstream and downstream segments when setting TMDL targets, thereby insuring that targets are protective for multiple segments.

Target identification for watershed TMDLs can be complicated when the watershed is multi-jurisdictional. Waterbodies that cross state or tribal boundaries might be subject to multiple or differing water quality criteria for the same pollutant. When dealing with numeric criteria, the watershed TMDL would typically apply the most stringent criteria.

Example:

Setting Variable Targets to Support the Tualatin Watershed TMDL, Oregon

Oregon Department of Environmental Quality developed a watershed-based TMDL to address impairments related to temperature, bacteria, dissolved oxygen, pH and chlorophyll *a* in the Tualatin River and several tributaries. The pH impairment is tied to excess algal growth, which is measured by chlorophyll *a* and driven by total phosphorus concentrations. Therefore, total phosphorus was used as the indicator for the combined pH and chlorophyll *a* TMDL. Natural conditions were chosen to represent target levels for phosphorus. Because the TMDL addressed several impaired segments, data analysis and mass balance evaluations were conducted for the impaired mainstem and tributaries to identify background levels of phosphorus for development of segment-specific total phosphorus targets. To read the Tualatin TMDL, please visit: www.deq.state.or.us/wq/TMDLs/willamette.htm#t.

However, because this might result in more stringent allocations in one jurisdiction to support criteria in the downstream jurisdiction, it is important to involve all jurisdictions and agencies in the process. When dealing with narrative criteria in multi-jurisdictional TMDLs, it is important to understand how each jurisdiction applies the criteria for impairment determination and listing. These assessment methodologies can support identification of an appropriate TMDL target, and when they vary by jurisdiction, all parties should be involved in identifying an acceptable TMDL target.

Varying water quality criteria or TMDL targets can also be an issue when dealing with multiple types of receiving waters (e.g., lakes, bays, rivers) or waterbodies that have site-specific targets that differ from the generally applicable criteria. Practitioners should consider this when selecting the most appropriate approach for TMDL development. The approach should be at a level of detail sufficient to evaluate the potential relationship among the targets and allow for evaluation of impacts of source loads on all of the waterbodies of concern to ensure that allocations meet all targets.

For watershed TMDLs, the process of identifying numeric targets can be more in-depth than for single-segment TMDLs because of multiple waterbodies and possible pollutants. Conclusions drawn from the data analysis and problem identification step should guide the development of targets for the impaired segments and pollutants of concern. It is possible that the analysis might indicate a need for different targets for different segments. For example, if a TMDL addressing sediments aims to develop in-stream or loading targets based on background conditions, the specific target value could vary throughout the watershed. In areas where pollutants subject to narrative criteria are the primary impairment, developing TMDLs on a watershed basis ensures that the targets work together to ensure use attainment throughout the watershed. If the TMDLs were developed individually, the variable targets might not be set at levels to ensure use support in downstream waters.

4.2.3. Source Assessment

A source assessment can significantly influence TMDL development, associated allocations, and subsequent implementation. The source assessment should be an extension of the analyses conducted during the problem identification step to further characterize the important sources and better define their location, behavior, magnitude and influence. The source assessment should result in an understanding of what major sources are contributing to impairment, which sources are contributing which pollutants and which sources have an impact on which segments. Again, this can affect what approach is selected and how it is applied for TMDL development and help to focus the allocation analysis as well as future implementation.

While the pollutant loads originating with each source are typically quantified during the linkage analysis (Section 4.3), the information necessary to understand their location and discharge behavior and characteristics is compiled and reviewed during this step. In general, the methods that are used to complete a source assessment do not differ between single-segment and watershed TMDLs, and they involve identification and characterization of point sources (e.g., wastewater treatment plants, industrial facilities) and nonpoint sources (e.g., grazing, timber harvest, septic systems). The methods for completing a source assessment vary with the type of watershed, pollutants, and sources but typically rely on information from state or national databases, literature reviews, and local knowledge from state or local contacts. It is important to correlate the assessment of both point and nonpoint sources the data analysis to characterize source impacts and behavior. For example, land use, locations of facility discharges and other source information should be evaluated along with water quality data analyses (e.g., spatial analysis) to understand potential impacts from the various sources or explore unknown sources.

> ***Resources:***
>
> Identifying Point Sources
>
> Information on point sources permitted through EPA's NPDES can be obtained from EPA's **Permit Compliance System (PCS)** database, which allows the user to query and obtain information on permitted facilities through an online interface. PCS is available at http://www.epa.gov/enviro/html/pcs/index.html.
>
> TMDL developers should also contact state permitting staff to obtain information. PCS might not include all available data or information. Some sources, such as permitted stormwater, might require additional information (e.g., MS4 drainage maps) than what is included in PCS to fully characterize.

Point sources are generally easier than nonpoint sources to identify and quantify as they are usually permitted and tracked under EPA's NPDES. Point sources might include surface water discharges from permitted facilities (e.g., WWTPs, industrial discharges), stormwater discharges, groundwater discharges, and construction discharges (depending on the watershed and the state or tribe's permitting program). Identifying the number, type and location of NPDES permitted point sources in a watershed can start with searching available databases (e.g., PCS) but might also require coordination with relevant state or tribal permitting staff to obtain further information about the source and its discharge. Typical information used to characterize a point source includes facility type, design flow, permit limits, number and location of permitted outfalls, and available discharge monitoring data. TMDL developers should coordinate with the state staff to identify and obtain additional information that might be available from the facilities. For example, facilities might collect more water quality data than are required for or reported in the discharge monitoring reports (DMRs), and these data could be helpful in calculating more accurate loads and in addressing seasonality.

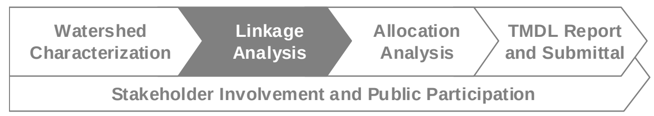
> ***Resources:***
>
> Compiling Land Use and Cover Information to Identify Nonpoint Sources
>
> Nationally available sources of land use data include satellite data from the Multi-Resolution Land Characteristics Consortium's (MRLC's) **National Land Cover Database (NLCD)** (available at http://www.epa.gov/mrlc/) and aerial photos available from the **National Agriculture Imagery Program (NAIP)** (described at http://165.221.201.14/NAIP.html). Local land use data might also be available through county agencies (e.g., planning offices, environmental offices).

Identification and assessment of nonpoint sources are usually based on review of aerial photos, satellite imagery, GIS coverages (e.g., land use/cover, soils), windshield surveys, and other maps and available data. TMDL practitioners can use these data to determine the location and extent of nonpoint sources at the watershed scale. Sometimes more information is available from literature reviews and previous studies of nonpoint sources in a given watershed. Conservation districts, county planning or environmental agencies, and state water quality programs might also have supplemental or site-specific information on land uses and sources.

Because of the larger area addressed in a watershed TMDL, there will likely be more sources to evaluate than when dealing with a single-segment TMDL. Because of this it is often important to use the source information to build off the data analysis, focusing the more detailed characterization to sources expected to be contributing to impairments. It is also important to decide the appropriate scale for source evaluation within a watershed TMDL. For example, at what level of detail will land uses be identified and evaluated, or how much effort will be expended for site-scale identification of sources (e.g., through watershed surveys)? The TMDL developer should balance the level of detail with the goals, priorities, and available data and resources for the project. The scale should capture the major sources without overburdening the analysis with little added benefit.

Although watershed TMDLs can expand the scale of and effort required for the source assessment in comparison to single-segment TMDLs, practitioners will realize the benefits of a watershed TMDL through this activity. Evaluating the sources at the watershed scale can focus the analysis to those sources that have the greatest impact on water quality. It also facilitates more targeted allocations by evaluating the relative magnitude and impact of sources. This is especially important when dealing with a watershed affected by both point and nonpoint sources. Watershed TMDLs can provide a platform for more effectively evaluating all sources and various combinations of source controls that can represent attainment of water quality standards. This is important in watersheds where water quality trading might be used as a tool for implementation.

4.3. Linkage Analysis



For all TMDLs, the linkage analysis establishes the cause-and-effect relationship between pollutant sources and the waterbody response. Selecting what approach is used for this analysis is often guided by a number of technical and practical factors, such as waterbody type, pollutant type and behavior, source type and behavior, data availability, spatial and temporal needs, and user considerations (e.g., experience needed, anticipated level of effort). When dealing with watershed TMDLs, there are a number of specific technical considerations that can affect what approaches can be used in TMDL development and how they are applied. This section identifies the factors unique to watershed TMDL development that can affect selection of a TMDL development approach. It then discusses commonly used TMDL approaches and some practical considerations for their application for development of watershed TMDLs.

4.3.1. Factors Affecting Selection of Technical Approach for Watershed TMDL Development

When selecting an approach for TMDL development, a number of factors are often considered. As shown in Figure 4-7, these can include user needs or requirements, programmatic considerations, and technical needs. While user needs and programmatic considerations will often guide the general type of approach (e.g., simple vs. complex, modeling vs. non-modeling), the technical considerations will weigh heavily in the selection of a specific approach or methodology. The technical considerations define the following three needs for the TMDL analysis:

- Spatial scale/resolution
- Temporal resolution/time scale
- Processes or features that need to be included (e.g., pollutant type, dynamic waterbody conditions, in-stream transport)

The watershed characterization step of TMDL development (Section 4.2) should generate the necessary information to define these needs by providing an understanding of the impaired waterbodies, the surrounding watershed and the associated impairments. Specifically, the major considerations or questions that were addressed during the watershed characterization that can support selection of an appropriate approach for TMDL development include:

- What are the applicable water quality criteria?
- What are the impairments and associated critical conditions?

- What are the sources?
- How are the multiple sources, impaired waterbodies or impairments related?

Table 4-1 summarizes the considerations related to each of the three technical needs for these defining topics of water quality standards, impairment, and sources. The answers to the questions outlined in Figure 4-7 and more specifically in Table 4-1 will guide approach selection for TMDL development. The following sections discuss these questions and how they relate to the selection of an appropriate approach for watershed TMDL development.

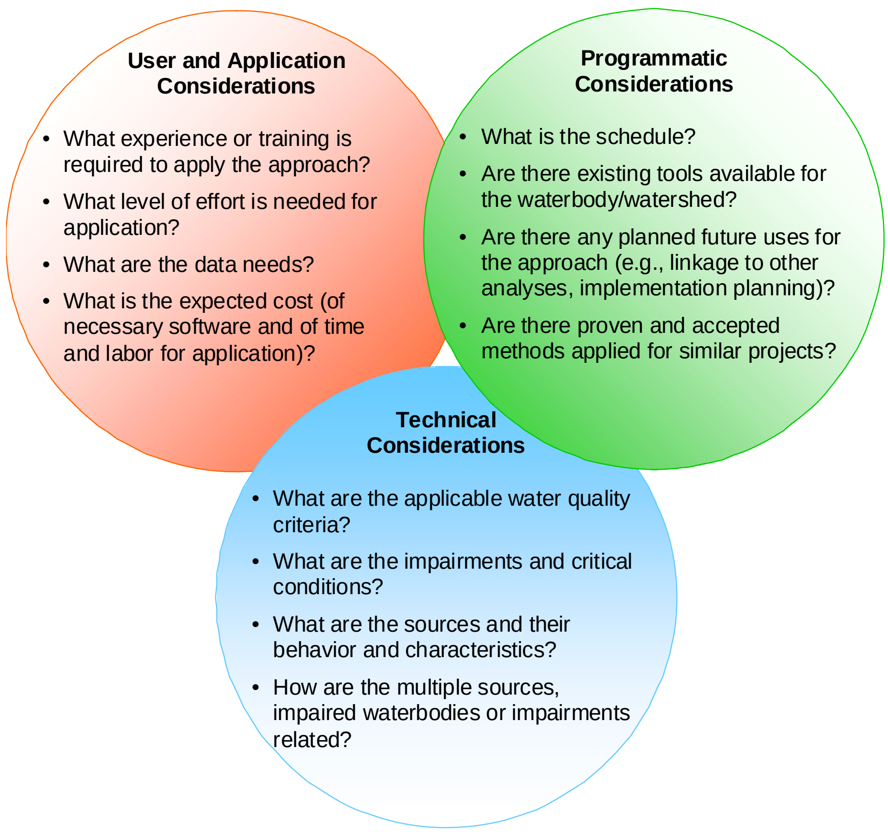


Figure 4-7. Considerations for selecting a TMDL development approach.

Table 4-1. Summary of Technical Considerations for Selecting a TMDL Development Approach.

Technical Needs of Approach	Technical Considerations for Approach Selection		
	Water Quality Criteria	**Impairments and Critical Conditions**	**Sources**
Spatial Needs	▪ Are different criteria applicable in different locations within the watershed?	▪ What is the location and distribution of impaired segments?	▪ What type of sources/land uses exist in the watershed? ▪ What is the location and distribution of sources? ▪ At what level do the sources need to be isolated (e.g., gross loading vs. land use specific loading)?

Technical Needs of Approach	Technical Considerations for Approach Selection		
	Water Quality Criteria	Impairments and Critical Conditions	Sources
Time-scale Needs	▪ What are the duration and frequency of applicable criteria?	▪ What is the timing associated with impairment (e.g., instantaneous vs. chronic or cumulative effects)? ▪ Are there any temporal trends to capture (e.g., seasonality in waterbody conditions)?	▪ Are the impacts due to cumulative or acute loading conditions? ▪ Are there temporal variations in source loading (e.g., due to weather patterns, seasonal activities)? ▪ At what temporal scale do the sources need to be estimated?
Processes to Include	▪ Is criterion based on pollutant level (e.g., concentration) or a measure of response or condition (e.g., DO, eutrophication)? ▪ What are the pollutants?	▪ Is meeting WQC dependent on or affected by other waterbody measures (e.g., nutrient levels, temperature, pH)? ▪ What are the in-stream critical conditions for loading response (e.g., dynamic, flow variable vs. steady-state)? ▪ If dealing with multiple pollutants, how are they related?	▪ What is the source loading behavior (e.g., precipitation-driven, direct discharge)? ▪ Do sources impact multiple impaired segments (i.e., need for in-stream routing and transport)? ▪ Does the analysis need to evaluate individual and/or cumulative impact of sources?

What Are the Applicable Water Quality Criteria?

Process Tip:

Selecting an Approach: Questions Related to Water Quality Criteria or Targets

- For what indicators (e.g., pollutant, parameter) are the targets set?
- How are the targets expressed (e.g., average, maximum, concentration, load)?
- How are the multiple targets similar or related?

Section 4.2 discussed the activity of identifying TMDL targets based on numeric water quality criteria or an interpretation of narrative water quality criteria. The type and expression of the TMDL target(s) is a major influence on approach selection. The most basic factor is the pollutant or other indicator for which the target is established because some approaches might be more or less appropriate for certain types of pollutants.

The applicability of an approach is also affected by its ability to simulate at a time-scale necessary for comparison to the TMDL target's magnitude, duration and frequency. While many established water quality criteria are based on daily maximums or daily averages, TMDLs are also commonly developed for water quality targets based on longer timeframes. For example, TMDLs developed to meet narrative criteria for sediment or nutrients can be developed to meet a target monthly loading rate based on loading conditions in a reference watershed. Endpoints designed to address acute (short-term) impairments are typically based on instantaneous maximums or daily averages while chronic (long-term) problems (e.g., eutrophication, sediment loading and deposition) can be represented by endpoints with longer durations (e.g., monthly average concentration, annual loading).

While these issues can affect approach selection for any TMDL, unique considerations for watershed TMDLs arise when dealing with multiple targets. A watershed TMDL can include a variety of targets, whether because of multiple types of waterbodies and impairments and associated pollutants or because of criteria that vary depending on waterbody-specific conditions (e.g., metals criteria based on site-specific hardness values). Criteria or targets with different time scales can impact selection of the TMDL approach and how it is applied because TMDL development approaches should be able to evaluate the water quality at a time scale sufficient to compare to targets. The similarity or differences in targets addressed in watershed TMDLs should be considered to select an approach or combination of approaches that can accommodate the multiple targets while still efficiently and effectively addressing all of the segments and impairments.

What Are the Impairments and Associated Critical Conditions?

EPA regulations require that TMDLs consider critical conditions to ensure that the established allocations will result in water quality standards. Understanding the critical conditions builds upon the previous analyses of spatial and temporal trends and relationships among pollutants and processes (discussed in Section 4.2) and identifies the environmental conditions under which impairment occurs. As with all the other analyses discussed, understanding critical conditions can provide clues about the location, timing and type of sources affecting impairment. In addition, understanding critical conditions, particularly with watershed TMDLs, is crucial in supporting selection and subsequent application of a TMDL technical approach.

Process Tip:

Selecting an Approach: Questions Related to Critical Conditions

- When do impairments occur?
- Where do impairments occur?
- What pollutants are causing impairment?
- What processes or conditions can affect the occurrence or magnitude of impairment?

Evaluating the impairment of concern and associated critical conditions helps to identify the watershed and waterbody processes, spatial scale and temporal scale necessary for the approach to capture the impairment and effectively evaluate the source impacts and identify allocations. Many impairments are based on levels of a specific pollutant (e.g., violation of aluminum criterion), while some are based instead on the resulting waterbody conditions (e.g., impaired biological community, eutrophication caused by elevated nutrients). Some impairments also depend on or are affected by a variety of in-stream measures and processes. For example, critical conditions related to low dissolved oxygen often relies on the timing and availability of nutrient loads but also on other factors such as resulting algal growth, flow and temperature.

With watershed TMDLs, the potentially greater number of sources, pollutant types, and waterbody types can lead to varying impairment and critical conditions. Sometimes this can require the selection of a more complex approach or combination of approaches that can simulate a number of processes with spatial and temporal variation. It is important to weigh the necessity of representing certain processes and variables for representing impairment conditions to effectively evaluate source loads and identify allocations.

What Are the Sources?

The most basic distinction in sources and how they affect selection of a TMDL technical approach is whether they are delivered through surface runoff (e.g., precipitation-driven) or discharged directly to the waterbody at a discrete location. This traditionally defined the differences in nonpoint (i.e., diffuse, unregulated) and point (i.e., discrete, regulated) sources; however, these distinctions are not as clear-cut when dealing with permitted stormwater or areas that experience unregulated direct discharges such as illicit discharges or watering livestock. Whether categorized as nonpoint or point sources, the representation of sources in a TMDL approach typically falls into the “precipitation-driven" or "direct-discharge" categories, and the number and distribution of these types of sources can significantly influence TMDL approach selection.

> ***Process Tip:***
>
> Selecting an Approach: Questions Related to Source Characteristics
>
> - How are source loads delivered to impaired waterbody?
> - How do the sources' characteristics and loads impact the waterbody?
> - How are sources distributed and located in relation to impaired segments?

The consideration of precipitation-driven sources sometimes necessitates the use of an approach that can simulate time-variable weather and resulting runoff and pollutant loading. However, it is important to carefully evaluate the level of detail in representing the variable loading in relation to the waterbody response when selecting the approach. For example, while some impairments are primarily influenced by precipitation-driven sources, evaluation of their impact on designated uses might be more appropriate on a longer-term, average basis. Consider a situation where sediment is causing impairment to a stream, stormwater runoff from agricultural and urban areas represent the major sources of sediment loading. While loads can change frequently and rapidly in response to rain events, they do not typically cause acute, instantaneous effects on designated uses. Their impacts are more chronic in nature, resulting from the continued delivery and accumulation of sediment. In this case, using an approach that evaluates longer-term loading (e.g., monthly, annual) and waterbody response might be appropriate (e.g., mass balance, simple watershed model), and a model simulating daily loading in response to precipitation and runoff would not be necessary.

Another consideration for approach selection regarding sources is how well they and their impacts are understood. The watershed characterization activities discussed in Section 4.2 should provide a general understanding of what and how sources are affecting impairment. This can help to identify the type of information that the technical approach will need to include and also produce, thereby narrowing the range of approach options. If sources and their impacts (to both immediate and downstream impaired segments) are well understood based on available data and local knowledge, it might not be necessary to use an approach that evaluates individual sources, provides the ability to predict effects from existing and future source inputs, or simulates the routing of source loads into upstream waterbody segments and through to downstream segments. Some approaches, such as receiving water modeling, can potentially provide a great deal of information on how known sources will affect receiving water quality but will not provide much information on unknown sources. Watershed modeling, on the other hand, can help to quantify the relative significance of various sources such as urban runoff compared to point source discharges and often include in-stream routing to evaluate the effect of upstream sources on downstream segments. Non-modeling approaches, such as load duration curves, that rely on evaluation of in-stream loads based on monitoring data do not typically support direct calculation of loads originating from individual sources. However, these types of approaches can still be meaningful and useful applied within a watershed context when sources are well understood or their application captures the conditions at key locations in the watershed.

In addition to understanding the individual sources, it is important to evaluate the distribution and location of all the major sources. Understanding the relationship among sources in regard to their individual and cumulative impact on impairments and impaired segments can support selection of the TMDL approach. For example, if sources throughout the watershed are fairly homogenous it might not be likely that single sources are affecting a great impact throughout multiple segments. In this case it might not be necessary to use an approach that relies of detailed and quantitative evaluation of source loads and assessing upstream-downstream effects. However, if there are a few sources that are expected to have a significant impact on not only the impaired segments to which they immediately drain but also on those impaired segments located downstream, it might be warranted to use a detailed watershed model that can simulate the upstream-to-downstream impacts of sources loads.

How Are the Sources, Multiple Impaired Waterbodies or Impairments Related?

This consideration builds on previous questions, evaluating the comprehensive effects and relationships among the multiple sources, impaired segments and impairments.

> **Process Tip:**
>
> Selecting an Approach: Questions Related to Overall System Behavior
>
> - At what scale should sources be evaluated and allocations be established?
> - What sources affect which impairments?
> - Which impairments are similar or related?

Similar to the relative impact of sources and how to represent that in a watershed TMDL approach, it is important to consider how to capture the relationship among sources, impaired waterbodies and the observed impairments when selecting an approach. This can affect both the necessary spatial scale of the approach and its application and also the processes that should be considered. Typically, watershed TMDLs involve identification of key “assessment locations” throughout the watershed to allow for calculation of allocations for each impaired segment. This can include division of the watershed into subwatersheds for modeling or individual application of non-modeling approaches such as load duration curves at multiple locations. The need for and location of the assessment locations can also be affected by the location of watershed sources. For example, if multiple sources impact an impaired segment it might be helpful to establish multiple assessment points to isolate areas dominated by certain sources.

Evaluating multiple impaired segments and possibly multiple pollutants and related parameters for watershed TMDLs might depend on the ability to consider the relationship among and impacts of individual segments and pollutants on other segments and waterbody conditions. For example, in watersheds where it is expected that there exists a common source(s) that is contributing to the impairment in multiple impaired segments or by multiple pollutants, it is useful to select an approach that can address the impact of and routing of loads from one segment to another and also the fate and transport of multiple inter-related pollutants.

Similarly, in cases where multiple impairments are related or even dependent on one another it is appropriate to select an approach that can consider all of the necessary pollutants and resulting waterbody impacts. For example, if the impaired segments are impaired by a variety of metals and pH due to mining activities, it would be helpful to select an approach that can account for the metals loadings and resulting waterbody impacts to concentrations and pH but also the waterbody conditions that can affect how metals behave and impact the waterbody (e.g., temperature, hardness).

4.3.2. Practical Applications of Various Approaches for Watershed TMDL Development

Most approaches used for single-segment TMDL development can also be applied for watershed TMDLs. However, the extent to which benefits or efficiencies are recognized can depend on the type of approach and how it is applied. For example, some approaches, such as watershed modeling, are able to simulate the relative magnitudes and relationship among sources and their impact on immediate and downstream impaired waters, allowing for more flexibility in setting and prioritizing allocations. Alternatively, non-modeling approaches that do not directly simulate the hydrologic network or relative impacts of sources still benefit from the comprehensive watershed approach for such things as stakeholder involvement, data analysis, source evaluations and implementation planning.

> **Process Tip:**
>
> Documenting Selection and Application of TMDL Development Approach
>
> Regardless of the approach(es) selected to develop watershed TMDLs, it is important to thoroughly document the rationale for using the approach and all assumptions and supporting data for its application. Documenting decisions throughout the process will facilitate preparation of the TMDL report and administrative record and will provide a foundation for explaining the process to stakeholders.

This section introduces some commonly used approaches for TMDL development and describes the considerations for their use in watershed TMDL development. The approaches are generally categorized as modeling approaches and non-modeling approaches. Modeling approaches include watershed modeling and receiving water modeling, while non-modeling approaches include a variety of approaches that depend on calculation of loading capacity using monitoring data, empirical approaches or literature values.

Modeling Approaches

Directly simulating the upstream-downstream effects of source loading and to support a top-down analysis of loading assessments is typically accomplished through dynamic modeling. With dynamic models, practitioners can track the fate of pollutant loads transported downstream from subwatershed to subwatershed. This section introduces some of the commonly used modeling tools applied to watershed TMDL development and provides information on where to obtain additional details about their use.

Watershed Models

Many TMDLs use watershed models to evaluate existing and allowable pollutant loads to identify allocations, load reductions and management scenarios. A primary advantage of developing a watershed TMDL using a watershed model is the ability to consider the entire watershed and use a “top-down” method of assessing loading and determining allocations. This maximizes the allocations and fully considers the relative impact of the various sources.

Watershed models emphasize description of watershed hydrology and water quality, including runoff, erosion, and washoff of sediment and pollutants. Some models simulate only the land-based processes while some can also include linked river segments and simulate in-stream transport and water quality processes. Watershed models vary in the level of detail, including what processes they simulate and the simulation timestep (e.g., daily vs. monthly). The complexity of watershed models can range from the use of loading functions—empirically based estimates of load based on generalized meteorologic factors (e.g., precipitation, temperature)—to physically based simulations—scientifically based equations to represent the physical, chemical, and biological processes associated with runoff, pollutant accumulation and washoff, and sediment detachment and transport.

> **Definition:**
>
> The Top-Down Approach
>
> In developing watershed TMDLs, the top-down approach consists of evaluating sources from upstream to downstream in watersheds with multiple impaired segments. Doing so can maximize the water quality benefits throughout the watershed of strategically applied reductions at upstream locations that impact multiple downstream impaired segments. The approach provides flexibility in targeting source controls and avoids the potential for redundant or overly stringent reductions resulting from individual analyses.

The primary reason, and benefit, for applying a watershed model for TMDL development typically is the ability to predict pollutant generation from varying land uses and from multiple subwatersheds. The level of detail for predicting spatial loading and then the fate and in-stream transport of the loads depends on the type of model used and the way in which it is setup and applied to the watershed. Several considerations for selecting a watershed model for use in TMDL development and in how to apply it include:

Resources:

Watershed Water Modeling

For more information on watershed models used in TMDL development and their applicability to different waterbody types, pollutants and sources, refer to the following EPA references:

Compendium of Tools for Watershed Assessment and TMDL Development—
www.epa.gov/owow/tmdl/comptool.html

TMDL Model Evaluation and Research Needs—
www.epa.gov/nrmrl/pubs/600r05149/600r05149.htm

- **Multiple impaired segments:** Watershed models with an in-stream routing component (e.g., HSPF, LSPC, SWAT) allow for the evaluation of pollutant loading and transport through a segmented network of connected waterbodies. This allows for the evaluation of multiple impaired segments and the impact of upstream controls on downstream segments, allowing for more efficient reductions throughout the watershed to address multiple segments.
- **Variable sources and land uses:** Watershed models can include land uses or individual sources as separate inputs with unique characteristics that define their related pollutant generation and delivery. This allows for the evaluation of the relative magnitude of various sources in a watershed.
- **Multiple subwatersheds:** Related to the evaluation of multiple waterbody segments and multiple land uses, watershed models can be set up to simulate multiple connected subwatersheds to capture the spatial variations in source inputs. This can target evaluations to specific impaired segments or areas of increased/concentrated source activity while still evaluating sources and water quality on a watershed-wide scale. However, those without in-stream routing do not simulate the transport of loads through a system, from one subwatershed to the next.
- **Evaluation of dynamic processes and relationships:** An important capability of watershed models is the ability to simulate dynamic relationships and processes that affect receiving water quality. For example, some models have the capability to simulate dissolved oxygen and the related processes and parameters, including available nutrient loads, algal processes, temperature, and sediment and biological oxygen demand. Additional examples include simulation of delivery and transport of pollutants adsorbed to sediment particles and simulation of die-off, settling, resuspension and other waterbody inputs and losses. The type and level of detail in these capabilities vary among watershed models.
- **Time-variable processes and conditions:** Some watershed models provide the capability to simulate time-variable watershed conditions affecting hydrology and pollutant transport. For example, some more detailed models include parameters that represent pollutant accumulation and can vary monthly. Another example are models that include modules to simulate snowfall and snowmelt.

These capabilities also present some considerations for setting up and applying the watershed model for TMDL development. The main consideration is the scale of the analysis, including the number of waterbody segments, number and size of subwatersheds, and the type and number of land uses. Using a watershed model for TMDL development typically involves representing the watershed as a system of connected waterbodies and their associated subwatersheds. A TMDL practitioner has flexibility in how to establish the network, whether using a coarser representation focusing on major river segments and tributaries or a more detailed division capturing major segments as well as smaller tributaries. However, the network should represent a balance between detail and usefulness. More detail (i.e., more segments and subwatersheds) will require more effort in the model setup and the processing and analysis of modeling results. The system configuration should be detailed enough to capture the major segments and isolate areas representing spatially diverse sources, while providing a scale that doesn't overburden the analysis. The system should also be designed to isolate the individual impaired segments within the network to facilitate identification of allocations for each impaired segment. The number of subwatersheds will be determined by the network configuration, with each waterbody segment having an associated subwatershed.

These level-of-detail considerations also extend to the representation of land uses and sources in the watershed model. Depending on the type of land use information that is being incorporated into the model, a watershed might have dozens of land use types. However, many of these land use types are similar, particularly when considering their related characteristics for pollutant generation and delivery. For example, a land use coverage might include multiple categories for residential land uses (e.g., single-family, low-density, high-density). The sources of pollutants for these categories are likely the same, with the main difference impacting the pollutant generation and delivery being the amount of impervious cover associated with each category. For a modeling analysis, it might be appropriate to consolidate all of the residential categories into one category and use an average value of imperviousness for its representation in the model. Eliminating multiple, similar land uses will promote more efficient model application and analysis. The pollutant of concern can also affect how the land uses in a watershed are evaluated within a model. The analysis should isolate land uses that represent different sources of the particular pollutant. For example, agriculture land uses might be represented by several subcategories (e.g., cropland, rangeland, pastures). For a watershed TMDL addressing metals loading, it would not be necessary to represent these subcategories, but rather group them into a general "agriculture" category. However, if the TMDL is addressing bacteria or nutrients, agricultural areas likely represent the primary sources and it might be meaningful to evaluate the subcategories because they represent distinct types of sources and delivery pathways.

Also affecting how a model is set up and applied for watershed TMDL development are the important processes affecting the pollutants, impairments and sources of concern. If the data analysis has indicated that sediment and nutrient impairments could be related, it might be appropriate to choose and apply a model that can simulate the adsorption of pollutants to sediment. Another example is the need to simulate and predict dissolved oxygen levels resulting from a combination of processes and conditions.

Process Tip:

Focusing and Maximizing Modeling Efforts

Using a watershed model can provide significant benefits to a watershed TMDL analysis but can also add a level of complexity and potentially time and effort. As with other tasks, it is important to use the available data to focus the efforts and maximize the use of resources. Rely on the conclusions of the Watershed Characterization to identify the level of detail (both spatially and temporally) necessary for the modeling analysis to represent sources, waterbody segments and in-stream conditions for effective TMDL development.

While these considerations are relevant to most watershed modeling applications, some watershed models commonly used for TMDL development have unique considerations, advantages and disadvantages, as summarized in Table 4-2. As discussed in the box below, EPA's *TMDL Model Evaluation and Research Needs* (USEPA 2005b) rates models in a number of categories that can affect their use in developing watershed TMDLs (e.g., pollutants, waterbody types, land uses, in-stream routing). This provides a consistent rating system for all models to allow a TMDL practitioner to compare the range of simulation needs across any number of models. Alternatively, Table 4-2 provides more qualitative descriptions of a number of watershed models. The table identifies considerations for the models, such as their ability or inability to route flow and loads from one subwatershed to the next, the pollutants they simulate or the land uses and source processes they include, that can determine their applicability to developing a watershed TMDL, both in general and on a project-by-project basis. For example, most watershed models include some level of in-stream routing for connecting the waterbody segments for each simulated subwatershed. However, simpler models such as GWLF do not include in-stream routing although it can be applied for multiple subwatersheds and land uses. Alternatively, detailed models such as HSPF and LSPC not only include in-stream routing but also include a full water quality component that can simulate chemical and biological processes within receiving water segments and simulate the fate and transport of flow and loads from one segment to the next. Table 4-3 identifies some example watershed TMDLs developed using the models discussed in Table 4-2.

Resources:

Which Model is the Right Model?

EPA and other agencies have developed a number of resources discussing the applicability of models for water resource and environmental management. There are two documents that specifically discuss the applicability of models to TMDL development and watershed assessment. Those documents include

- *Compendium of Tools for Watershed Assessment and TMDL Development* (USEPA 1997a, www.epa.gov/owow/tmdl/comptool.html)
- *TMDL Model Evaluation and Research Needs* (USEPA 2005b, www.epa.gov/nrmrl/pubs/600r05149/600r05149.htm

Both of these documents provide detailed information on the capabilities, limitations, appropriate uses, and input and resource requirements of a wide-variety of models. The information contained in these documents can provide useful insight into the appropriateness of a given model for watershed TMDL development. For example, *TMDL Model Evaluation and Research Needs* provides a series of tables rating the capabilities or applicability of more than 60 available watershed and receiving water models in the following categories:

- **TMDL Endpoints.** Considers the model's ability to simulate typical TMDL target pollutants (e.g., nutrients, toxics, bacteria) and expressions (e.g., load vs. concentration). Characterizes the models depending on the timestep of the simulation for the target—steady state, storm event, annual, daily or hourly.
- **General Land and Water Features.** Rates models according to their ability to simulate general land uses (e.g., urban, agricultural) and waterbody types (e.g., river, lake, estuary).
- **Special Land Processes.** Rates models on their ability to simulate more than 15 special land processes such as wetlands, hydrologic modification, urban BMPs (e.g., street sweeping, detention ponds) and rural BMPs (e.g., nutrient control practices, irrigation practices).
- **Special Water Processes.** Rates models on their ability to simulate special processes occurring in receiving waterbodies such as air deposition, stream bank erosion, algae and fish.
- **Application Considerations.** Rates models on the following practical considerations affecting their application—experience required, time needed for application, data needs, support available, software tools and cost.

Table 4-2. Watershed Models Commonly Used for TMDL Development

Model	Considerations
AGNPS/ AnnAGNPS	▪ Is a distributed model, providing information on impacts at various locations in a watershed ▪ Originally designed to evaluate agricultural management practices but can also be applied to mixed-land-use watersheds. ▪ Simulates only sediment, nutrients and pesticides ▪ Includes simplified stream routing to allow for multiple drainage areas with runoff and pollutants routed to downstream areas ▪ Includes special components to handle concentrated sources of nutrients (e.g., feedlots, point sources), sediment (e.g., gullies) and added water (e.g., irrigation) ▪ Can be used to simulate effect of agricultural BMPs (e.g., ponds, irrigation, tile drainage, vegetative filter strips, riparian buffers) ▪ Is appropriate for use on watersheds up to 200 mi^2 ▪ Can simulate precipitation-driven sources and direct discharge sources (i.e., point sources)
GWLF	▪ Designed to simulate mixed land use watersheds ▪ Simulates sediment, nitrogen and phosphorus ▪ Typically used to evaluate long-term loading; provides monthly output ▪ Does not include stream routing in the original version ▪ Can simulate precipitation-driven sources, direct discharge sources (i.e., point sources) and inputs from septic systems ▪ Requires a low level of expertise ▪ Appropriate for situations of limited data for calibration ▪ Requires combination with a receiving water model to directly evaluate water quality impacts
HSPF	▪ Simulates watershed runoff and hydrology, pollutant buildup and washoff processes, and in-stream water quality and routing ▪ Appropriate for all types of land uses; distinguishes pervious and impervious areas ▪ Simulates wide range of conventional and toxic organic pollutants and sediment ▪ Simulates on a daily, hourly, or sub-hourly timestep, capturing variable flow conditions ▪ Can simulate snowfall/snowmelt processes ▪ Includes agricultural components for land-based nutrient and pesticide processes ▪ Includes a special actions block for simulating management activities ▪ Has a number of modules representing different processes, allowing flexibility in how simple or complex the model is set up ▪ Can simulate precipitation-driven sources and direct discharge sources (i.e., point sources) ▪ Requires extensive calibration ▪ Requires experience or training to setup and apply and understand model assumptions ▪ Can be applied for streams/rivers and well-mixed reservoirs
LSPC	Similar considerations as HSPF, but with the following additions or enhancements: ▪ Simulates multiple modules simultaneously at each timestep, allowing for simulating dynamic interaction between land and stream modules for representing processes such as irrigation, BMP/impoundment interaction with the landscape, and other more complex water routing configurations. ▪ Has no inherent limitations in terms of modeling size or model operations; is capable of simulating thousands of subwatersheds in a single file, as needed ▪ Is designed to accommodate large-scale model development in areas with a high degree of spatial resolution (especially beneficial in mountainous areas) ▪ Provides post-processing and analytical tools designed specifically to support TMDL development and reporting requirements ▪ Has data management tools to facilitate evaluation of multiple watersheds simultaneously ▪ Includes specialized MDAS (Mining Data Analysis System) module for simulating pH associated with mining activities ▪ Simulates time-variable land use change (e.g., urbanization of a watershed, forest fires, harvesting and regrowth)

Model	Considerations
SWAT	▪ Simulates watershed hydrology, sediment and water quality ▪ Can network multiple subwatersheds and representative streams ▪ Division within subwatersheds is based on Hydrologic Response Units (HRUs), unique combinations of soil and vegetation type, rather than land use ▪ Appropriate for streams ▪ Is suitable for watersheds from small to very large in size ▪ Simulates agricultural practices (e.g., planting, tillage, irrigation, fertilization, pesticide management, grazing and harvesting) ▪ Simulates in-stream biological and nutrient processes, including algal growth, death and settling
SWMM	▪ Is primarily applied to urban areas with impervious drainage ▪ Was originally developed for the analysis of surface runoff and flow routing through complex urban sewer systems ▪ Simulates watershed hydrology and water quality ▪ Can network multiple subwatersheds and representative streams ▪ Can be applied for single-event or long-term simulations ▪ Provides flexibility in simulation of quality through buildup/washoff, rating curves or regression techniques, providing varying levels of data input needs ▪ Simulates pollutants typically associated with urban areas (nutrients, metals, sediment, pathogens) ▪ Can simulate storage, treatment and other BMPs

Table 4-3. Example Watershed TMDLs Developed with Commonly Used Watershed Models

Model	Example Watershed TMDLs
AGNPS/ AnnAGNPS	▪ Zorinsky Lake, NE (siltation, nutrients and organic enrichment/low dissolved oxygen): www.deq.state.ne.us/Publica.nsf/0/113b45ab14a8f68206256be5005874ff/$FILE/zorinsky-tmdl.PDF ▪ Carbury Dam, ND (nutrients, sediment and dissolved oxygen): http://www.health.state.nd.us/WQ/SW/Z2_TMDL/TMDLs_Completed/Carbury%20Dam%20Final%20TMDL%2020061113.pdf
GWLF	▪ Conodoguinet Creek Watershed, PA (sediment and phosphorus): www.dep.state.pa.us/dep/deputate/watermgt/wqp/wqstandards/tmdl/Conodoguinet_TMDL.pdf ▪ Wissahickon Creek, PA (sediment and nutrients): www.epa.gov/reg3wapd/tmdl/pa_tmdl/wissahickon/index.htm ▪ Little Beaver Creek watershed, OH (phosphorus, ammonia, dissolved oxygen, fecal coliform, siltation): www.epa.state.oh.us/dsw/tmdl/LittleBeaverCreekTMDL.html
HSPF	▪ Suwannee River Basin, GA (dissolved oxygen): www.gaepd.org/Files_PDF/techguide/wpb/TMDL/Suwannee/FinalSuwanneeDOTMDLs.pdf ▪ Ballona Creek, CA (metals): www.waterboards.ca.gov/losangeles/board_decisions/basin_plan_amendments/technical_documents/bpa_28_2005-007_td.shtml
LSPC	▪ Cahaba River watershed, AL (nutrients): www.adem.state.al.us/WaterDivision/WQuality/TMDL/CRNutTMDL.pdf ▪ Los Angeles River, CA (metals): www.waterboards.ca.gov/losangeles/water_issues/programs/tmdl/tmdl_list.shtml ▪ Mahoning River, OH (fecal coliform): www.epa.state.oh.us/dsw/tmdl/MahoningRiverTMDL.html
SWAT	▪ Huron River, OH (sediment, nutrients): www.epa.state.oh.us/dsw/tmdl/HuronRiverTMDL.html ▪ Pajaro River, CA (sediment): www.waterboards.ca.gov/centralcoast/TMDL/303dandTMDLprojects.htm
SWMM	▪ Winter Haven Southern Chain of Lakes, FL (nutrients): www.epa.gov/region04/water/tmdl/florida/documents/WHaven_chainlakes_Nutrient_TMDL_001.pdf

Receiving Water Models

> ***Resources:***
>
> Receiving Water Modeling
>
> For more information on watershed models used in TMDL development and their applicability to different waterbody types, pollutants and sources, refer to the following EPA references:
>
> *Compendium of Tools for Watershed Assessment and TMDL Development*—
> www.epa.gov/owow/tmdl/comptool.html
>
> *TMDL Model Evaluation and Research Needs*—
> www.epa.gov/nrmrl/pubs/600r05149/600r05149.htm

In some cases, receiving water models are used to support TMDL development, either alone or in combination with a watershed model. Receiving water models differ from watershed models in that they only represent conditions within a receiving water, such as a stream or reservoir. Receiving water models simulate conditions within a receiving waterbody (e.g., lake, stream, estuary) based on representation of physical, chemical and biological processes. Inputs to the waterbody are often defined as boundary conditions or developed using linked dynamic output from a watershed model. Receiving water models are typically either steady-state or dynamic models. Steady-state models operate under a single nonvariable flow condition with constant inputs, typically used to evaluate conditions for a design or critical flow. Dynamic models allow for variations in both flow and meteorologic conditions on a small timestep, typically shorter than daily. Level of complexity in receiving water models is also determined by spatial detail described as one, two or three dimensions.

While the capabilities and applicability of receiving water models can vary widely, they generally provide the capability of simulating a number of water column processes unavailable in many watershed models, such as the effects of nutrient cycles on dissolved oxygen. For TMDLs addressing waterbodies with complex biological and chemical processes impacting water quality and associated impairments, receiving water models can more accurately evaluate the allowable pollutant loads. Because they can represent a stream, lake, or estuary using numerous analytical elements – in some cases tens of thousands – model predictions can be very accurate at many locations along the length of a receiving water. With this capability, receiving water models can be used to most accurately determine the specific amount of a contaminant that can enter a receiving water at different locations while still achieving water quality criteria throughout. Thus, allocations can potentially be made at the very detailed spatial level. However, they do not explicitly represent land-based contributions, which are typically addressed through designation of boundary conditions (often based on monitoring data) or through development of a separate watershed model. Therefore, when applied alone, the allowable loads calculated at different points represent a cumulative load entering the waterbody at that point. Because of this, it is important to understand the watershed and related sources and impairments when using a receiving water model for supporting watershed TMDLs independently from a watershed model. When applied alone, they do not explicitly represent land-based sources and a separate analysis might be needed to allocate the allowable load among land-based sources within the drainage area.

Non-modeling Approaches

Sometimes there is a misperception that developing watershed TMDLs requires the use of complex models. However, it is not always feasible or necessary to use watershed or receiving water models. Using a watershed framework to develop TMDLs accommodates various non-modeling approaches while still providing many of the same benefits. Non-modeling approaches to TMDL development are typically based on statistical analysis of ambient data or on an empirical calculation representing land-based processes. As compared to modeling approaches they typically include a more simplified representation of watershed and receiving water processes. However, they typically require less effort, time and experience to apply and can often be more easily communicated to the public. While non-modeling approaches, such as load duration curves, statistical approaches or mass balance analyses, might not quantitatively track the transport of loads as a model can, the TMDL still involves a thorough data analysis and source evaluation to identify critical loading conditions for significant sources in the watershed and helps to identify key areas for management. Even though the analysis does not employ a quantitative link between various sources and segments, by understanding the contributions and impacts of all sources in the watershed, the analysis is still holistic.

> ***Process Tip:***
>
> **Considerations When Selecting and Using Non-Modeling Approaches for Watershed TMDL Development**
>
> - Ability to evaluate and quantify relative magnitude and impact of multiple sources
> - Ability to evaluate the impact of and relationship among multiple pollutants
> - Ability to link hydrologic segments or consider in-stream fate and transport
> - Ability to capture spatial variability in waterbody conditions and source loading
> - Ability to evaluate time-variable processes and conditions

When applying non-modeling approaches for watershed TMDL development, many of the same considerations are important as when using a modeling approach. The most important of these are representation of the multiple pollutants and sources, level of spatial and temporal detail, and the considerations of important processes affecting impairment. For example, regardless of the approach used it is important to evaluate the appropriate temporal and spatial scale for application to evaluate the important sources, capture the conditions of impairment and allow for comparison to applicable water quality criteria or TMDL targets. For example, when using a load duration approach, the in-stream analysis of flow and water quality can be conducted at any point in the watershed with sufficient data. Evaluating such characteristics as the location of impaired segments, locations of key sources, land use distribution, and data availability to capture variable in-stream conditions can support selection of assessment points for conducting the analysis and ultimately setting allocations.

Within the non-modeling categories, there are various types of approaches, all of which can be further characterized based on the type of simulation or calculation they perform. The approaches either calculate land-based loads or the resulting waterbody loads. The “land-based” approaches, such as using export coefficients or the Simple Method, calculate loading from land-based runoff processes assuming some measure of precipitation and characteristics representative of the watershed (e.g., soils, imperviousness). The “waterbody-based” approaches, such as load duration curves or mass-balance analyses, calculate the “delivered” load in the waterbody based on waterbody conditions, either using observed monitoring data (i.e., concentration and flow) or assuming some user-defined load inputs and outputs. Many of these approaches are applied in combination to represent both source loading and waterbody response to develop TMDLs. Some examples of non-modeling approaches are discussed below.

Load Duration

The load duration methodology (USEPA 2007c) relies on using observed flows and water quality criteria to establish a curve of loading capacities for various flow conditions. This builds on using flow duration curves, which use hydrologic data to evaluate the cumulative frequency of historic flow data over a specified period. A water quality criterion or other target concentration can then be multiplied by the observed flows to create a curve representing the distribution of allowable loads as a function of daily flow, representing the loading capacity of the stream. The entire curve can be used to represent flow-variable loading capacities or allowable loads can be identified for specified flow intervals, used as a general indicator of hydrologic condition (e.g., wet versus dry and to what degree).

Because the method identifies the allowable and existing loads for all flow conditions, it provides insight into the critical conditions and inherently accounts for the natural variations in loading and in-stream conditions. However, because the methodology is based on observed in-stream conditions, it provides limited information regarding the relative magnitude of source loads and requires a supplemental analysis to distribute the calculated loading capacity into source-based allocations. This does not typically present a problem in watersheds where the sources are well understood. When using the approach for watershed TMDLs, one consideration is the need for robust and consistent records of flow and in-stream water quality data. Because it is necessary to identify allocations for each impaired segment, it would be likely that the load duration approach be applied for each impaired segment. However, sometimes data, especially flow, are not sufficient to perform the analysis. In this case, assumptions are usually made to extrapolate flow and/or water quality conditions from nearby segments to support TMDL calculation for the impaired segments. In addition, load duration curves for TMDL development are applicable only to non-tidal streams or rivers and might not be appropriate or would require combination with other approaches in watersheds with different types of impaired waterbodies (e.g., lakes and streams).

Example:

Using a Load Duration Approach and Field Work to Focus Resources
in the Duchesne River Watershed TMDL, Utah

Several segments in the Duchesne River watershed, Utah, are listed as impaired by TDS due to elevated in-stream salinity, the result of natural geology and years of hydromodification for irrigation. TMDLs for the Duchesne River watershed were calculated using the load duration approach, a statistical method relating pollutant loads to the frequency of observed in-stream flows. The load duration approach uses flow with observed TDS data to estimate existing loads and with the TDS TMDL target to estimate allowable loads over a range of flow percentiles. The approach was applied at representative monitoring stations for each impaired segment and provided information on water quality and flow conditions to support TMDL calculation.

To supplement the analysis, a series of watershed surveys and a variety of statistical analyses on historical data were conducted to better understand sources and water quality conditions. During the watershed surveys the types, locations, and severity of sources expected to contribute to water quality impairment were noted. Two visual, screening level assessments of TDS sources were conducted throughout the watershed and included photo documentation, global positioning system (GPS) locational indexing, and narrative descriptions of current and potential sources of water quality impairment in listed segments. Each of the listed segments was surveyed from available access points and road networks, and relevant features were documented. Obvious water quality impairments associated with the identified sources were noted (e.g., streambank erosion and destabilization, dewatered stream channels, natural sources).

Statistic analyses were also performed to evaluate the water quality conditions in the streams, particularly evaluation of background and natural conditions. Evaluation of historical data and local historical observations and anecdotal information suggested that natural conditions in two of the listed segments were in exceedance of water quality criteria. For these segments, site-specific TDS criteria were calculated to reflect the naturally elevated TDS.

Because the multijurisidictional watershed includes federal, state and tribal lands, an extensive stakeholder coordination process supported the TMDL process. Stakeholder involvement facilitated increased access to streams during the field surveys, improved historical and local knowledge of sources and conditions, and consensus on decisions regarding allocations and site-specific criteria.

Steady-State or Mass-Balance Analysis

The steady-state and mass-balance type approaches rely on the assumption of conservation of mass into a waterbody. The analysis might calculate loads entering a waterbody using export coefficients or observed data and calculate the resulting waterbody concentrations on the basis of simple representation of pollutant fate and transport, typically including estimated losses (e.g., settling, decay) and inputs. The approach relies on identifying the necessary loads entering a waterbody that will meet the desired waterbody target after the consideration of all inputs and losses.

Applying a mass balance or steady-state analysis to calculate a loading capacity relies on some calculation of the incoming existing pollutant load. This might be done by "back-calculating" an existing load based on observed concentrations and stream flow (or volume for lakes and reservoirs) and accounting for any expected losses (e.g., die-off, settling). If this is the case, the existing load represents a cumulative load from all of the sources contributing the pollutant of concern to that segment. In other cases source load inputs can be calculated using observed data (e.g., monitoring data for tributaries, DMR data for point sources). Assuming there are no data available to directly calculate loads from individual sources, the most likely approach for distributing the total load into source allocations will be to use some measure of source area (e.g., percent land use area), not accounting for natural variations in loading from different sources. Another option for calculating the existing load for a mass-balance analysis is the use of export coefficients. Similar to the Percent Reduction method, this would produce source-specific loads that could be applied a reduction to calculate allocations that meet the overall loading capacity. However, the loads are typically based on literature values representing longer-term loading (e.g., monthly, annual).

In the context of a watershed TMDL, the steady-state or mass-balance analysis can accommodate inputs of multiple sources. There is also the capability, although simplified, to route output of flow and load from one segment to the next, assuming some constant input and losses. However, the analysis is typically a static calculation, evaluating either a critical condition (e.g., design flow) or a longer-term average condition (e.g., average monthly loading). This can limit the ability to evaluate different types of sources and variability in source behavior (especially precipitation-driven sources) and impairment conditions. As with all approaches, the technical needs of the watershed TMDL analysis should be weighed against the necessary level of detail to develop effective allocations.

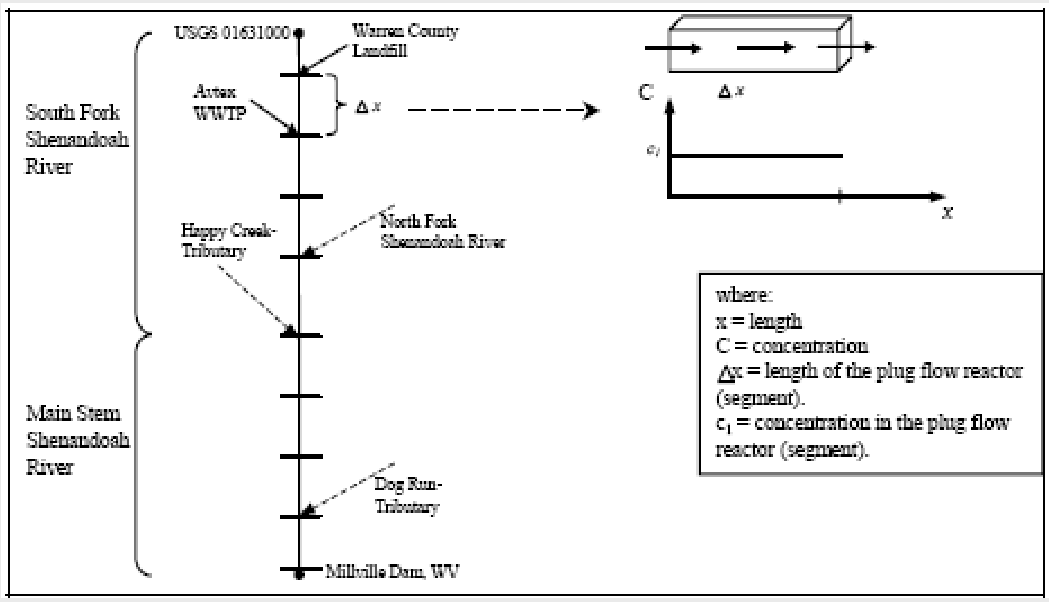
Percent Reduction

The percent reduction method assumes a 1:1 relationship between surface water concentrations and pollutant loading to calculate a loading capacity. The existing pollutant concentrations are compared to applicable water quality criteria to calculate a necessary reduction. This reduction is then applied to an estimate of "existing" loading to calculate the loading capacity. Existing loads are often calculated using ambient monitoring data (e.g., concentration and flow) or some estimation of land-based loading (e.g., export coefficients). While this methodology is easily applied and requires little effort, it also provides little to no information on watershed sources and does not provide the ability to evaluate the relationship among multiple impairments and impaired segments. The approach uses a static calculation, focusing on a critical condition (e.g., maximum concentration) or a long-term average condition, not allowing for evaluation of variability in loading or waterbody response.

Example:

Using a Mass Balance Analysis to Develop PCB TMDLs in the Shenandoah River Watershed, VA/WV

Several segments of the Shenandoah River were identified on Virginia's and West Virginia's 1998 303(d) lists as impaired due to fish consumption advisories for PCBs. A TMDL was developed to address the PCB impairments using a mass balance approach. Based on the data availability for the river, a one-dimensional, steady-state, plug-flow system was developed to represent the linkage between PCB sources in the Shenandoah watershed and the in-stream response. The Shenandoah River was segmented into a series of plug-flow reactors (defined along the entire length of the impaired segment) to simulate a steady-state distribution of PCBs. This approach accounted for the water balance between each segment and the impact of point sources and tributaries to the main stem of the Shenandoah River. Each of the plug-flow reactors defined a mass balance for PCBs for the sediment-water system. PCBs in the water column and sediment layers were computed as concentration profiles with respect to distance.



The Shenandoah River Watershed PCB TMDL is available online at
http://www.epa.gov/reg3wapd/tmdl/wv_tmdl/Shenandoah/index.htm

Export Coefficients/Pollutant Budgets

This category encompasses a number of approaches built on empirical relationships among watershed processes and pollutant loading as well as the use of literature values of typical watershed loading rates. Examples include using monthly load rates from various land uses to calculate allowable loading from an impaired watershed. Another example is using an empirical relationship that allows a user to calculate an allowable load depending on desirable conditions (e.g., target runoff/waterbody concentration or indicator levels). An example of such an analysis is using the Vollenweider approach for identifying an allowable phosphorus loading rate for a lake to meet a desired trophic level and based on such lake characteristics as depth.

Export coefficients are measures of typical loading rates from certain land uses or sources. Used within a TMDL analysis they would typically be used to calculate existing loads based on the land use distribution in a watershed and would often be combined with a supplementary approach that calculates an allowable load based on waterbody targets (e.g., percent reduction, mass balance). Export coefficients can be obtained for literature values from regional or national studies (e.g., EPA's Nationwide Urban Runoff Program [NURP] study [USEPA 1983]) or based on site-specific sampling of runoff from individual land uses. Issues or cautions in using export coefficients in watershed TMDLs are the same as when using them in all TMDLs. The TMDL practitioner should evaluate the applicability of the coefficients to the watershed of the impaired waterbodies and decide whether they are representative and appropriate. Because export coefficients only represent loading rates from designated land uses, direct-input sources or those that are not precipitation-driven will not be accounted for in the analysis. In addition, export coefficients do not evaluate or consider waterbody conditions. To provide even a simple evaluation of waterbody response or in-stream routing, the export coefficients would be used with some type of analysis of waterbody conditions to support calculation of a loading capacity.

For development of a watershed TMDL, this approach provides little utility in the evaluation of relative magnitude or impact of watershed sources, and the utility of any evaluation of waterbody response to individual or multiple sources would depend on what supplementary waterbody-based approach were used.

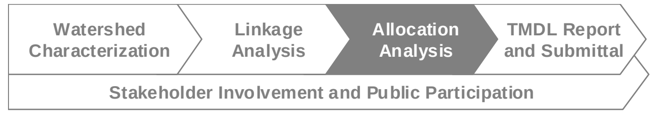
Simple Method

The Simple Method (CWP 2005, Schueler 1987) is an empirical equation used to calculate pollutant loading based on drainage area, pollutant concentrations, a runoff coefficient and precipitation. In the Simple Method, the amount of rainfall runoff is assumed to be a function of the imperviousness of the contributing drainage area. When using the Simple Method, the TMDL loading capacity would typically be calculated using a combination approach with the percent reduction method or similar approach. As with the other non-modeling approaches, using the Simple Method for a watershed TMDL would require its application at key locations in the watershed to calculate a loading capacity for each impaired segment. Because the method assumes all loading originates on impervious surfaces during storm events, it does not account for runoff from impervious areas or subsurface inputs and baseflow loading. Therefore it would not be appropriate for watersheds with sources such as agricultural runoff, failing septic systems, or direct inputs. The method also uses a static runoff concentration (e.g., event mean concentration), not accounting for variability in loading or in-stream levels. Because the method was originally developed to evaluate site-scale stormwater loading in urban areas, it is not typically appropriate for large watersheds (>1 mi^2) or non-urban areas.

Integration of Different Technical and Modeling Approaches

Using a watershed approach also lends itself well to the use of multiple technical and analytical tools to evaluate water quality conditions and loading, and to considering equitability in making allocations. Due to the complexities and heterogeneities of systems addressed by watershed TMDL analyses, it is sometimes helpful to combine multiple technical and modeling approaches to develop the TMDL. Various tools can be utilized to assist with loading estimations for different pollutant parameters. For example, while an overall TMDL for nutrients might be developed using the Soil and Water Assessment Tool (SWAT) model, site-specific nutrient export studies using a field scale model can be utilized to refine the parameterization of the SWAT model. While using combination approaches might make the analysis more difficult, it is sometimes necessary to represent the various sources and their unique features or impacts. A watershed TMDL allows for integrating multiple approaches for the most benefit. Because the framework allows for maximum flexibility in applying approaches and facilitates a more comprehensive and integrated evaluation of the watershed, it avoids added burden without added value to the analysis.

4.4. Allocation Analysis



As with the other tasks, developing and evaluating allocations for a watershed TMDL follows much the same process as that of a single-segment TMDL, but it is applied at a larger scale and likely involves more potential allocation combinations. Generally, a TMDL's allocation analysis involves applying load reductions to combinations of watershed sources to identify various scenarios that meet water quality standards. The final scenario is then selected and used to establish LAs for nonpoint sources and WLAs for permitted point sources. Developing TMDLs on a watershed basis often provides greater flexibility in developing source allocations. Although the level of detail might vary depending on the approach used, a watershed TMDL considers all the sources in a watershed and evaluates their relative magnitude to some extent. Because of this, there will likely be a number of allocation scenarios that will result in meeting the overall water quality goals. Deciding which scenario to choose can sometimes be a difficult task. Considerations to support the decision include:

- Scale or resolution of source allocations
- Equitability or feasibility of allocations
- Stakeholder priorities and implementation plans

> ***Process Tip:***
>
> Factors Affecting Allocation Decisions
>
> - Location and relative magnitude of sources
> - Pollutants of concern
> - Feasibility of necessary load reductions
> - Equitability among sources
> - Ongoing or planning controls
> - Stakeholder priorities

4.4.1. Scale or Resolution of Source Allocations

The scale at which an analysis considers pollutant loading from sources can affect the identification of allocations. The spatial scale of allocations can range from a gross load for an entire watershed to loads by land use to loads by land use by subwatershed. The watershed TMDL approach allows for the spatial evaluation of sources and their impacts and that should be captured in the allocations. Establishing a gross allocation for an entire watershed defeats the purpose of conducting a watershed TMDL analysis; it ignores the spatial variability of sources throughout the watershed and their relative magnitude and influence. Establishing allocations at a smaller scale will likely be more meaningful and effective.

An analysis that evaluates sources at a more detailed scale provides the greatest flexibility in identifying and targeting source reductions to meet water quality goals. The allocation analysis should establish loads and necessary reductions at a scale that maximizes the benefits from the established allocations, especially when addressing multiple impaired segments and multiple pollutants, without overburdening the analysis. For example, when evaluating a watershed with multiple impaired segments, source reductions can be targeted to upstream subwatersheds first because they will have an impact on water quality in upstream and downstream segments. Evaluating the upstream-to-downstream effects of pollutant loading is a primary benefit of developing TMDLs on a watershed scale, particularly when using a watershed model. After identifying necessary load reductions to meet targets in upstream impaired segments, the model can evaluate the effect on downstream water quality. Upstream reductions can significantly

Program Notes:

TMDL Allocations to Sources Upstream

In the context of a watershed TMDL, developers might wonder about possible implications of LAs or WLAs developed for sources that are not directly discharging to a listed waterbody. To answer this question it helps to distinguish the different types of waterbodies relative to the impaired segments for which the TMDL is to be developed. As such, there are essentially four kinds of waterbodies for which source allocations might be developed in a watershed TMDL:

1. Waterbodies that are included in the state's Section 303(d) list
2. Waterbodies that are not on the state's Section 303(d) list but are shown to cause and contribute to the impairment based on data and/or observations
3. Waterbodies that are not on the state's Section 303(d) list and are not proven to cause or contribute to the impairment
4. Waterbodies that are unassessed or not listed but for which modeling or analysis indicates that there might be an impairment

Allocations might be required for sources that are contributing either directly or indirectly to impaired segments to meet water quality standards in downstream impaired segments. Allocations can also be developed for sources on unimpaired and or non-contributing waterbodies that, for implementation or other programmatic reasons, a state might wish to identify reasonable allocations. These allocations would not be formally approved by EPA but would be developed as part of the overall assessment of loading in the watershed. In essence, they can be considered "for your information" allocations.

decrease or even eliminate the need for reductions in the lower subwatersheds, thereby optimizing the necessary reductions and associated source controls.

Similarly, depending on the approach chosen, the TMDL might consider pollutant loading down to the land use or source level. When addressing multiple impairments, certain land uses or sources might impact the levels of multiple pollutants while others only impact single pollutants. For example, when developing TMDLs for bacteria and nutrients, many of the sources are the same, such as failing septic systems or livestock related areas or activities, and targeting single sources will have benefits in reducing both pollutants. However, some sources might only impact one of the pollutants, such as cropland runoff that contains elevated nutrients but minimal bacteria, and therefore targeting that source might not provide the maximum benefits in addressing both impairments. While watershed TMDLs allow for identifying these efficiencies when targeting source controls, the allocation analysis should evaluate the benefit of such reductions in the context of the state's overall priorities. For example, a source might contribute multiple pollutants but is already subject to a number of controls, making further load reductions infeasible.

> ***Process Tips:***
>
> How to Integrate Pre-existing Approved TMDLs
>
> The TMDL practitioner might find in some situations that TMDLs already exist (for one or more segments) within the watershed addressed by the watershed TMDL. The practitioner has at least two options for dealing with these pre-existing TMDLs:
>
> - Incorporate the existing TMDL and analysis into the ongoing watershed TMDL and let the existing allocations remain in effect, or
> - Apply the new analysis to calculate new allocations that reflect the interactions of all segment within the hydrologically linked watershed.
>
> If it is decided to use the existing TMDL allocations, it is a good idea to make certain that the current land use, loadings and other key assumptions used to develop the original TMDL are still representative. In some cases, states might want to consider selecting the most stringent allocations by comparing the new calculation with the allocations contained in the existing TMDL. If the state decides to replace the existing TMDLs, they are in effect withdrawing and redoing the in-place TMDLs. This should be done in accordance with any state requirements and should be clearly explained in the watershed TMDL report distributed for public review and comment.

4.4.2. Priority and Feasibility of Source Allocations

Another consideration for the development of effective allocations in a watershed TMDL is the relative priority and feasibility of potential allocations scenarios. Whether or not developed on a watershed basis, TMDLs typically include multiple sources, often including both point and nonpoint sources. When establishing allocations and necessary load reductions among various sources, the issues of equitability and feasibility often arise. The allocation analysis can be used to evaluate a variety of possible allocation schemes to target or prioritize source controls as appropriate. For example, a goal might be to strike a balance among allocations and distribute necessary load reductions equitably among sources. Alternatively, the allocations might target those sources that represent the majority of the load input or those that are more feasible to control. For example, some sources that already contribute a small portion of the overall load might not be able to reduce the load any further. Other sources that represent a larger percentage of the total load and have a greater opportunity for reductions (e.g., more land area and delivery pathways to apply BMPs) can be targeted with larger reductions. Table 4-4 illustrates this concept, presenting two scenarios that meet the same overall allowable load with different approaches to source-level allocations. Scenario 1 represents an equitable distribution of load reduction among sources. Reductions are applied so that the resulting loads are the same percentage of the total as under existing conditions. Alternatively, Scenario 2 represents a scenario in which more controllable sources (e.g., roads, cropland, pasture) are targeted to meet the load reduction target.

Even when trying to target those sources that have the most impact on receiving water quality and that are more controllable, there will likely be multiple scenarios that result in meeting the water quality target (Figure 4-8), and there will be case-specific challenges, priorities and issues to consider in choosing the final TMDL allocations. This is the case with all TMDLs, regardless of whether developed as single-segment or watershed

> ***Process Tip:***
>
> Capitalizing on the Use of a Watershed-based Framework to Establish Accepted Allocations
>
> One of the greatest benefits of evaluating sources and engaging stakeholders within a watershed TMDL framework is realized during the allocation stage. Dealing with multiple sources provides increased opportunities for allocations and allows for flexibility in establishing the final allocations. In addition, stakeholders gain valuable perspective on their allocations in the context of the watershed and other sources when they are involved in evaluating TMDL allocations scenarios.

TMDLs. However, watershed TMDLs provide more flexibility in identifying and evaluating potential allocation schemes because there are more sources to consider when identifying the ultimate cumulative impact. Because the watershed analysis framework allows for relative comparison of sources and an evaluation of the cumulative affect of source inputs, it can more effectively be used to identify an appropriate allocation scenario.

Program Notes:

Reasonable Assurance in Watershed TMDLs

Based on EPA guidance (USEPA 1991, 1997b) all TMDLs that include a mix of point sources and nonpoint sources, whether single-segment or watershed, should include reasonable assurances that nonpoint source control measures will achieve expected load reductions. The watershed TMDL framework typically provides greater flexibility in targeting source controls and potential for increased stakeholder participation, thereby facilitating identification of feasible allocation options and supporting reasonable assurance.

Table 4-4. Examples of Different Scenarios to Meet the Same Load Target

Source	Existing Phosphorus Loading	Scenario 1		Scenario 2	
		% Load Reduction	Allowable Load	% Load Reduction	Allowable Load
Roads	78	26%	58	20%	62
Pasture/Hay	21	26%	16	10%	19
Cropland	218	26%	162	55%	98
Forest	97	26%	72	0%	97
Landfill	7	26%	5	0%	7
Residential	6	26%	5	0%	6
Groundwater	111	26%	83	0%	111
Total	539	26%	400	26%	400

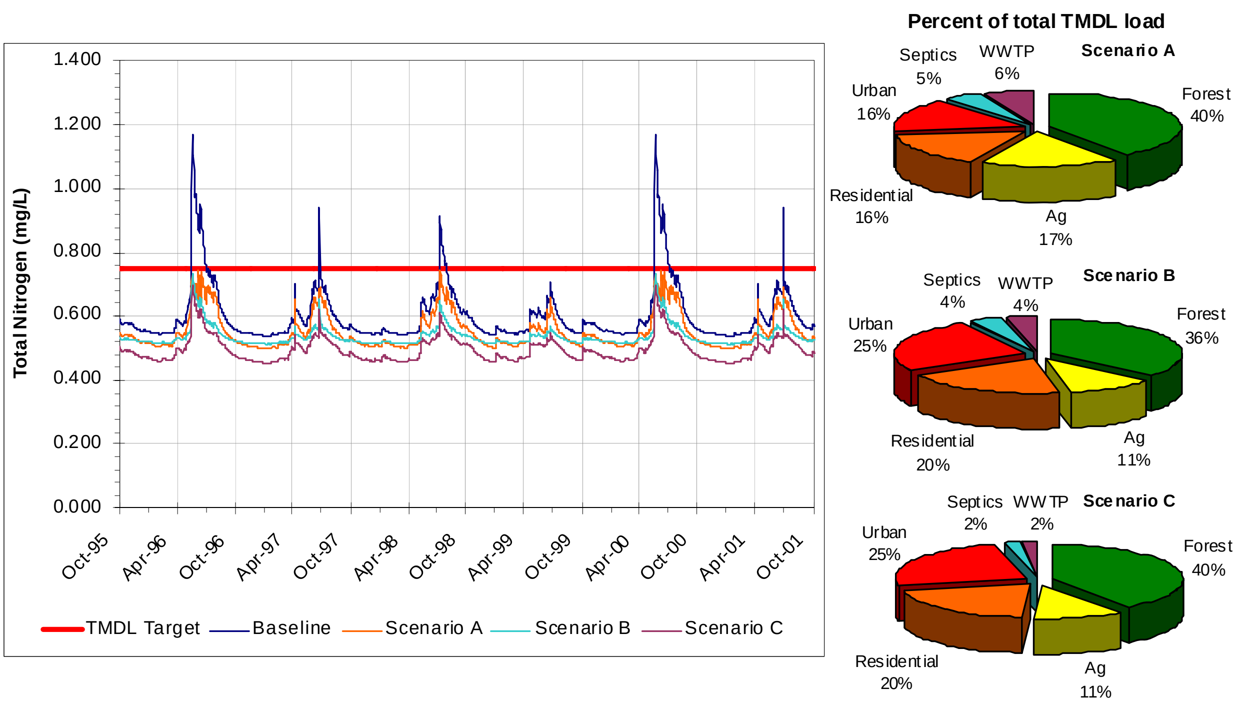


Figure 4-8. Model output illustrating multiple allocation scenarios that meet water quality standards.

4.4.3. Stakeholder Priorities and Implementation Goals

Stakeholder concerns can also be a significant factor in establishing allocations for a watershed TMDL. Ideally, major stakeholders have been involved throughout the watershed TMDL development process and were involved in decisions regarding the scale of the analysis and the representation of the sources in the analysis. Stakeholders can provide valuable information in establishing and evaluating the appropriateness of allocation scenarios, such as information on planned or expected implementation activities and the likelihood of meeting necessary reductions (i.e., feasibility). For example, a major source of bacteria in a watershed might be outdated and failing septic systems. Through coordinating with stakeholders to identify and understand sources, the TMDL practitioner learned that the city sewer is being extended to the area of the watershed currently served by septic systems, thereby eliminating a major source over the next few years. Because of this, a TMDL practitioner can target significant reductions to the septic system load knowing that it will be met and therefore avoid applying unnecessary reductions to other sources.

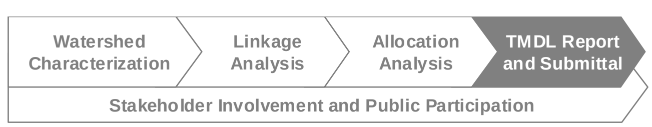
In addition, when stakeholders are involved throughout the TMDL process, it is more likely that they will be involved in implementation planning. Having an understanding of which stakeholders are more interested, willing, and able to implement control efforts as a result of the TMDL process allows a TMDL practitioner to identify management scenarios that are more likely to be implemented. Having stakeholders involved in the decision-making process for establishing allocations will result in more realistic allocations and will also open a dialogue among stakeholders that can support such efforts as watershed-based permitting and water quality trading.

Example:

Using Stakeholder Input to Identify, Understand and Evaluate Potential Management Strategies in the Lower Fox River Watershed, Wisconsin

Many of the BMPs that will be necessary to achieve the phosphorus and sediment reduction goals for the Lower Fox River Basin TMDL will require voluntary cooperation from landowners. If landowners are expected to voluntarily implement the elements of a TMDL implementation plan, the plan must not only address ecological functions in the basin, but also consider issues that directly impact the individual. To account for this, the TMDL for the Lower Fox River Basin includes extensive stakeholder involvement, including development of an Outreach Committee to implement a communication and outreach strategy for TMDL development and implementation and meet with key stakeholder groups. To facilitate more successful BMP implementation, the Lower Fox River TMDL process also includes an evaluation of social indicators to gain a better understanding of the potential effectiveness of BMPs that rely on outreach and behavior change. The process has included source-specific stakeholder meetings or “focus groups” (agriculture, stormwater, dischargers) to identify BMP scenarios to evaluate in the TMDL and optimization studies. A watershed survey of area farmers was also conducted to identify what BMPs are currently used and why.

4.5. Development and Submittal of TMDL Report



Preparing the TMDL report and assembling the submittal package for EPA’s review and approval can be one of the most important steps in the TMDL process. No matter how in-depth, accurate or meaningful the analysis, if it is not documented and represented in the report and associated administrative record, EPA and the public might not understand the TMDL and associated allocations. When dealing with a watershed TMDL, there is likely more information and more intricacies to the approach to document, making it important to organize the information in a useful and understandable manner.

Special considerations for preparing for submittal of a watershed TMDL mostly relate to the organization of the report. Often a comprehensive report for a watershed TMDL can result in more efficient report preparation when developing supporting information for the TMDL report that is common to all listed segments/impairments, such as maps, data analysis graphics, and language on watershed characteristics and sources. On the other hand, when dealing with multiple impaired segments, multiple pollutants, and a variety of source allocations, a TMDL report can become cumbersome and confusing. Redundancies can occur across sections that discuss similar or common information for different areas of the watershed. It is important to decide how to present allocations to not only meet regulatory requirements and accurately represent specific waterbody-pollutant combinations being addressed by the TMDLs but also to support public consumption. There are a number of ways to present individual TMDLs developed within the watershed TMDL—by impaired segment, by pollutant, by subwatershed or planning basin, etc. The TMDL writers should evaluate what format and structure is most meaningful for the specific watershed.

Some of the considerations for deciding how to structure and prepare a watershed TMDL report include:

- **Organization of Multiple Waterbodies and Impairments.** A watershed TMDL might address only two waterbody-pollutant combinations or it could address hundreds. When dealing with multiple TMDLs in one report, deciding how to organize the TMDL report can be difficult and affect how readily the TMDL is understood and accepted by the public. Many times the background information such as watershed characteristics, land use, and water quality standards can be described for the entire watershed and all pollutants, rather than addressing each waterbody or impairment in separate sections. Usually the more difficult decisions arise when deciding how to present allocations. Regardless of how many pollutant-waterbody combinations are addressed in the watershed TMDL, TMDL allocations (WLAs and LAs) need to be documented for each combination. When dealing with multiple impaired segments and multiple impairments, there will be a number of options for how to present allocations. Some reports provide sections for each impaired waterbody and document allocations for the various pollutants within the segment-specific sections (Figure 4-9). Others group all of the impairment-specific TMDLs together to provide allocations for multiple segments within sections dedicated to individual pollutants (Figure 4-10 and Figure 4-11). Regardless of how the allocations are presented, it can also be helpful to present them in an alternate manner in an appendix. For example, if the main report presents allocations by subwatershed to target areas of concern and specific sources, it might also include the allocations grouped by pollutant in an appendix to illustrate the distribution and relative magnitude of pollutant-specific load reductions throughout the watershed.
- **Audience.** For any TMDL report, it is important to consider the audience when developing the outline and preparing the document. This is especially true for watershed TMDLs that might have a greater number of involved stakeholders and affected sources. The organization and content of a report can be critical to the comprehension and acceptance of the TMDL by the affected parties. Many sources (e.g., MS4s, private farmers, WWTPs) might not be familiar with the location, or even concept, of watersheds and subwatersheds. Depending on how the report is written and the allocations are presented, sources might not understand where they

are located in relation to impaired segments and related allocations. To facilitate an understanding by the public and affected parties of the relative location of segments, sources and areas targeted for controls, it is useful for watershed TMDL reports to include descriptive maps with such things as roads, boundaries (counties, towns, parks, federal lands) and other recognizable landmarks or points of reference.

- **Level of Detail.** Watershed TMDLs typically generate more information to present in the TMDL report when compared to reports addressing single-segment TMDLs. Because of the larger area evaluated and the multiple waterbodies and impairments, there will likely be more information to document for such topics as watershed characteristics, impairment information, data analysis, sources and technical analyses. The level of detail included for each topic can help or hinder the readability of the document. A high level of detail, particularly on the data analysis and technical approaches, can result in a cumbersome document that is daunting to stakeholders and members of the public and difficult to navigate for EPA reviewers. The use of appendices can alleviate this problem by moving some of the background details out of the main body of the report. For example, watershed TMDLs that involve complex modeling sometimes include a short summary of the technical modeling approach in the main report with additional details on model development, calibration and application and associated assumptions and data inputs in a technical appendix. This way, the analysis information is available to those interested (and also for the administrative record) but does not overwhelm the main report and bury the allocations.

TMDLs for the Beaver Creek and Grand Lake St. Marys Watershed, Ohio

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Figure 4-9. Example outline for a watershed TMDL report organized by impaired segment.

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Figure 4-10. Example outline for a watershed TMDL report organized by impairment type.

TUALATIN RIVER SUBBASIN TMDL

TUALATIN RIVER SUBBASIN TOTAL MAXIMUM DAILY LOAD (TMDL)
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TUALATIN RIVER SUBBASIN TMDL

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Figure 4-11. Example outline for a watershed TMDL report organized by impairment type.

Example:

Watershed TMDL Demonstration Projects Sponsored by EPA

EPA is currently sponsoring three pilot projects to demonstrate the efficiencies (both in pollutant reductions and cost) of using a watershed approach to TMDL development. The following are summaries of the projects:

Lower Fox River, Wisconsin

A watershed TMDL is being developed for the Lower Fox River (LFR) Basin, including the Green Bay Area of Concern (GB AOC) to address 13 waterbodies impaired due to excessive sediment and phosphorus. Highlights of the project include:

- **Pre-TMDL Analysis of the Cost-effectiveness of Agricultural BMPs.** Used SWAT in conjunction with an optimization model to compare 416 BMP scenarios along with implementation costs to identify optimal BMPs for reducing phosphorus.
- **Extensive Stakeholder Involvement.** Developed a multi-agency Outreach Committee to work with key stakeholders (agriculture, stormwater, industrial and municipal dischargers, etc.) to determine and analyze BMP scenarios. Conducted targeted stakeholder meetings (agriculture, stormwater). Conducted basin-wide survey of 300 dairy farmers to raise awareness about water quality issues, identify existing agricultural practices and gain information to support modeling scenarios and TMDL implementation planning.
- **Application of Multiple Technical Tools for TMDL Development.** Will apply SWAT to estimate existing loads and calculate necessary load reductions to meet the numeric targets. Will include evaluation of phosphorus and sediment loading MS4 urban areas covered under WPDES Municipal General Permits. Will incorporate data from recent urban stormwater modeling using the Source Loading and Management Model (SLAMM) conducted for MS4s within the LFR Basin. Will use load duration curves to illustrate the water quality targets and modeling results for each impaired segment.

Lower Silver Creek, Utah

A TMDL was developed previously to address cadmium and zinc impairments in Lower Silver Creek. Estimates for the cost of implementation were greater than $100 million dollar with no incentive to begin cleanup. The initial TMDL assessment included gross (watershed-scale) allocations but provided an insufficient level of detail necessary to justify the expense of specific source reduction and remediation efforts. This demonstration project is designed to address the ongoing need for additional analysis of the pollutant source reduction options to better understand how to optimize cost and pollutant reduction effectiveness at the watershed scale and to inform regulators on the best mix of NPDES, nonpoint source, and other cleanup options. Because Lower Silver Creek watershed includes CERCLIS NPL "Alternative" Sites as well as 303(d) impaired waters, the project uses a cross-programmatic (Water and Waste Programs) approach to assessment and cleanup. Activities include:

- Watershed reconnaissance survey to fill the data gaps and characterize the nonpoint and point sources for model development.
- Conceptual model development to identify known and suspected pathways of pollutant transport, known and suspected sources of pollutants, and known or potential human and environmental receptors.
- Detailed water quality and stream sediment sampling throughout the upper and lower watershed to support model calibration and validation.
- Development of reactive transport models for both the Upper and Lower Silver Creek watersheds to quantify significant sources of metals loadings, addressing the geochemical behavior of the source materials as well as the fate and transport of metals via surface and subsurface pathways, and evaluate various remedial scenarios.
- Identification and evaluation of load reduction options and remedial action objectives for the identified sources of pollutants associated with mining activities.
- Quantitative evaluation of watershed-scale options and development and optimization of alternatives for cleanup that consider their effectiveness, implementability, and cost.

Watershed TMDL Demonstration Projects Sponsored by EPA (continued)

Ballona Creek and San Gabriel River, Greater Los Angeles Area, CA

The purpose of this pilot project is to develop a cost-benefit framework for optimizing BMP selection in watershed TMDLs being developed in the Los Angeles Region. The project will compare alternative pollutant reduction and associated cost scenarios that result in the most efficient and timely attainment of standards in two watersheds (Ballona Creek and San Gabriel River), using the following 4-step process:

1. Select a suite of BMPs for testing of various attainment scenarios.
2. Apply a watershed model to evaluate the effectiveness of various BMP scenarios in the two watersheds to meet water quality standards.
3. Evaluate the relative costs of the BMP scenarios against the expected reductions in pollutant loadings and water quality concentrations.
4. Design a monitoring framework to demonstrate attainment with water quality standards.

This BMP analysis and optimization tool will be integrated with the allocation scenario and selection process to be implemented over the next 2 years as part of TMDL development for Dominguez Channel and the Ports of Los Angeles and Long Beach (all part of the same integrated watershed-scale TMDL project). This pilot project will also be used to assist development and revision of several additional TMDLs in the Los Angeles Region, including the Los Angeles River bacteria TMDL. The optimization tool can provide a framework for pollutant trading scenarios within a TMDL and can be applied in other Southern California counties facing similar problems.

5. Supporting Implementation of Watershed TMDLs

This section focuses on activities and issues related to watershed TMDL implementation. As noted in Section 2.3, watershed TMDLs can generate a variety of implementation benefits. Through a watershed TMDL approach, implementation has the potential to connect to a broader variety of watershed-based tools and activities. Watershed TMDLs support and inform other watershed-focused efforts, such as watershed planning, permitting and trading. TMDLs often provide the core quantitative analysis for these programs and implementation activities. As a result, these programs and activities represent major vehicles for watershed TMDL implementation. Watershed TMDLs establish comprehensive stakeholder involvement processes to garner support from all watershed interests. As the watershed TMDL process moves from the development phase to the implementation phase, watershed stakeholders are more likely to identify as a watershed group and collectively identify and implement strategies to achieve LAs.

5.1. Multiple Program Involvement/Coordination

Watershed TMDLs set the stage for TMDL practitioners and stakeholders to consider innovative approaches to implementation that focus on broad watershed issues and require broad stakeholder involvement. These innovative implementation approaches, such as watershed-based NPDES permitting, water quality trading, and watershed-based planning, often work in concert, resulting in a coordinated effort across multiple programs to achieve water quality goals. Provided below are brief descriptions of watershed-focused implementation programs and activities that can support and be coordinated with watershed TMDL implementation.

5.1.1. Watershed-based Permitting

The NPDES program is an important part of an integrated watershed approach to achieving water quality goals. To integrate NPDES permitting into a watershed approach, NPDES permit writers need to develop or use an existing watershed-based analysis as part of the permitting process. A watershed-based analysis, referred to as a watershed permitting analytical approach in the context of watershed-based permitting, considers watershed goals, identifies and evaluates multiple pollutant sources and stressors, including nonpoint source contributions, and constructs an NPDES watershed framework that identifies NPDES permitting implementation options and other water quality program tools to achieve water quality goals. Where TMDL practitioners develop watershed TMDLs, the TMDL development process is likely to serve as a basis for the watershed permitting analytical approach necessary to support the development and implementation

> ***Resources:***
>
> Watershed-based Permitting
>
> For more information on watershed-based NPDES permitting, including watershed-based permitting implementation and technical guidance, as well as case studies, visit EPA's watershed permitting web site at http://cfpub.epa.gov/npdes/wqbasedpermitting/wspermitting.cfm.

of an NPDES watershed framework. Implementation options available under an NPDES watershed framework can include a wide range of activities, such as:

- NPDES permit development and issuance on a watershed basis
- Wet-weather integration
- Indicator development for watershed-based stormwater management
- Monitoring consortium development
- Permit synchronization
- Statewide rotating basin planning approach (USEPA 2007a)

Through the watershed TMDL development process, TMDL practitioners might have obtained the information necessary to demonstrate to NPDES permit writers that NPDES permit development and issuance on a watershed-basis is a technically feasible option for permittees in the watershed. For example, the watershed TMDL analysis might show that the conditions in the watershed are well understood, that there are common pollutants of concern among sources in the watershed, and that point sources have a significant impact in the watershed. In this case, the NPDES permit writer, along with point source dischargers and other watershed stakeholders, might determine that developing and issuing NPDES permits on a watershed basis is an appropriate approach for addressing point source loads of one or more pollutants. The specific conditions and types of point source dischargers located in the watershed will influence the type of NPDES permit that is appropriate for the watershed. Information generated through the watershed TMDL will help NPDES permit writers evaluate the applicability of the following permit types: coordinated individual permits, integrated municipal permits, and multisource watershed-based permits. It is important to keep in mind that NPDES permit writers might want to include other pollutants in NPDES permits developed for point source dischargers within a watershed to address other local water quality goals and concerns. As a result, NPDES permit writers might find it necessary to supplement the watershed TMDL analysis with a watershed permitting analytical approach to address pollutants outside the scope of the watershed TMDL.

Definition:

Types of NPDES Permits Issued on a Watershed-basis to Facilitate Watershed TMDL Implementation

Coordinated Individual Permits: Individual permits issued to each point source discharger in the watershed that contains water quality-based effluent limits and other conditions based on the watershed TMDL analysis (i.e., holistic analysis of watershed conditions) rather than on a permit-by-permit basis.

Integrated Municipal Permits: A single individual permit issued to a municipality that bundles a number of point source permit requirements (e.g., publicly-owned treatment works, stormwater, combined sewer overflows, pretreatment) that take place within a watershed's boundaries and contain effluent limitations and permit conditions designed to specifically address watershed goals, including WLAs under a watershed TMDL.

Multisource Watershed-based Permits: A single permit, either individual or general, issued to a group of point source dischargers located within a watershed either to address a single pollutant or to address multiple pollutants from similar types of discharges that contain requirements specific to achieving watershed goals, such as water quality-based effluent limits generated using a holistic watershed analysis based on the watershed TMDL, watershed monitoring requirements, and other watershed provisions (e.g., trading, stakeholder involvement, reporting).

For more information on developing NPDES permits on a watershed-basis refer to EPA's *Watershed-based NPDES Permitting Technical Guidance* at www.epa.gov/npdes/pubs/watershed_techguidance_entire.pdf

5.1.2. Water Quality Trading

> ***Resources:***
>
> Water Quality Trading
>
> For more information on the type of information necessary to develop and implement water quality trading activities to achieve WLAs under watershed TMDLs, see EPA's *Toolkit* available at www.epa.gov/waterqualitytrading/WQTToolkit.html.

Water quality trading most often takes place on a watershed-basis under a pollutant cap established through a TMDL analysis, allowing point sources that face higher pollutant control costs to achieve pollutant reduction goals by purchasing pollutant reduction credits from other sources, both point and nonpoint, that can generate reductions at a lower cost. EPA's *Water Quality Trading Toolkit for Permit Writers (Toolkit)* provides the fundamental information necessary to develop and conduct water quality trading through NPDES permitting as a tool for TMDL implementation. Information generated through watershed TMDLs is essential to support key components of water quality trading programs, including defining the appropriate geographic area, identifying potential trading program participants within the watershed, establishing baselines (i.e., WLAs and LAs) for all potential participants, and conducting the necessary technical analysis to support the development of trade ratios based on watershed conditions and characteristics.

Defining the appropriate geographic scope is an essential first step to ensure water quality trading will effectively address water quality concerns. According to EPA's *Toolkit*, the geographic scope of water quality trading should occur only within a hydrologic unit that is defined to ensure that trades will maintain water quality standards within that unit, as well as within downstream and contiguous waters. Because the purpose of water quality trading is to more cost effectively improve water quality, buyers and sellers should discharge directly or indirectly (e.g., to a tributary within the impaired watershed) to the same waterbody where pollutant load reductions are necessary to achieve water quality standards or sellers could discharge to an upstream tributary within the watershed. The analyses done for watershed TMDLs are likely to provide more information on potential buyers and sellers of pollutant credits and on pollutant fate and transport in a watershed, which will better support a water quality trading feasibility analysis, as opposed to single-segment TMDLs that might have a more limited geographic scope and would require additional pollutant analyses beyond this limited geographic area to determine if a trading program could be feasible.

Watershed TMDLs comprehensively and simultaneously address the development of WLAs and LAs for sources contributing to the water quality impairment within the watershed. In the context of water quality trading, WLAs and LAs serve as the baseline for point sources and nonpoint sources potentially involved in trading. It is imperative that the WLAs and LAs are set consistently among potential trading partners and are not likely to change as a result of having to "redo" upstream TMDLs based on pollutant load reductions necessary to achieve downstream TMDLs. Unexpected changes to WLAs and LAs for trading partners can create uncertainty in the trading market and result in decreased willingness to participate.

Water quality trading might require the use of one of two types of fate and transport trade ratios – location and delivery ratios. Location and delivery ratios account for the unique watershed conditions and characteristics that affect pollutant fate and transport between upstream and downstream locations. Models used to support watershed TMDL development are likely to address these fate and transport issues when calculating loading capacity and allocations. This information can directly support the development of

> ***Example:***
>
> Using Water Quality Trading to Implement the Long Island Sound Nitrogen TMDL
>
> The states of New York and Connecticut jointly submitted a TMDL for nitrogen which was approved by EPA in 2001. The TMDL includes reductions to in-basin (phase III) and out-of-basin (phase IV) point and nonpoint sources. In-basin sources refer to those sources within the Connecticut and New York portions of the drainage basin, while out-of-basin reductions refer to those nutrients from all other sources beyond the in-basin boundaries, including tributary transport from north of Connecticut and oceanic transport. The first phase of reductions (phase III) focus on in-basin reductions, since the majority of nitrogen loading is attributed to those sources. Phase V of TMDL implementation actually addresses non-treatment alternatives such as outfall relocation, seaweed farms and oxygen injection techniques.
>
> One of the primary mechanisms for implementation of the TMDL was the option for nitrogen trading among sources. Because 90 percent of the reductions were expected to be from point sources, the State of Connecticut developed a trading program to address its 84 municipal treatment facilities. Geographically, the in-basin areas were divided into 12 management zones, one of which comprised the Sound itself. The terrestrial zones generally follow river basin boundaries in Connecticut and political boundaries in New York. To accommodate the development of Connecticut's trading program, the larger management zones in Connecticut were also subdivided into tiers. The tiers were designed to account for differences in attenuation and transport of nitrogen from one tier to the next and were used in assigning attenuation factors. Attenuation factors are used in quantifying the relationship between a discharge point and actual delivery of nitrogen to the Sound and help to determine allowable trades between facilities.

location and delivery ratios necessary to understand the downstream impact of a pound of pollutant on the waterbody of concern discharged by an upstream source.

5.1.3. Watershed-based Planning

While TMDL implementation for point sources occurs through NPDES permits, the primary mechanism for addressing nonpoint source pollutant load reductions is often through watershed-based planning. More specifically, watershed stakeholders often develop watershed-based plans eligible for funding through EPA's section 319 nonpoint source pollution control grant program or other funding sources. The process for watershed-based planning includes characterizing the watershed, identifying watershed-specific problems, setting goals, identifying solutions, establishing partnerships, and measuring progress. EPA recently identified nine elements that are critical for developing and implementing effective watershed-based plans to improve water quality (USEPA 2002b, 2008). EPA now requires these nine minimum elements for watershed plans funded through section 319 grants and strongly recommends the use of these elements in all watershed plans intended to address impaired watersheds. Development of watershed TMDLs address many of the nine minimum elements necessary to include in watershed plans that stakeholders will use to secure section 319 grant funds to implement nonpoint source pollution control measures. Specifically, watershed TMDLs will produce a watershed pollutant source characterization that identifies major sources and causes of impairment, as well as water quality standards and other watershed goals for addressing the impairments (Element a). Watershed TMDLs also quantify pollutant loads for sources within the watershed and identify the reductions necessary to achieve water quality standards (Element b). Of all the nine minimum elements, quantifying the pollutant loads and pollutant load reductions necessary to meet water quality standards is likely the most significant contribution that a watershed TMDL can make to the development of a watershed-based plan intended to satisfy EPA's

> ***Resources:***
>
> Watershed-based Planning
>
> EPA's *Handbook for Developing Watershed Plans to Restore and Protect Our Waters* (USEPA 2008), available at www.epa.gov/owow/nps/watershed_handbook/, provides a step-by-step approach for developing a watershed plan that addresses each of the nine elements.

Definition:

Nine Minimum Elements of a Watershed-based Plan

a. An identification of the **causes and sources** or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan), as discussed in item (b) immediately below. …

b. An **estimate of the load reductions** expected for the management measures described under paragraph (c) below (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time). …

c. A description of the **NPS management measures** that will need to be implemented to achieve the load reductions estimated under paragraph (b) above (as well as to achieve other watershed goals identified in this watershed-based plan), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.

d. An estimate of the amounts of **technical and financial assistance** needed, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. …

e. An **information/education component** that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented.

f. A **schedule for implementing the NPS management measures** identified in this plan that is reasonably expeditious.

g. A description of **interim, measurable milestones** for determining whether NPS management measures or other control actions are being implemented.

h. A **set of criteria** that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether this watershedbased plan needs to be revised or, if a NPS TMDL has been established, whether the NPS TMDL needs to be revised.

i. A **monitoring component** to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (h) immediately above.

requirements. Watershed TMDLs can also help with the development of progress indicators to assess achievement of pollutant reduction targets (Elements g and h) and the development of a monitoring component to assess implementation efforts over time (Element i).

5.2. Structuring the TMDL to Support Implementation Activities

In addition to organizing the TMDL process and analytical activities to support the needs of other CWA programs, both the TMDL process and document itself need to be structured in such a way that they facilitate implementation.

Building on the early stakeholder involvement efforts of the TMDL process, as discussed in Section 4.1, can facilitate implementation activities. Continual stakeholder support and involvement ensures consideration of important analytical considerations for implementation. This might include stakeholder input regarding the relative amount of reductions or allocations and what pollutant parameters should receive greater focus for reductions. For example, modeling might indicate that several NPDES dischargers in a watershed need to reduce BOD, TP, and TN discharge concentrations to specific levels to reduce periphyton and nuisance algal growth in a waterbody. Given the ability to participate in the reduction scenario analysis, the dischargers' input might indicate that greater relative controls on BOD discharges from the facilities can be more effective than equal reductions on all three.

Program Notes:

How Are WLAs Translated into NPDES Effluent Limitations?

TMDL WLAs are assigned for both continuous discharging facilities and for diffuse discharges such as stormwater outfalls that are covered by a Phase II NPDES stormwater permit. NPDES regulations at § 122.44(d)(1)(vii)(B) require that any NPDES permits subject to a TMDL WLA be updated to include effluent limitations that are consistent with the assumptions and requirements of the WLA. To facilitate implementation, it can be helpful for TMDL practitioners to understand the basic procedures used by permit writers in translating TMDL WLAs into permit limits. EPA guidance is available to assist permit writers in developing effluent limits from TMDL WLAs. Separate techniques are applied for aquatic life WLA's and human health WLA's.

Implementing Aquatic Life WLAs
For continuous discharges, permit writers often use a statistical procedure such as the one discussed in Section 5.4 of the EPA's *Technical Support Document for Water Quality-based Toxics Control* (Technical Support Document), or similar procedures adopted by the permitting authority, to translate WLAs expressed as a monthly average or shorter time period (e.g., 4-day average) into effluent limits.

The statistical process consists of the following steps:

- Calculate a long-term average (LTA) pollutant concentration for each WLA (generally an acute and chronic WLA)
- Select the lowest (most protective) LTA as the performance basis for the permitted discharge

Calculate an average monthly limitation (AML) and maximum daily limitation (MDL) from the most protective LTA

Implementing Human Health WLAs
The exposure period of concern for human health water quality standards can be up to 70 years and the average exposure rather than the maximum exposure is usually of concern. Because compliance with effluent limitations is normally determined on a daily or monthly basis, it is necessary to set human health effluent limitations for continuous discharges so that they meet a human health WLA every month. In Section 5.4 of the Technical Support Document, EPA recommends a procedure for establishing effluent limitations for protection of human health:

- Set the AML equal to the human health WLA
- Calculate the MDEL for human health by multiplying the AMEL by the ratio MDEL:AMEL ratio provided in the Technical Support Document

For both human health and aquatic life WLAs, the Technical Support Document provides formulae and tables to assist with calculating effluent limitations for human health protection.

Long-Term Effluent Limitations
In some cases, the long-term nature of impacts from pollutants such as nutrients, especially in downstream waterbodies such as lakes and estuaries, combined with the difficulty of predicting seasonal fluctuations in treatment efficiency and loading of such pollutants have led to development of annual WLAs. If a WLA is expressed as an annual requirement (e.g., annual average concentration or annual loading), and fluctuations in treatment efficiency and loading make establishing shorter-term (e.g., monthly, weekly, or daily) effluent limitations impracticable, the NPDES permit could include an annual effluent limitation. In such cases, the NPDES permit should clearly state the method for determining compliance with the annual limitation.

Concentration-based and Mass-based Effluent Limitations
Where a WLA is expressed in terms of concentration, effluent limitations calculated from the WLA should be expressed in terms of concentration. Likewise, if a WLA is expressed in terms of mass, the corresponding effluent limitations should be expressed in terms of mass. If there are WLAs that apply to a discharger expressed in terms of both concentration (e.g., WLAs calculated directly from concentration-based standards to prevent near-field impacts) and mass (e.g., WLAs from a TMDL) it might be necessary to calculate the corresponding effluent limitations in more than one form to allow comparison and selection of the most protective limitations for the permit.

Water Quality-based Effluent Limitations for Permitted Stormwater
EPA recommends that for NPDES-regulated municipal and small construction stormwater discharges effluent limits should be expressed as BMPs or other similar requirements, rather than as numeric effluent limits, to be consistent with the WLA. (USEPA 2002c)

In preparing the final document and deciding how to present allocations, practitioners should consider the ultimate implementation goals of the TMDL. For example, are there going to be both LAs and WLAs? What types of facilities will receive WLAs and how do permit writers include WLAs in their permits? This can facilitate adaptation of the required WLAs by NPDES permits, as well as LAs through necessary BMP implementation to reach land-use based loading goals. Developers and stakeholders might work together to determine what format the TMDL document should use to present LAs and WLAs to ensure the allocations are understandable and readily translated to promote implementation. Especially for MS4 permits, where TMDLs are sometimes referenced in or attached to the implementing permits, it is especially important for TMDL practitioners to provide adequate information in the text and analysis so that permittees can identify appropriate BMPs to implement WLAs. TMDL practitioners might consider presenting MS4 allocations at various levels of detail to assist permittees. For example, MS4 WLAs might be provided for the MS4 area as a whole, but also describe the associated reductions identified for subbasins and individual land uses in the boundary area. This additional detail and context for the WLAs, (e.g., 80 percent of loading reductions must come from urban areas as compared to residential areas) permittees will have more information to support them in meeting their allocations.

Program Notes:

Approved vs. FYI WLAs in Watershed TMDLs

When applying the watershed approach in the development of TMDLs, pollutant sources are identified and quantified throughout an entire waterbody and multiple impaired segments. The process might identify the need to establish allocations in segments not formally defined as impaired (on the state's 303(d) list of waters requiring a TMDL).

As stated in 40 CFR 130.7(d)(1), "all WLAs/LAs established …for water quality limited segments [any segment where it is known that water quality does not meet applicable water quality standards] shall continue to be submitted to EPA for review and approval." Clearly, then, WLAs developed in TMDLs for waters on the State's 303(d) list are formally approved by EPA, and must be incorporated into NPDES permits (see CFR section 144). However, WLAs developed for un-listed segments that are an integral part of the watershed's hydrologic network might not need to be formally approved by EPA. WLAs developed in the TMDL for unlisted segments fall into two categories, WLAs for segments "causing and contributing" to a listed segment's impairment and WLAs for segments not "causing or contributing" to a listed segment's impairment.

The WLAs for segments determined to be ""causing or contributing" to an impairment will be acted upon by EPA in an identical manner as those for the formally listed segments. The allocations to these segments will be formally approved by EPA when the TMDL is submitted, and the WLAs must be incorporated into permits (see CFR section 144). The WLAs for segments determined not to be "causing or contributing" to an impairment will not be formally approved acted upon by EPA, and are for informational purposes only.

5.3. Follow-up Monitoring

Post-implementation monitoring is critical to determining the success of any implementation effort and this is no different for watershed TMDLs. States should ideally plan for both pre- and post-TMDL monitoring needs as a regular part of their monitoring strategies to effectively allocate resources to conduct both activities. The TMDL modeling analysis can be used to assist in the development of the post-implementation monitoring plan to identify the location of assessment points and the frequency of assessment in the follow-up period. If detailed enough, the modeling can even be used to help measure compliance with the TMDL by developing rating curves of allowable loads against which post-implementation monitoring results can be compared.

By comparing monitoring results at key locations against specific metrics obtained with model results at those locations states can have a real measuring stick to guide them in assessing the success of their reduction efforts.

Often with large area TMDLs there are significant areas or categories of information for which additional detail or monitoring can help to more fully inform the analysis. For situations such as these, the TMDL analysis is useful in identifying what information (either geographic locations or specific parameters) needs to be addressed in the post-implementation monitoring. Upon further investigation, results can be incorporated into an updated TMDL in an adaptive implementation process.

Example:

Watershed TMDL Development in the DuPage River and Salt Creek Watersheds, Illinois: Promoting Development of a Stakeholder Workgroup and Monitoring to Guide Post-TMDL Implementation Efforts

TMDL development in Illinois is conducted on a watershed basis using a three stage process that emphasizes the importance of monitoring and implementation. Stage 1 consists of watershed characterization and data analysis. Stage 2 involves follow-up data collection for situations where additional information is deemed needed. Stage 3 is focused on modeling, TMDL development, and preparation of implementation plans. In the case of the DuPage River / Salt Creek, development of the watershed TMDL and implementation plans led to the formation of local stakeholder group that is taking a distinctive approach to address the findings of the TMDL reports.

The DuPage River and Salt Creek, significant tributaries of the Des Plaines River, flow through rapidly urbanizing watersheds in the Chicago metropolitan area. The two watersheds combined encompass an area of approximately 360 mi^2. The watersheds are home to 55 municipal entities and 25 POTWs, and at least 21 dams have been constructed in the watersheds to address issues such as flooding and recreational needs. Illinois EPA developed watershed TMDLs to address impairments to several segments by chloride and low dissolved oxygen.

Representatives from municipalities affected by the TMDL discussed the need for a framework to collect data and carry out other technical activities to support implementing the TMDLs. This led to creation of the DuPage River Salt Creek Workgroup (DRSCW, www.drscw.org), a collaborative effort by sanitary districts, municipalities, counties, forest preserve districts, state and federal agencies, and private environmental organizations. Stakeholders affected by the TMDL allocations wanted an opportunity to “substantiate” implementation strategies and determine whether there were other cost-effective options. It was also envisioned that the DRSCW could help stakeholders establish a solid foundation for future TMDLs, contribute to the development of nutrient criteria, and address other water quality or regulatory issues in the watersheds.

At the outset, DRSCW members acknowledged the need for better data to make informed decisions. As a result, establishing and implementing a monitoring program have been the DRSCW's highest priorities and have helped to unify the group. Better monitoring data allows the DRSCW to understand the sources of impairment, identify priority restoration activities and track implementation effectiveness, calibrate water quality and watershed models, determine progress toward achieving water quality standards, and assess the overall health of the watersheds. To augment routine fixed-station monitoring by the Illinois EPA, Metropolitan Water Reclamation District (MWRD) of Greater Chicago and USGS, the DRSCW established a network of continuous monitoring probes throughout the watersheds. To date, the monitoring network includes 10 submerged probes that measure DO and collect hourly data on pH, conductivity, and temperature. Agency members of the DRSCW also contribute data from an additional five probes. The Workgroup also initiated an extensive bioassessment program across DuPage County.

The collaborative, locally led approach initiated by DRSCW members, while still in its beginning phases, has several early indicators of success, including support from state and federal regulatory agencies, financial support from all levels of watershed stakeholders, membership that continues to grow, and more watershed monitoring data to facilitate science-based collaborative decision-making.

5.4. *Financial Resources for Implementation*

The early engagement of stakeholders in a watershed TMDL is not only an opportunity for better coordination of activities, data integration and increased buy-in, but it is also an opportunity for the identification and coordination of funding resources.

Many sources of funding require a "match." For every dollar a funder provides, the recipient organization or agency must "match" a certain percentage of the grant with funds obtained from other entities. By requiring a match, the funder guarantees that they are not the sole supporter of a project and that partnering with other funders or stakeholders will occur. Stakeholders can be source of matching funds when implementing a watershed TMDL. Matching funds can be in the form of cash raised or in the form of in-kind contributions for allowable costs under the grant. For example, if a professional donates their time to conduct a stream assessment, their hourly rate for the time they spent conducting the assessment might be used as a match. Other examples of in-kind match include donated tools, the rental value of meeting space used for the project, mileage, postage and materials. Every match, whether in-kind or cash, should have clear, supporting documentation as federal grants are subject to audits.

Resources:

Watershed Funding

EPA's Section 319 Grant program provides states with funding to address nonpoint source pollution. Within this funding program, "incremental funds" are available for the development and implementation of watershed-based plans and TMDLs. State agencies might offer subawards of this money to public and private entities. Section 319 Grant guidance can be found in *Applying for and Administering CWA Section 319 Grants: A Guide for State Nonpoint Source Agencies* (http://www.epa.gov/owow/nps/319/319stateguide-revised.pdf).

The Watershed Funding Web site (www.epa.gov/owow/funding.html) includes tools, databases, and information about sources of funding to watershed practitioners. The *Catalog of Federal Funding for Watershed Protection* can be accessed through this site and it includes a searchable database of more than 80 federal programs offering financial assistance. Also accessible through this site is the Plan2Fund Objective Prioritization Tool (Plan2Fund OPT). This web-based decision model generates comparative reports based on the user's objectives and decisions related to the project and was designed to help an organization develop and implement a long-term financial strategy to meet strategic goals.

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Appendix: Case Studies

This appendix highlights a number of watershed TMDL efforts in various stages of completion, from some that are just beginning to those that are years into implementation. To illustrate a greater range of issues, the cases presented include both state TMDL efforts as well as regional TMDLs. While some technical issues are discussed, the case studies try to focus on issues such as the development process and other topics related to the implications of using a watershed approach to develop TMDLs, including insights from individuals involved in the actual development process and ensuing implementation activities. To the extent information was available, various “lessons learned” are presented highlighting difficulties encountered, realized benefits of the watershed process, and implementation highlights.

Note that most of the case studies represent fairly large-scale efforts, allowing for the illustration of multiple issues, sometimes on an exaggerated scale, related to watershed TMDL development. For example, large watershed TMDLs can address hundreds of waterbody-pollutant combinations and include multiple states and numerous stakeholders. The increased scale provides more opportunity for unique technical and programmatic issues to arise and therefore illustrate in these case studies. However, this is in no way meant to imply that “watershed TMDLs” must be, by definition, large in area. Small-scale watershed TMDLs can still result in the same types of efficiencies and benefits as those developed for larger geographic areas.

The following table summarizes the case studies included in this appendix.

	Type		Pollutants															Program Factor							
Case Study	State	Regional	Phosphorus	Nitrogen	Sediment	Bacteria	Total Dissolved Solids	Dissolved Oxygen	Biological Impairment	Temperature	Aluminum	Iron	Manganese	Hg	Salts	PCB	Heavy Metals	NPDES Permitting	Trading	MS4	CSO	CAFO	Source Water Protection	Multi-Jurisdictional	Consent Decree
Callegas Creek, CA	x			x	x		x	x							x	x	x								
Gauley River, WV	x										x	x	x												
Long Island Sound, NY & CT		x		x				x										x	x						
Lower Fox River, WI	x		x		x																			x	
Potomac River PCB, VA, WV, MD		x														x					x				x
St. Mary's River, IN	x				x	x			x											x	x	x		x	
Tualatin River, OR	x		x	x		x		x		x								x	x	x					
Virgin River, Utah	x		x				x	x		x													x		

Case Study 1: Calleguas Creek, California

Watershed TMDL at a Glance

Waterbody:
Calleguas Creek

***Drainage Area*:**
343 square miles

Parameters:
Organochlorine (OC) Pesticides and PCBs
Trash
Nutrients (ammonia, oxidized nitrogen, and algae/dissolved oxygen (DO))
Salts (boron, chloride, sulfate, total dissolved solids (TDS))

Additional TMDLs were developed separately for siltation, metals, and toxicity.

Development Status:
The TMDLs were developed from 2001 to 2007.

Developed by:
Larry Walker Associates on behalf of the Calleguas Creek Watershed Management Plan for the Los Angeles Regional Quality Control Board

Jurisdictions:
Ventura County and a small portion of western Los Angeles County.

\# ***Impaired Segments Listed***:
OC pesticides and PCBs – 11 segments
Trash – 2 segments
Nutrients – 12 segments
Salts – 11 segments

Technical Approach*:*
The OC pesticides and PCB loads into and out of Callegas Creek subwatersheds were calculated using DDE as a representative constituent. A numerical model was developed for this purpose.
A conceptual mass balance spreadsheet model forms the basis of the information used to develop the nutrient and salts TMDLs.

Source Types*:*
NPS and PS

Background

Calleguas Creek and its tributaries are located in southeast Ventura County and a small portion of western Los Angeles County. Calleguas Creek drains an area of approximately 343 square miles from the Santa Susana Pass in the east to Mugu Lagoon in the southwest. The main surface water system drains from the mountains in the northeast part of the watershed toward the southwest where it flows through the Oxnard Plain before emptying into the Pacific Ocean through Mugu Lagoon. The watershed, which is elongated along an east-west axis, is about thirty miles long and fourteen miles wide. The Santa Susana Mountains, South Mountain, and Oak Ridge form the northern boundary of the watershed; the southern boundary is formed by the Simi Hills and Santa Monica Mountains. <<insert map>>

Land uses in the Calleguas Creek watershed (CCW) include agriculture, high and low density residential, commercial, industrial, open space, and a Naval Air Base located around Mugu Lagoon. The watershed includes the cities of Simi Valley, Moorpark, Thousand Oaks, and Camarillo. Most of the agriculture is located in the middle and lower watershed with the major urban areas (Thousand Oaks and Simi Valley) located in the upper watershed. The current land use in the watershed is approximately 26% agriculture, 24% urban, and 50% open space. Patches of high quality riparian habitat are present along the length of Calleguas Creek and its tributaries.

The watershed is generally characterized by three major subwatersheds: Revolon Slough in the west, Conejo Creek in the south, and Arroyo Simi/Las Posas in the north. Additionally, the lower watershed is also drained by several minor agricultural drains in the Oxnard plain. Figure 1 depicts the CCW with reach names and designations used in the OC Pesticides and PCB TMDL, the three major subwatersheds, and six smaller subwatersheds which are defined for analysis and modeling in this TMDL (Mugu, Revolon, Calleguas, Conejo, Arroyo Las Posas, and Arroyo Simi).

The main surface water system drains from the mountains toward the southwest, where it flows through the Oxnard Plain before emptying to the Pacific Ocean through Mugu Lagoon. Dry weather surface water flow in the Calleguas Creek watershed is primarily composed of groundwater, municipal wastewater, urban non-stormwater discharges, and agricultural runoff. In the upper reaches of the watershed, upstream of any wastewater discharges, groundwater discharge from shallow surface aquifers provides a constant base flow. Additionally, urban non-stormwater runoff and groundwater extraction for construction dewatering or remediation of contaminated aquifers contribute to the base flow. Stream flow in the upper portion of the watershed is minimal, except during and immediately after rainfall. Flow in Calleguas Creek is described as storm peaking and is typical of smaller watersheds in coastal southern California.

Impairment Listing Information

There are 11 waterbodies included on the 303(d) impaired list for OC pesticides and PCBs, 2 for trash, 12 for nutrients, and 11 for salts (Table 1).

Table 1. 303(d) Impaired Waterbodies

Waterbody	Pollutant
Mugu Lagoon, Lower	OC Pesticides, PCB, Nutrients
Calleguas Creek, Upper	Nutrients, Chloride, TDS
Calleguas Creek, Lower	OC Pesticides, PCB, Nutrients
Camrosa Diversion	Sulfates, TDS
Revolon Slough	OC Pesticides, PCB, Trash, Nutrients, Boron, Sulfates, TDS
Beardsley Channel	OC Pesticides, PCB, Trash
Arroyo Las Posas	OC Pesticides, PCB, Nutrients, Chlorides, Sulfates, TDS
Arroyo Simi, Upper	Nutrients, Boron, Chlorides, Sulfates, TDS
Tribs to Arroyo Simi	Boron, Chlorides, Sulfates, TDS
Dry Calleguas	Nutrients
Arroyo Conejo, Upper	Nutrients
Arroyo Conejo, Lower	Nutrients
Conejo Creek	OC Pesticides, PCB
Conejo Creek, Mainstem	OC Pesticides, PCB, Chlorides, Sulfates, TDS
Conejo Creek, Hill Canyon	OC Pesticides, PCB, Chlorides, Sulfates, TDS
Arroyo Santa Rosa	OC Pesticides, PCB, Nutrients, Sulfates, TDS
Conejo Creek, North Fork	OC Pesticides, PCB, Nutrients, Sulfates, TDS
Conejo Creek, South Fork	OC Pesticides, PCB, Nutrients, Chlorides, Sulfates, TDS

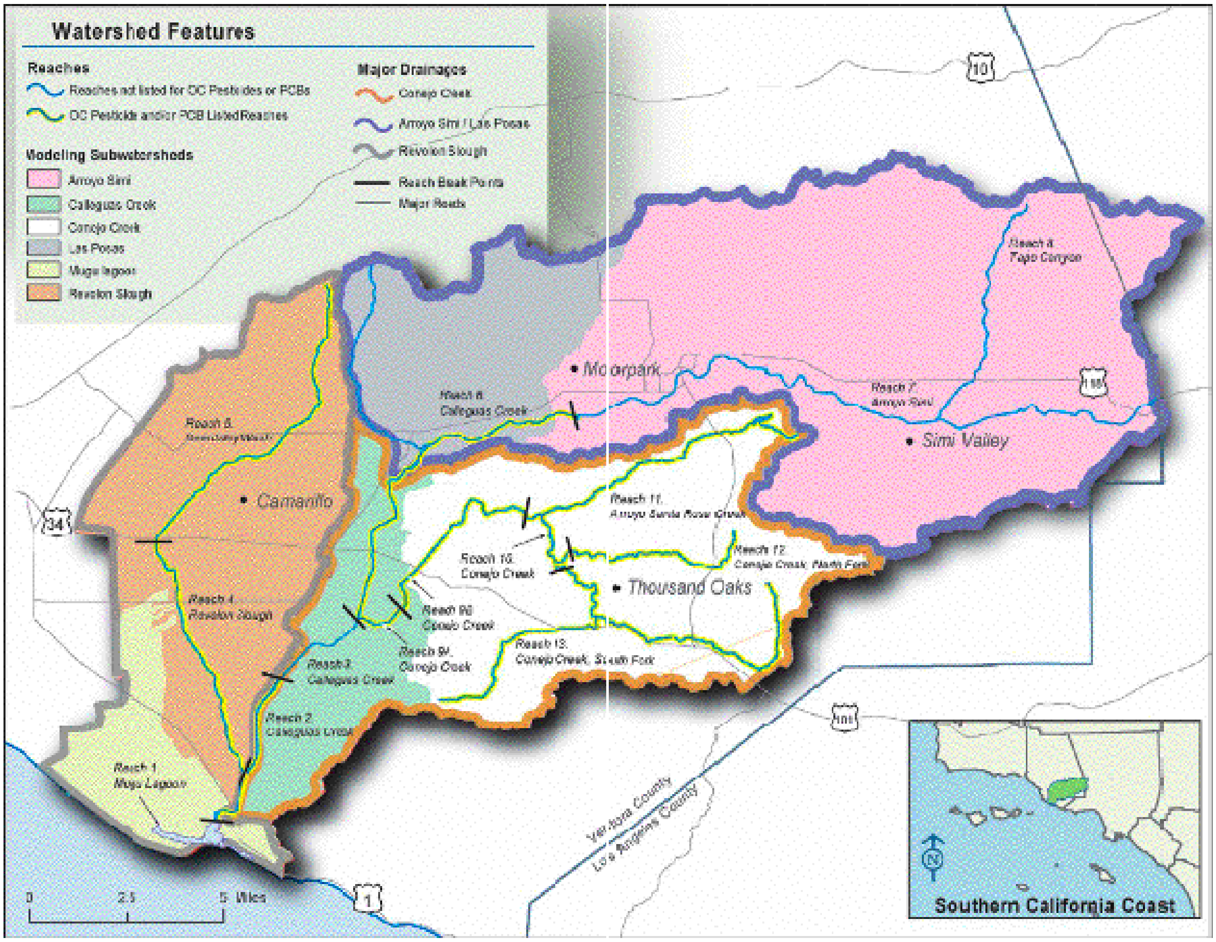


Figure 1. Map of Calleguas Creek Watershed, showing 303d listed reaches for OC pesticides and PCBs. (Source: Larry Walker Associates, 2005)

Applicable Standards and Water Quality Targets

California implements the federal water quality standard requirements by providing for the reasonable protection of designated beneficial uses through the adoption of water quality objectives (CA Water Code §13241)which may be numeric values or narrative statements. For inland surface waters in the Los Angeles Region, beneficial uses and numeric/narrative objectives are identified in the Basin Plan and additional numeric objectives for toxic pollutants are contained in the California Toxics Rule as adopted by the U.S. EPA (40 CFR 131.38).

OC Pesticides and PCBs

Numeric targets identify specific goals for the OC Pesticides and PCBs TMDL. Multiple numeric targets are often considered when there is uncertainty that a single numeric target is sufficient to ensure protection of designated beneficial uses. The 2002-303(d) list for the Calleguas Creek Watershed contains listings for OC pesticides and PCBs (OCs) in the water column, fish tissue, and sediment. In order to address these listings, water criteria, and fish tissue and sediment guidelines were selected as numeric targets (Table 2).

Table 2. Numeric targets for water, fish tissue, and sediment for OC Pesticides and PCBs (Larry Walker Associates 2005)

Constituent	Water Quality Targets[1] (ug/L)		Fish Tissue Targets[2] (ug/Kg)	Sediment Targets[3] (ug/dryKg)	
	Freshwater	Marine		Freshwater, TEL	Marine, ERL
Aldrin	3.0[4]	1.3[4]	0.050	NA	NA
Chlordane	0.0043	0.0040	8.3	4.5	0.5
Dacthal	3500[5]	NA[5]	NA[5]	NA	NA
DDD	NA	NA	45	3.5	2.0
DDE	NA	NA	32	1.4	2.2
DDT	0.001	0.001	32	NA	1.0
Dieldrin	0.056	0.0019	0.65	2.9	0.02
Endosulfan I	0.056	0.0087	65,000	NA	NA
Endosulfan II	0.056	0.0087	65,000	NA	NA
Endrin	0.036	0.0023	3200	2.7	NA
HCH (alpha-BHC)	NA	NA	1.7	NA	NA
HCH (beta-BHC)	NA	NA	6.0	NA	NA
HCH (delta-BHC)	NA	NA	NA	NA	NA
HCH (gamma-BHC)	0.95[4]	0.16[4]	8.2	0.94	NA
Heptachlor	0.0038	0.0036	2.4	NA	NA
Heptachlor Epoxide	0.0038	0.0036	1.2	0.6	NA
PCBs	0.014[6]	0.030[6]	5.3	34[7]	23[7]
Toxaphene	0.00020	0.00020	9.8	NA	NA

[1] USEPA. 2000. Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule.
May 18, 2000. The human health criteria listed are "For the Consumption of Organisms Only".
[2] Obtained from the USEPA 1980 Ambient Water Quality Criteria Documents for each constituent.
[3] Included in the list of "Chem A" pesticides.
[4] The numeric target for aldrin was derived from a combination of aldrin and dieldrin risk factors and BCFs as recommended in "Ambient Water Quality Criteria for Aldrin/Dieldrin" (USEPA 1980, 1990).
[5] Applies to the sum of all congener or isomer or homolog or Aroclor analyses.
[6] PCBs in water are measured as sum of seven Aroclors.
[7] PCBs in fish tissue and sediment are measured as sum of all congeners.
"NA" indicates that no applicable target exists for the constituent.

Trash

The target for trash is zero.

Nutrients

Multiple, nutrient related numeric targets are applicable to the CCW. Ammonia and oxidized nitrogen targets apply to all reaches of the watershed. The dissolved oxygen target applies only to the Conejo Creek system, which is the only reach listed on the 303(d) list for low dissolved oxygen. Algal biomass targets only apply to the Conejo Creek system, Revolon Slough, and Beardsley Channel, because these are the only reaches for which algae is listed on the 303(d) list. Table 3 summarizes the nutrient targets for the watershed.

Table 3. Nutrient targets for the Calleguas Creek watershed (Larry Walker Associates 2001)

Reach	30-Day average ammonia target (mg/L) [1]	1-Hour maximum ammonia target (mg/L) [1]	Nitrate-N + nitrite-N target (mg/L)	Dissolved oxygen target (mg/L)	Algal biomass target (mg/m^2 chl-a) [2]
Arroyo Simi, Upper	1.8 x WER	3.9 x WER	10		
Arroyo Simi/ Las Posas	2.7 x WER	8.4 x WER	10		
Dry Calleguas	1.0 x WER	5.7 x WER	10		
Arroyo Conejo Upper	1.7 x WER	3.2 x WER	10	Minimum 5.0	150
Arroyo Conejon, Lower	3.1 x WER	8.4 x WER	10	Minimum 5.0	150
Arroyo Santa Rosa	2.4 x WER	5.7 x WER	10		
Conejo Creek, Upper	3.3 x WER	5.7 x WER	10	Minimum 5.0	150
Conejo Creek, Lower	3.5 x WER	4.1 x WER	10	Minimum 5.0	150
Calleguas Creek, Upper	2.7 x WER	2.7 x WER	10		
Calleguas Creek, Lower	2.2 x WER	2.7 x WER	10		
Revolon Slough and Ag drains	2.5 x WER	4.9 x WER	10		150

Mugu Lagoon	2.7 x WER	2.7 x WER	10		

1 A Water Effects Ratio (WER) is a mechanism for adjusting national criteria to reflect site-specific conditions in the Calleguas Creek watershed based on monitoring conducted in the watershed. In the event a site specific WER is not developed for a given reach, the WER for that reach will be set equal to 1.0.
2 This algal biomass target has been selected from literature and is not based on local consensus as to what constitutes nuisance conditions. This target can be adjusted based on further studies and public input.

Salts

The Basin Plan numeric water quality objectives were selected as numeric targets for the salts TMDL covering boron, chloride, sulfate and TDS (Table 4). These numeric targets were applied at the base of each of the subwatersheds defined in the TMDL for allocations.

Table 4. Salts numeric targets (Larry Walker Associates 2007)

Subwatershed	Boron target (mg/L)[1]	Chloride target (mg/L)	Sulfate target (mg/L)	TDS target (mg/L)
Simi	1.0	150	250	850
Las Posas		150	250	850
Conejo		150	250	850
Camarillo		150	250	850
Pleasant Valley (Calleguas Creek Reach 3)[2]		150	250	850
Pleasant Valley (Reaches 4 and 5)[3]	1.0	150	250	850

1. The Boron target only applies to the subwatersheds containing listed reaches. The other subwatersheds do not exceed the boron objective.
2. The targets apply upstream of Potrero Road. Downstream of Potrero Road, the creek is tidally influenced and the salt objectives do not apply.
3. The targets apply upstream of Laguna Road. Downstream of Laguna Road, the creek is tidally influenced and the salt objectives do not apply.

Stakeholder Process: A Third Party TMDL

The Calleguas Creek Watershed Management Plan Committee has been active since 1996, with its initial purpose being to develop a comprehensive watershed management plan for Calleguas Creek that addresses a broad range of land use, environmental, resource management, economic, public infrastructure, recreation, and other issues. Participants on the Committee included representatives of public agencies as well as private stakeholders. In 2001, the group began discussions with the Regional Board and USEPA to provide assistance in the development of the TMDLs for the watershed, making the Calleguas Creek TMDLs some of the first third-party TMDLs to be developed and approved. In December 2002, the group developed TMDL work plans for most constituents on the 2002-303(d) list. A Watershed Management Plan subcommittee assisted with the development of the TMDLs to ensure input from local expertise and reach a broad group of stakeholders. The subcommittee also participated in development of implementation plans to resolve the water quality problems within the watershed. Stakeholders included representatives of cities, counties, water districts, sanitation districts, private property owners, agricultural organizations, and environmental groups with interests in the watershed.

As a third party TMDL, a high level of stakeholder involvement has occurred throughout the TMDL development process. There have been no interventions from outside groups, and much of the work has been performed, or paid for, by members of local government agencies with partial USEPA grant funding.

Pollutant Sources

OC Pesticides and PCBs

Most sources of pesticides and PCBs to surface waters in the CCW are related to historical uses. . Agricultural runoff is likely responsible for the majority of OC pesticides introduced into the watershed over time. Past use of PCBs as coolants and lubricants in transformers, capacitors, and other electrical equipment is suspected as the primary source of PCB residues. Available evidence suggests that POTWs, groundwater, atmospheric deposition, and imported water are not responsible for major contributions to current loading of OCs in the watershed (Larry Walker Associates 2005).

Trash

Sources of trash in Revolon Slough and Beardsley Wash include: storm drains, wind action, and direct disposal. It is estimated that 80% is due to nonpoint sources and 20% is due to point sources (CRWQCB 2007).

Nutrients

POTWs were identified as the most significant source of ammonia and TKN in the watershed. Nonpoint sources, groundwater, and atmospheric deposition did not contribute significant loads of ammonia or TKN to the creek system. For oxidized nitrogen compounds (nitrate+nitrite), POTWs are only a significant source if they have implemented nitrification treatment processes without also denitrifying. Agriculture contributes significant oxidized nitrogen loadings to the watershed, especially in Revolon Slough. Other nonpoint sources, groundwater, and atmospheric deposition contribute significantly smaller loadings of oxidized nitrogen (Larry Walker Associates 2001).

Salts

Conceptually, six possible sources of salts to the watershed exist: water supply (water imported from the State Water Project or Freeman Diversion and deep aquifer groundwater pumping), water softeners, POTW treatment chemicals, atmospheric deposition, pesticides and fertilizers, and indoor water use (chemicals, cleansers, food, etc.). These salts are then transported through POTW discharges and dry weather runoff to three possible endpoints: surface water, shallow groundwater, and/or stranded on the watershed in the soils. The salts stranded in the soils are eventually transported to surface water when precipitation mobilizes them and carries them to the creek system. Groundwater pumping and exfiltration move salts from groundwater to surface water and surface water infiltration transports salts from the surface water to groundwater. Additionally, groundwater saturation of historic marine sediments can mobilize existing background salts from previously dry soil and transport them to the groundwater. However, none of these transport mechanisms add salts, they just move salts from one endpoint to another. Salts transported in the surface water to the ocean are currently the only salts that are exported from the watershed (Larry Walker Associates 2007).

Available Data

Since the mid-1990s various studies have been conducted to assess water, sediment, and fish tissue quality in the CCW. Portions of the data collected through these studies were incorporated into the 1996,1998, and 2002 LARWQCB Water Quality Assessments to identify exceedances of water quality objectives.

Technical Approach

OC Pesticides and PCBs

Concentrations of OCs in water are primarily the result of loads from nonpoint sources and discharges from point sources. The TMDL analysis considers OC loads into and out of CCW subwatersheds, using DDE as a representative constituent. The numerical model developed for this purpose is characterized as:

- Empirical – Based on the statistics of the available data;
- Static – Simulating conditions as annual averages;
- Stream reach based – Simulating conditions in representative stream reaches; and
- Water quality based – Focused on the physical and chemical conditions in the modeled stream reaches that determine concentrations and loads of OCs in water.

Load (mass per time, L) is calculated as the product of concentration (C) and flow rate (Q):

$$L = C * Q$$

Flow rates for each land use in each subwatershed were calculated from daily mean values or water years 1990-2003 estimated by the Dynamic Calleguas Creek Modeling System, or DCCMS (LWA, 2004b). DDE concentrations from major sources to water were estimated based on the land-use runoff and discharge data.

Loads were calculated according to two different methods. First, DDE sources from land-use runoff and point source discharges to receiving water were quantified. The sum of those loads presumably represents the total load of DDE to water. Second, actual DDE loads in water from representative reaches were quantified using receiving water data presented in the Current Conditions section. These loads should mirror the loads to water, but could vary depending on the effects of in-stream processes (Larry Walker Associates 2005).

Trash

Final WLA and LA are zero trash (CRWQCB 2007).

Nutrients

Conceptual models of nutrient inputs and interactions were developed…..The assumptions and analyses used to develop the conceptual models formed the basis of the information used to develop the nutrient TMDLs. The conceptual models were used to assess potential sources of nutrients to the watershed and identify processes that impact surface water concentrations of these constituents. A spreadsheet model was used to obtain a general idea of the impacts on surface water concentrations resulting from implementation of BMPs in the watershed (Larry Walker Associates 2001).

Salts

The framework for the salts modeling effort was a numerical mass balance water quality model originally developed for use in the Calleguas Creek Nutrient TMDL effort and accepted by State and Federal regulatory authorities for use in the Nutrient TMDL process for the CCW.

The water quality simulation component of the CCMS (**acronym)** is built on a spreadsheet mass balance model. To model the CCW, the entire watershed was divided into 15 subwatersheds based on drainages to sampling locations and significant tributaries. A computational element was assigned to each subwatershed for calculating the changes in stream flow and water quality due to processes present along stream reaches circumscribed by the subwatersheds. The model was expanded to accommodate stochastic input, which allows calculation of the likely distribution of in-stream salts concentrations (Larry Walker Associates 2007).

Allocations

OC Pesticides and PCBs

Table 5. DDE Allocations

Subwatershed	Average Annual DDE Load (lbs/yr)					
	Urban	Native	Agric	POTW	GW	Total
Mugu Lagoon	0.07	-	2.79	-	-	2.9
Calleguas Creek	0.31	-	5.48	0.21	0.03	5.8
Revolon Slough	0.16	-	11.3	-	-	11.5
Arroyo Las Posas	0.09	-	6.84	0.09	-	6.9
Arroyo Simi	0.93	-	2.05	0.67	0.02	3
Conejo Creek	0.8	-	2.09	0.79	0.01	2.9
Total (lb/yr)=	2.35	-	30.55	1.76	0.06	32.9
Percent of Total	7.1%	-	92.9%	5.3%	0.2%	100.0%

Trash

Both point sources and nonpoint sources were identified as sources of trash in Revolon Slough and Beardsley Wash. For point sources, the strategy for attaining water quality standards focuses on assigning WLAs to the California Department of Transportation (Caltrans) Permittees and Co-Permittees of the Ventura County Municipal Separate Storm Sewer System (MS4) Permit, including the Ventura County Watershed Protection District, the City of Camarillo, and the City of Oxnard. The WLAs will be implemented through permit requirements. For nonpoint sources, the strategy for attaining water quality standards focuses on assigning LAs to land owners and agencies in the vicinity of Revolon Slough and Beardsley Wash, including the County of Ventura, City of Camarillo, City of Oxnard, and Agricultural entities in the Revolon Slough and Beardsley Wash subwatersheds. The LAs will be implemented through regulatory mechanisms that implement the State Board's 2004 Nonpoint Source Policy such as conditional waivers. Final WLA and LA are zero trash (CRWQCB 2007).

Nutrients

Both WLAs and LAs were expressed as concentrations, not loads. WLAs for oxidized nitrogen and ammonia were set for five of the six POTWs in the watershed. Wasteload allocations were not determined for the Olsen Road treatment plant because it was in the process of being shut down. WLAs for TKN were developed only for the two treatment plants that discharge to the Conejo Creek system, the Hill Canyon and Camarillo plants. The Camrosa plant is able to achieve all proposed nutrient WLAs with existing facilities and operations. Moorpark is currently constructing facilities that will allow compliance with the WLAs by September 2001. The Camarillo plant is able to achieve the proposed ammonia WLA with existing facilities and operations but would have to reduce oxidized nitrogen levels by about 70% to achieve the proposed WLAs for these pollutants. The Hill Canyon plant is able to achieve the proposed oxidized nitrogen and ammonia WLAs with existing facilities and operations but would have to reduce TKN levels by about 60% to achieve the TKN WLA. The Simi Valley plant would have to reduce ammonia levels by between 70% and 90% (depending on the site-specific adjustment to the ammonia criteria) to achieve the ammonia WLA and would have to reduce nitrate levels by between 40% and 70% (depending on the degree of nitrification needed to achieve the ammonia WLA) to achieve the oxidized nitrogen WLA.

Load allocations were set only for agricultural discharges of oxidized nitrogen. In the Calleguas Creek watershed, agriculture is assigned a load allocation of 10 mg/L of nitrate-N + nitrite-N. All other non-point sources of nutrients were sufficiently below the numeric target and comprised such a small portion of the total pollutant loading that they were not considered to be significant loadings and, consequently, were not assigned load allocations. Load allocations were assigned to agriculture as a category, rather than to individual dischargers. Agricultural loadings of oxidized nitrogen would require an average reduction of about 70% to meet the assigned load allocations.

Salts

The loading capacity was calculated using the average of the critical condition dry weather flow rates. The following table (Table 6) represents the current loading capacity of the stream with the percent reductions in current average loads to achieve loading capacity. However, the loading capacity will increase over time as the POTW flows increase to design flow. The loading capacity shown in the table represents all of the flow discharged to the stream. Some of this flow is removed from the stream through groundwater recharge and diversions. However, the flow is available for carrying load prior to its removal from the stream and is therefore considered in the loading capacity.

Table 6. Current salt loading capacity with the percent reductions in current average loads to achieve loading capacity.

Subwatershed	Boron loading capacity (lbs/day)	Chloride loading capacity (lbs/day)	Sulfate loading capacity (lbs/day)	TDS loading capacity (lbs/day)
Simi	117 (0%)	17,593 (0%)	29,322 (28%)	99,695 (14%)
Las Posas	131 (0%)	19,721 (0%)	32,869 (28%)	111,754 (14%)
Conejo	127 (0%)	19,073 (7%)	31,788 (0%)	108,080 (0%)
Camarillo	152 (0%)	22,756 (13%)	37,927 (0%)	128,953 (2%)
Pleasant Valley (Calleguas)	182 (0%)	27,247 (12%)	45,411 (4%)	154,398 (3%)
Pleasant Valley (Revolon)	50 (39%)	7,552 (4%)	12,586 (38%)	42,793 (15%)

Implementation

Each TMDL report includes an Implementation Plan. Implementation of the TMDLs operates within an adaptive management framework where compliance monitoring, special studies, and stakeholder interaction guide the process as it develops through time. Compliance monitoring is envisioned to generate information critical for measuring progress toward achievement of WLAs and LAs, and may suggest the need for revision of those allocations in some instances. Additionally, data from ongoing monitoring could reveal necessary adjustments to the implementation timeline and may serve to initiate reevaluation when appropriate. Special studies will increase understanding of specific conditions/processes in the watershed, allowing for more accurate prediction of results expected from various implementation efforts. Thus, adaptive management allows this TMDL to be an ongoing and dynamic process, rather than a static document.

OC Pesticides and PCBs

The Implementation Plan includes the following elements:

- Source control activities to reduce any active sources of OC pesticides and PCBs in the watershed;
- Implementation and evaluation of agricultural best management practices (BMPs) in the watershed;
- Special studies to identify sediment transport and OC content and areas where BMP implementation may be more effective.
- Monitoring for OC pesticides and PCBs in water, fish tissue, and sediment throughout the watershed.

Trash

Compliance with the TMDL is based on the Numeric Target and the Waste Load and Load Allocations, which are defined as zero trash in Revolon Slough, Beardsley Wash and their tributaries. Consequently, compliance is based on implementing a program for trash assessment and collection, or alternatively for point source dischargers, full capture devices, to attain a progressive reduction in the amount of trash in Revolon Slough, Beardsley Wash and their tributaries. Dischargers who do not implement full capture devices shall propose a program for a Minimum Frequency of Assessment and Collection (MFAC). The MFAC program is required to attain a progressive reduction in the amount of trash collected from Revolon Slough, Beardsley Wash and their tributaries through implementation of BMPs. Dischargers may implement structural or nonstructural BMPs as required to attain a progressive reduction in the amount of trash in Revolon Slough, Beardsley Wash and their tributaries (CRWQCB 2007).

Nutrients

Implementation of the TMDLs is phased to allow implementation of the ammonia TMDL first and the oxidized nitrogen and algae/dissolved oxygen TMDLs at a later date. The implementation plan includes a schedule with the dates by which wasteload allocations are to be incorporated into NPDES permits and load allocations go into effect. The implementation plan also outlines special studies that may be conducted during the implementation period to address the uncertainties in the TMDLs.

Salts

The goal of the TMDL implementation plan is to achieve a salts balance within the CCW, attain water quality standards, and protect salt-sensitive beneficial uses. Through achieving a salts balance, water quality is expected to improve and allow achievement of water quality standards.

Through achievement of a salts balance, surface water and groundwater quality within the CCW should improve because salt will no longer build-up in surface soils and groundwater basins. In addition, the implementation actions include elements to ensure the protection of sensitive beneficial uses in the CCW.

A salt balance will be achieved through the implementation of actions to:

1. Reduce the amount of salts imported into the CCW.
2. Reduce the amount of salts added to water in the CCW.
3. Transport salts down gradient and export them out of the watershed.
4. Provide protection to sensitive beneficial uses.
5. Monitor and track achievement of the salt balance and the associated impacts on water quality.

The implementation actions described in this plan represent a range of activities that could be conducted to achieve a salts balance in the watershed. The implementation plan has been developed as a phased plan to allow for a review of implemented actions to assess the impacts on the salt balance and water quality. The specific actions taken to achieve the salt balance may vary to some degree from the elements presented here based on this evaluation and future analyses of the most cost effective and beneficial mechanisms for achieving the salt balance. To the extent possible, all ideas being considered as mechanisms for implementing the TMDL have been included in the plan. Future considerations may result in other actions being implemented rather than the options presented. However, any proposed actions will be reviewed using the salt balance model to ensure the action does not adversely impact other implementation actions in the watershed or the salt balance of a downstream subwatershed.

References

California Regional Water Quality Control Board (CRWQCB). 2007. Trash Total Maximum Daily Load For Revolon Slough and Beardsley Wash in the Calleguas Creek Watershed.

Larry Walker Associates. 2007. Calleguas Creek Watershed Boron, Chloride, TDS, and Sulfate TMDL, Public Review Technical Report.

Larry Walker Associates. 2005. Calleguas Creek Watershed OC Pesticides and PCBs TMDL Technical Report.

Larry Walker Associates. 2001. Calleguas Creek Nutrient TMDLs.

Case Study 2: Gauley River TMDLs, West Virginia

Watershed TMDL at a Glance

Waterbody:
Gauley River

***Drainage Area*:**
8-digit HUC, 1,419 square miles

Parameters:
Total Iron
Dissolved Aluminum
Fecal coliform bacteria
Total selenium
pH
Biological Impairments addressed as well

Development Status:
Submitted to EPA Sept. 2007

Developed by:
West Virginia DEP

Jurisdictions:
Watershed incorporates all or portions of 8 counties

 # Impaired Segments Listed:
2006 303(d) List included 104 impaired streams

Technical Approach:
Selenium – criterion x flow
All other pollutants: Continuous Simulation - Mining Data Analysis System (MDAS)

Source Types:
NPS and PS

Background

The Gauley River watershed, in southern West Virginia encompasses approximately 1,419 square miles of mountainous, mainly forested (85.7%) lands. Other important landuses include grasslands (7%), mining (2.4%), abandoned mine lands (AML) (1.5%), and urban/residential (1.3%). The TMDLs developed for streams in the Gauley River watershed were completed in the context of significant historical TMDL activity in West Virginia. From 1997 to September 2003, the USEPA developed a series of large scale waershed TMDLs in West Virginia under the settlement of a lawsuit which resulted in a consent decree between EPA and the plaintiffs[1]. The consent decree established a rigorous schedule under which TMDLs were to be completed for the waters included on West Virginia's 1996 303(d) list. The schedule included TMDL development dates extending into March 2008. Beginning in October 2003, West Virginia took over development of the consent agreement TMDLS. Since then, all TMDLs developed for West Virginia streams have been developed by the West Virginia Department of Environmental Protection (WVDEP). The Gauley River watershed TMDLs account for a portion of the TMDLs required under the consent decree plus additional TMDLs for segments identified as impaired since the 1996 listing cycle.

Prior to October 2003, while WVDEP was assisting EPA in the development of the consent decree TMDLs, WVDEP was also working to build its own TMDL program. With the help of a TMDL stakeholder committee, the agency secured funding from the state legislature and created the TMDL section within the Division of Water and Waste Management.

The TMDL stakeholder committee consisted of 22 members with balanced interests among extractive and manufacturing industry, environmental advocates, agriculture, forestry, state and federal government, sportsmen associations, and municipalities. The committee made recommendations for WVDEP TMDL development and supported general revenue funding. For additional details please see the highlight box in Section 2 of the main document.

[1] Ohio Valley Environmental Coalition, Inc., West Virginia Highlands, et al., v. Browner et al.

Since WVDEP assumed responsibility for development of its consent decree related and other TMDLs, they have worked to enhance and broaden the applicability of the watershed TMDL development tools initially developed by EPA as a matter of necessity to facilitate development of large scale TMDL in a timely manner. They have also integrated the TMDL program into the overall watershed management program, utilizing a rotating basin monitoring framework and a 48 month TMDL development cycle. The process used to develop the TMDLs for the Gauley River watershed are typcial of all TMDLs developed for West Virginia waterbodies.

Impairment Listing Information

Based on extensive pre-TMDL monitoring conducted from July 2003 to June 2004, WV DEP refined the impairments of previous listing cycles and identified other impaired waterbodies that were not previously listed. After the 2006 listing cycle, 104 streams were included on WV's 303(d) list for impairments related to numeric criteria for fecal coliform bacteria, dissolved aluminum, total iron, total selenium, and pH. In addition, waters were also included for biological impairments.

For assessment and modeling purposes, the Gauley River watershed was divided into TMDL watersheds, major contributing streams draining directly to the Gauley mainstem for which TMDLs were to be developed. TMDL watersheds were further subdivided into subwatersheds, a more detailed delineation of smaller catchments where pollutant sources, allocations and reductions are better incorporated into permitting activities and TMDL implementation (Figure 2). The entire Gauley watershed contains 520 subwatersheds. The 15 TMDL watersheds were delineated into 447 subwatersheds containing impaired waters or contributed to impaired waters.

Applicable Standards and Water Quality Targets

Because multiple listings and parameters of concern were involved in the TMDLs for the Gauley River watershed, the array of uses, standards and applicable targets is wide. WVDEP issued a single TMDL report document that discussed the individual TMDLs separately. However, the analysis performed to develop the TMDLs for parameters and impairments that are related (e.g., iron, dissolved aluminum, pH, fecal coliform bacteria, and biological) was not done separately. For example, to account for all potential stressors affecting benthic organisms (biological impairment), it was necessary to evaluate multiple factors such as sedimentation, acidity, dissolved metals toxicity, and organic enrichment. Once the potential stressors for each biologically impaired stream were identified, one or more pollutant specific TMDLs were developed to address the biological impairment. Table 7 summarizes the applicable water quality standards and targets of each TMDL analysis.

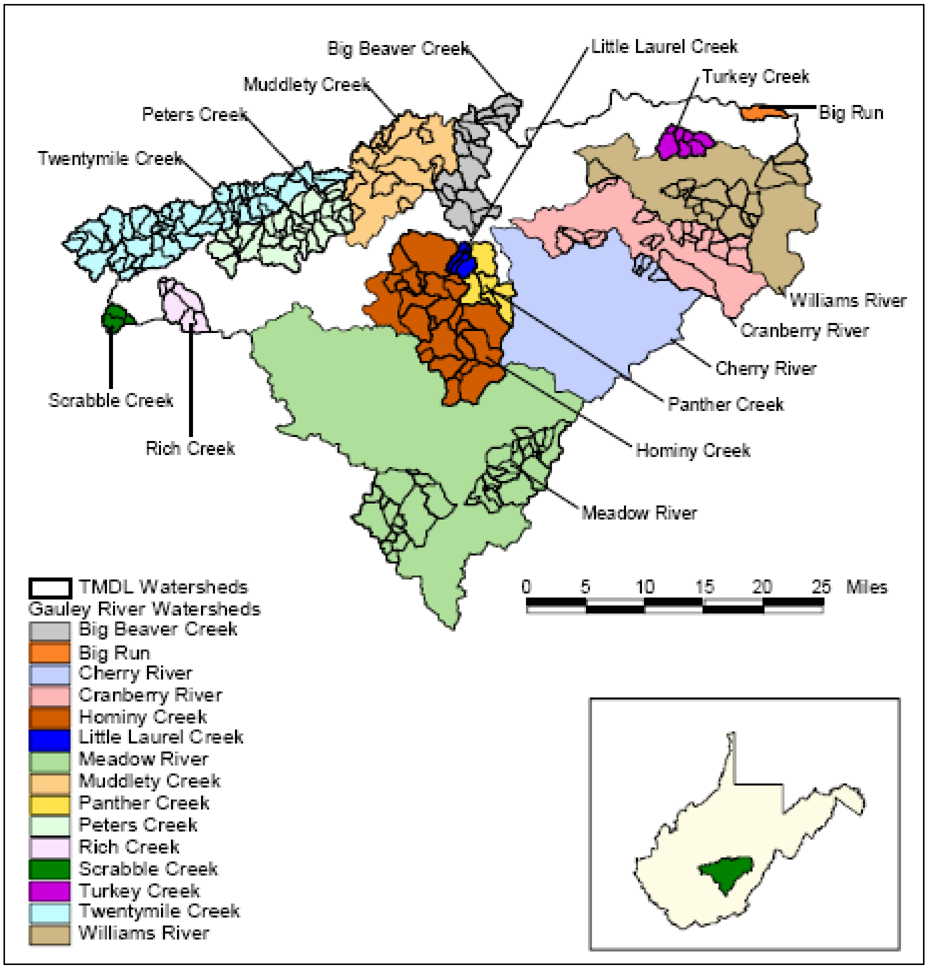


Figure 2. Gauley River watershed subbasin delineation

Table 7. Applicable Standards and Water Quality Targets

POLLUTANT	USE DESIGNATION				
	Aquatic Life				Human Health
	Wamwater Fisheries		Troutwaters		Contact Recreation/Public Water Supply
	Acute[a]	Chronic[b]	Acute[a]	Chronic[b]	
Aluminum dissolved (µg/L)	750	750	750	87	--
Iron, total (mg/L)	--	1.5	--	0.5	1.5
Selenium, total (µg/L)	20	5	20	5	10
pH	6.0 to 9.0	6.0 to 9.0	6.0 to 9.0	6.0 to 9.0	6.0 to 9.0
Fecal coiform bacteria	**Human Health Criteria** Maximum allowable level of fecal coliform content for Primary Contact Recreation (MPN or MF) shall not exceed 200/100 mL as a monthly geometric mean based on not less than 5 samples per month; nor to exceed 400/100 mL in more than 10 percent of all samples taken during the month.				

[a] One hour average concentration not to be exceeded more than once every 3 years on the average
[b] Four-day average concentration not to be exceeded more than once every 3 years on the average

Pollutant Sources

As one might expect for such a large watershed, with the exception of selenium, pollutant sources include both point and nonpoint sources. Hughes Fork of Bells Creek in the Twentymile Creek TMDL watershed, was the only impaired reach listed for selenium. The listing was based on WVDEP collected data during the pre-TMDL monitoring period for two violations of the chronic aquatic life criterion. Given the high selenium content of coals in the region, the prevalence of mining activity and the association of selenium mobilization from surface disturbance activities, it was deemed that the only source of selenium is from mining activities in the watershed. Therefore the TMDL assigned WLAs to all mining permits in the watershed, applying the water quality criteria as end of pipe concentrations. For the other impairments, bacteria, metals, pH and biological impairments, source assessments found that both point and nonpoint sources attributed to impairments. Generally, pollutant sources included mine drainage from active sites and abandoned mine lands, untreated sewage and sediment.

To assess the biological impaired streams, a stressor identification process was applied. Sources of biological stressors are often analogous to those already described: mine drainage, untreated sewage, and sediment. The general stressor identification process involved reviewing available information, forming and analyzing possible stressor scenarios, and implicating causative stressors. Candidate causes of biological stresses included metals contamination, acidity (low pH), high sulfates and increased ionic strength, increased TSS and erosion, altered hydrology, algal growth (food supply shifts), ammonia toxicity, and chemical spills. Ultimately, metals toxicity, pH toxicity, ionic toxicity, sedimentation and organic enrichment were implicated as stressors responsible for the biological impairment listings. TMDLs were developed for all except the ionic toxicity listings, for which adequate data were not available for TMDL development. Those listings were retained on WV's 303(d) list for future assessment.

Waters identified with metals and pH toxicity also demonstrated exceedences of iron, aluminum or pH criteria. WVDEP determined that implementation of those TMDLs would address the biological impairments. Waters identified with organic enrichment stressors also demonstrated exceedences of fecal coliform criteria; WVDEP determined that implementation of the bacteria TMDLs would address those impairments.

The stressor identification process indicated sedimentation as a causative stressor for four biologically impaired streams. WVDEP initially pursued the development of TMDLs directly for sediment for those streams. The approach involved selection of a reference stream with an unimpaired biological condition, prediction of the sediment loading present in the reference stream, and use of the area-normalized sediment loading of the reference stream as the TMDL endpoint for sediment-impaired waters. Additionally, all of the sediment-impaired waters also were impaired pursuant to total iron water quality criteria and the TMDL assessment for iron included representation and allocation of iron loadings associated with sediment. In each stream, the sediment loading reduction necessary for attainment of water quality criteria for iron exceeds that which would be necessary under the reference approach. As such, the iron TMDLs were deemed an acceptable surrogate for biological impairments from sedimentation.

Technical Approach

To address the selenium impairment, WVDEP used a simple calculation of the assimilative capacity for selenium available at the mouth of Hughes Fork (the only stream impaired by selenium) at 7Q10 flow. WLAs for contributing sources are based on achieving the chronic aquatic life criterion in the discharge.

Additional impairments for which TMDLs were developed were addressed using a modeling application, the Mining Data Analysis System (MDAS) that was originally developed by EPA Region III to complete several early consent decree TMDLs that necessitated analysis of large scale, data intensive analyses. Since WVDEP began developing their own TMDLs in 2003, they have continued to apply the MDAS system, supporting development of additional capabilities as the needs of the TMDL program have required. MDAS allowed for a performing a continuous simulation of loading in the watershed, predicting both loads and in-stream concentrations, and representation of all major pollutant sources. With customization, the watershed model was used to represent critical processes and factors associated with evaluating compliance with water quality critieria such as frequency and duration of exceedences. Key technical factors associated with developing TMDLs for the Gauley River and accommodated by the model include:

- Large scale analysis,
- Point and nonpoint sources,
- Temporally and flow variable metals and bacteria impairments,
- pH related impairments,
- Time-variable landuse practices and their impacts on water quality,
- Variable and weather-dependant transport mechanisms for metals and bacteria.

From the data analysis, it was determined that separate processes may be contributing to pH impairments in the watershed, either historical mining related metals discharges or acid deposition (wet and dry) in conjunction with low watershed buffering capacity. MDAS was enhanced with new simulation modules to more explicitly simulate the processes associated with both sources of pH impairments. For details on the model and specific processes represented, please see the Gauley River Watershed TMDL Report and its supporting technical report and appendices (West Virginia DEP, 2007).

Allocations

Generally, WV's water quality critieria and an explicit margin of safety were used to identify endpoints for the TMDLs and associated allocations. An implicit MOS was included in the selenium TMDL, where WLAs were prescribed for the surface mining point sources at water quality criteria at the end-of-pipe.

Except for selenium, the TMDLs are presented as average annual loads because they were developed to meet TMDL endpoints under a range of conditions observed throughout the year. Analysis of available data indicated that critical conditions occur during both high- and low-flow events; the TMDLs were therefore developed using continuous simulation (modeling over a period of several years that captured precipitation extremes), which inherently considers seasonal hydrologic and source loading variability. Equivalent, daily average TMDLs are also presented.

The selenium TMDL is presented as an equation for the maximum daily load that is variable with receiving stream flow. For pH impairments associated with atmospheric deposition, TMDLs are presented as the annual net acidity load associated with maintenance of the pH TMDL endpoint of 6.02.

The allocation process applied a "top-down' methodology, where headwaters were first analyzed because of their impacts on downstream water quality. Load contributions were reduced from applicable sources and the TMDLs were identified. The loading contributions of unimpaired headwaters and the reduced loadings for impaired headwaters were then routed through downstream waterbodies. Using this method, contributions from all sources were weighted equitably. Reductions in sources affecting impaired headwaters ultimately led to improvements downstream and effectively decreased necessary loading reductions from downstream sources. Nonpoint source reductions did not result in loadings less than natural conditions, and point source allocations were not more stringent than numeric water quality criteria.

Critical source categories receiving allocations for each TMDL are summarized in Table 8. Due to the level of detail at which source allocations were determined, WVDEP presented summary allocation tables for LAs and WLAs in the TMDL document. For detailed, source-specific allocations by subbasin, WVDEP also developed spreadsheet tables in Microsoft Excel to assist in implementation efforts.

Table 8. Allocated Sources for the Gauley River Watershed TMDLs

TMDL	Sources receiving LAs	Sources receiving WLAs
Dissolved Aluminum Total Iron	Abandoned mine lands (disturbed land, highwalls, deep mine discharges and seeps) Bond forfeiture sites (unreclaimed mine areas) Sediment associated landuses (barren land, harvested forest, oil and gas well operations, unpaved roads, streambank erosion)	Active mining operations Non-mining point sources (e.g., industrial stormwater) Construction stormwater Future growth construction stormwater
Fecal coliform	Pasture/Grass areas Onsite Sewage Treatment Systems [a] Residential areas Background and Other NPS (wildlife) [b]	NPDES permitted facilities (e.g., STPs)
pH	Atmospheric deposition	NA
Selenium	NA	Active mining operations

[a] illegal discharges such as those from failing septic systems and straight pipes as well as sanitary sewer overflows received zero allocations
[b] received no reductions

Implementation

Because of the prevalence of mining related permits in the watershed, the WLAs assigned to those facilities represent the results of what is in fact a watershed-based permitting analysis. Individual WLAs were presented in terms of both load and concentration. The concentration-based WLAs were prescribed as the operable term since the TMDL allocations reflected pollutant loadings that are necessary to achieve water quality criteria at distinct locations (i.e., the pour points of delineated subwatersheds). In contrast, effluent limitation development in the permitting process is based on the achievement/maintenance of water quality criteria at the point of discharge. Future permits are not precluded in impaired watersheds and will be assigned end-of-pipe limits at applicable water quality criteria. For aluminum, where the criterion relates to the dissolved portion of the metal, an appropriate total to dissolved translator must be applied. In many cases, the implementation of the TMDLs for fecal coliform will consist of providing public sewer service to unsewered areas.

With regard to water quality trading to implement TMDL allocations, the TMDL neither prohibits nor authorizes trading in the watersheds addressed in the document. According to the TMDL document:

> "WVDEP generally endorses the concept of trading and recognizes that it might become an effective tool for TMDL implementation. However, significant regulatory framework development is necessary before large-scale trading in West Virginia can be realized. Furthermore, WVDEP supports program development assisted by a consensus-based stakeholder process. Before the development of a formal trading program, it is conceivable that the regulation of specific point source-to-point source trading might be feasible under the framework."

As part of the permit review process, permit writers must incorporate the required TMDL WLAs into new or reissued permits. Both the permitting and TMDL development processes have been synchronized with the Watershed Management Framework cycle, such that TMDLs are completed just before the permit expiration/reissuance timeframes. Existing permit reissuance in the Gauley watershed is scheduled to begin in July 2007 for non-mining facilities and in January 2008 for mining facilities. Therefore, the WLAs for existing activities will be promptly implemented. New facilities will be permitted in accordance with future growth provisions.

WVDEP uses a geographically based approach to manage water resources - the Watershed Management Framework. WVDEP uses the Framework to organize and prioritize activities associated with monitoring and TMDL development and implementation. Each year, TMDLs are developed in specific geographic areas according to the schedule and priorities mapped out in the Framework. In addition to scheduling and developing TMDLs, the Framework includes a schedule for TMDL implementation.

The Framework provides a six-step process for developing integrated management strategies (monitoring, TMDLs, implementation through permitting, grants, etc.), and action plans for achieving the state's water quality goals. Step 3 of the process involves identification of strategies needed to meet needed pollutant reductions (TMDLS). Steps 5 and 6 provide for preparation, finalization and implementation of a Watershed Based Plan to improve water quality. These plans are based on the efforts of locally based watershed teams composed of members of the West Virginia Watershed Network.

The West Virginia Watershed Network is an informal association of state and federal agencies, and nonprofit groups promoting watershed management in the state. On an annual basis, the Network evaluates WVDEP's Watershed Management Framework to coordinate and prioritize its existing programs, local watershed associations and limited resources. The evaluation includes a review of TMDL recommendations for watersheds under consideration. Formation of local teams and development of Watershed Based Plans is assisted by WVDEP's Nonpoint Source Program.

Lessons Learned: Developing Watershed TMDLs in the Real World[2]

WV has chosen to continue the precedent set by the early consent decree TMDLs of large-scale analysis because it allows for a more coordinated response to water quality issues both in terms of collecting data, analyzing pollutant sources (modeling), and implementing solutions. Critical lessons learned by the program are summarized below.

- **Pre-TMDL monitoring and pollutant source tracking is important not only for adequately representing sources but for achieving programmatic efficiency.** WVDEP strategically plans water quality monitoring prior to TMDL development where numerous monitoring locations are established and a comprehensive suite of analytes are sampled. This fine scale monitoring resolution coupled with identification and characterization of problematic sources through field-based source tracking activities provides a sound basis for assessment and TMDL development for all streams and impairments within the watershed. This watershed based approach allows WVDEP to maximize efficiency throughout all phases of TMDL development and thereby minimizing funding requirements of their TMDL program.

- **Large scale, highly detailed modeling facilitates efficiency and permit coordination.** As noted above, the comprehensive watershed based approach employed by WVDEP, typically includes all known impairments in the watershed. This involves a multi-faceted modeling approach to address total recoverable metals, dissolved metals, acidity (pH), bacteria, and biological impairments. WVDEP has created unique ways to integrate large-scale, watershed based TMDLs with fine-scale, highly technical methodologies that produce "implementable" TMDLs in cost-effective manner. Over time, this has led to WVDEP utilizing predicted model output in absence of water quality data to identify waters as threatened and present "modeled impairment TMDLs".

- **Highly detailed, source specific allocations must be verified in reality.** Typically when large scale TMDLs are developed, allocations are presented across broad categories that can often "hide" pollutant sources allowing for significant interpretation for implementation. However, presenting highly detailed, source specific allocations forces the need to assess the practicality of implementation and management objectives – a process that can be very complex and labor intensive.

- **Large scale modeling facilitates permit coordination.** Based on the history of TMDLs in WV, where large watersheds have been involved, with literally hundreds of point source discharges, WV has realized the importance of synchronizing the permitting and TMDL development processes. In effect, all TMDLs in the state are essentially, watershed-based permits. The permitting mechanism relies on issuance of individual permits to facilities but provisions of applicable TMDLs are incorporated.

[2] Special thanks to Dave Montali, TMDL Program Manager, WVDEP

- **Developing user-friendly TMDL end products provides sound basis for implementation guidance.** WVDEP has designed a "TMDL on CD" concept where all relevant TMDL information (TMDL Reports and Appendices, Technical documentation, and supporting data) is included on a CD-ROM. To further improve the "usability" of the TMDLs, WVDEP developed a series of interactive tools to provide TMDL implementation guidance. These tools are designed to simplify and assist "implementers" (nonpoint source staff and permit writers) in using the TMDLs to develop watershed plans and issue/renew permits. An interactive ArcExplorer geographic information system (GIS) project allows the user to explore the spatial relationships of the source assessment data, as well as further details related to the data. Users are also able to "zoom in" on streams and other features of interest. In addition, spreadsheet tools (in Microsoft Excel format) were developed to provide the data used during the TMDL development process, and the detailed source allocations associated with successful TMDL scenarios. These tools provide guidance for selection of implementation projects as well as for permit issuance and are also included on the TMDL Project CD.

- **Continual improvement – a key to success.** As WVDEP's TMDL program continues to evolve, focus is placed on refining all facets of TMDL development. Over the past 5 years, significant improvements have been made in pollutant source tracking and data transfer from WVDEP to their TMDL development contractor, where spreadsheet tools and databases have been developed to specifically address issues that have been previously encountered. Furthermore, WVDEP continually attempts to improve upon programmatic issues as feedback is provided from stakeholders and interagency personnel.

References

West Virginia DEP, 2007. Total Maximum Daily Loads for Selected Streams in the Gauley River Watershed, West Virginia. September 2007. Prepared by Tetra Tech, Inc., Charleston, WV.

West Virginia DEP, 2007. Total Maximum Daily Loads for Streams in the Gauley River Watershed, West Virginia. FINAL TECHNICAL REPORT, September 2007. Prepared by Tetra Tech, Inc., Charleston, WV.

Case Study 3: Long Island Sound Nitrogen TMDL

Watershed TMDL at a Glance

Waterbody:
Long Island Sound

Area:
16,000 square miles

Parameters:
Nitrogen

Year Developed/Approved:
2001

Developed by:
Connecticut Department of Environmental Protection (CDEP) and New York State Department of Environmental Conservation (NYDEC)

Impaired Segments Addressed:
Long Island Sound in its entirety; TMDL addresses all sources of Nitrogen to the sound

Jurisdictions:
Watershed includes most of Connecticut, portions of Massachusetts, New Hampshire, Vermont, a small area in Canada, as well as portions of New York City, and Westchester, Nassau, and Suffolk Counties in New York.

Technical Approach:
Developed and applied a linked circulation and water quality model (LIS 3.0) to simulate hypoxia in Long Island Sound
Incoming loads were represented based on a variety of data.
Nonpoint source loads: atmospheric monitoring data, landuse specific export coefficients based on literature and calibrated to monitoring data
Point source loads: point source monitoring data

Source Types:
Point and Nonpoint

Background

The watershed of Long Island Sound (LIS) drains an area over 16,000 square miles, covering most of Connecticut, portions of Massachusetts, New Hampshire, Vermont, a small area in Canada, as well as portions of New York City, and Westchester, Nassau, and Suffolk Counties in New York. The Sound itself is about 1300 square miles, measuring about 100 miles long and 21 miles at its widest point. Depths in the middle of the Sound range from 60-120 feet. It is one of the most highly urbanized and suburbanized areas on the eastern seaboard.

Hypoxia has for sometime been a common occurrence in the bottom waters of Long Island Sound, usually occurring in the late summer months of July through September. It is linked to excess nitrogen and is exacerbated by the naturally occurring density stratification of the water column. Resulting algal blooms and anoxic conditions contribute to insufficient habitat for submerged aquatic vegetation and overall impairment of the health and functioning of the Sound. Due to the complexity of the problem and the cost magnitude of potential remedies, it was understood from an early point that new, flexible approaches would be needed to address and implement solutions to the hypoxia issue.

Applicable Standards

In neither New York nor Connecticut, were there numeric criteria for nitrogen. The LISS determined however that reducing nitrogen loads necessary to achieve water quality standards for dissolved oxygen (DO) would protect and maintain designated uses in the Sound. In both cases, DO standards for saline (New York) and coastal/marine waters (CT) were used (Table 9).

Table 9. DO criteria for Long Island Sound

Class	Description	DO Criterion	State
SA	Marketable shellfishing, recreation, fishing	Not less than 5.0 mg/L	NY
SB	Recreation and fishing	Not less than 5.0 mg/L	NY
SC	Fishing (must be suitable for fish propagation and survival)	Not less than 5.0 mg/L	NY
I	Secondary contact recreation and fishing	Not less than 4.0 mg/L	NY
SD	Fishing (must be suitable for fish survival)	Not less than 3.0 mg/L	NY
SA	Marine fish, shellfish and wildlife habitat, shellfish harvesting for human consumption, recreation	Not less than 6.0 mg/L	CT
SB	Marine fish, shellfish and wildlife habitat, shellfish harvesting for transfer to depuration, recreation, industrial and other such as navigation	Not less than 5.0 mg/L	CT

Pollutant Sources

Nitrogen is provided by multiple sources, which enter through tributary inputs, the two ocean boundaries and by atmospheric deposition. Nonpoint sources include traditional land-based runoff such as from agricultural and developed land areas. Point sources include over 80 treatment plants. Additionally, CSOs and stormwater discharges also provide significant loading to the Sound. Given the geographic scale of the Long Island Sound TMDL and the land use based approach used to estimate loadings, it was not feasible to meaningfully separate loadings from point source stormwater runoff and CSOs from the general nonpoint source categories, with the exception of the New York City CSO loads. As a result, these loads were considered nonpoint sources for the TMDL.

Available Data

Beginning in 1985, New York, Connecticut and the EPA formed the Long Island Sound Study (LISS) to promote measurable improvements to the water quality of the Sound. Intensive water quality monitoring of the Sound was conducted from April 1988 to September 1989. Over 25 constituents were monitored, including transparency, salinity, temperature, nutrients and their forms, chlorophyll *a*, DO, BOD, total organic carbon, and suspended solids. CTDEP expanded on this monitoring to include monthly sampling at 18 stations with expansion to 30 additional stations in the summer months. Data from NYCDEP's Harbor Survey (16 stations) were used as well. Additionally, the Interstate Sanitation Commission has collected weekly surveys in the Narrows and western basin during summer months (21 stations) for which temperature, salinity, and DO at multiple levels is measured. Several citizens monitoring programs also made data available to the effort.

Watershed loads were estimated from various data sources. Categories of loading data evaluated included point source related data and nonpoint source data. The bulk of nitrogen loading was determined to be due to point source contributions. CTDEP and NYSDEC collected NPDES discharge monitoring data (flow and effluent quality) from the major municipal and industrial dischargers in the drainage area. CSO data (for New York City) were used in determining incoming loads; while CSO related loads (and other stormwater and landuse related loads) for CT and the rest of the contributing area were estimated using landuse specific export coefficients. Additionally, attenuation in rivers was estimated based on flow data and other information. Atmospheric deposition was estimated based on wet deposition monitoring data.

TMDL Development Approach

In 1994, the LISS completed what is known as a Comprehensive Conservation and Management Plan (CCMP) under the EPA's National Estuary Program. The CCMP for Long Island Sound identified seven priority issues for the Sound, the highest of which was low dissolved oxygen levels in the Sound. By 1998, the LISS CCMP adopted a 58.5 percent reduction target for nitrogen loads to the Sound and specified in its implementation plan that a TMDL for nitrogen be adopted with load and waste load allocations for all sources in the watershed. As a result, the states of New York and Connecticut jointly submitted a TMDL for nitrogen which was approved by EPA in 2001.

Partner Coordination and Stakeholder Involvement

The states were primarily responsible for writing and submitting the TMDL for EPA approval. However, in this case, the LISS partnership provided the bulk of the technical support, including water quality modeling, which provided the scientific underpinning for the TMDL. Although the TMDL is clearly identified as a CT and NY product, there was a lot of effort on the part of EPA Long Island Sound Office and a very comprehensive public process providing input and comment that went well beyond the LISS partnership.

Technical Approach – Linking Sources and Water Quality

A three-dimensional, time-variable hydrodynamic/water quality model (LIS 3.0) of Long Island Sound was developed to simulate hypoxia conditions in the Sound. The model incorporates advanced physical, biological and chemical processes that in turn relate nutrients and carbon-based pollutants to phytoplankton dynamics and DO. The model was calibrated with extensive monitoring data collected as part of the LISS. Boundary conditions for the model were established based on analysis of various types of data related to nutrient loading from the contributing area.

The LIS 3.0 model was calibrated using 18-months of ambient monitoring data (April 1988 through September 1989). Tributary loadings and CSO contributions to the model were determined using time-variable rainfall and flow data. The calibrated model was reviewed by the LISS Modeling Evaluation Group and approved as being appropriate for use as a predictive tool. It was then applied to TMDL development.

Based on model results, it was demonstrated that nitrogen loadings throughout the year contribute to the pool of nitrogen available for phytoplankton uptake and therefore, long-term annual loading controls rather than seasonal or shorter term limits are warranted.

Allocations

For purposes of implementation, the LIS TMDL distinguishes between in-basin and out-of-basin sources. In basin sources are those originating from within the CT and NY portions of the drainage basin including those directly deposited to the Sound's surface. Out-of-basin sources are all other sources beyond the in-basin boundaries. Both the in- and out-of-basin sources were also further subdivided into a pre-colonial load and a human induced load. The pre-colonial condition estimates what natural loading may have been. Both the in-basin and out-of-basin loads are made up of various sources such as wastewater treatment facilities, nonpoint runoff, CSOs and atmospheric deposition. Atmospheric deposition was accounted for in the geographic category in which it is deposited. Table 10 provides a summary of what sources were considered under either the Load or Wasteload Allocation portion of the TMDL. Because CT and NY cannot enforce nitrogen reductions from point and atmospheric sources in other states, specific WLAs for facilities contributing to out-of-basin loads were not identified in the TMDL.

Table 10. Sources considered under WLA and LA portions of the TMDL

In-basin		Out-of-basin	
WLAs	WWTPs	WLAs	None There was a gross 25% WLA recommended for out of basin sources. EPA Region I is treating that as a binding WLA.
	CSOs (NY)		
LAs	Pre-colonial	LAs	Pre-colonial
	Terrestrial[a]		Tributary Loads [b]
	Atmospheric		Boundary Loads [c]

[a] includes CSOs in CT as well as stormwater contributions
[b] Include contributions from groundwater, overland runoff, atmospheric deposition, CSOs and WWTP discharges in Massachusetts, Vermont and New Hampshire
[c] from Atlantic Ocean and New York Harbor

Note that with the exception of New York City CSOs, for which monitoring data were available to characterize loading quantities, nitrogen loads from stormwater runoff and CSOs (in CT) were given load allocations. The TMDL states that “development of the phase II stormwater permitting program over the next few years will provide opportunities for the states to elucidate the load from stormwater sources and, building on the phase II regulations, identify appropriate wasteload allocations.”

Implementation

The TMDL is designed to be implemented in phases. Phase III represents achieving a 58.5% reduction from in-basin sources within a 15-year time frame (beginning August 1999) with five-year incremental targets. 100% of the 58.5% reduction is to be met by 2014. However, Phase III reductions are not enough to meet the necessary reductions for attaining water quality criteria. The entire TMDL is the sum of the Phase III reductions (58.5% of in-basin sources), reductions from outside the basin, and application on non-treatment alternatives necessary to meet water quality standards for DO with an implicit margin of safety.

TMDL = 58.5 % in-basin reduction + out-of-basin reductions + non-treatment alternatives + margin of safety

Phases IV and V address action necessary to meet out-of-basin reductions and non-treatment alternatives.

Significant implementation activities under Phase III have involved the development of a general permit for nitrogen discharges in CT covering all 79 of the state’s WWTPs as well as a nitrogen credit exchange program. Each year the permit specifies an annual statewide aggregate target for nitrogen removal as new upgrades are brought online. It also sets annual end-of-pipe limits in pounds per day of TN, apportioned by plant discharge volume to meet the aggregate statewide target. Under the permit, facilities can purchase or sell nitrogen credits annually based on the facilities’ performance with respect to their annual limit. According to state program staff, development of the trading program was a considerable effort, but has paid dividends in terms of rate of implementation, and cost efficiency.

CT has also seen some cross-program implementation successes in focusing stormwater permitting towards nitrogen control, and emphasizing nitrogen controls in Sec. 319 nonpoint source program. In terms of impacting atmospheric sources, the TMDL has resulted in pushing atmospheric controls forward, particularly through NOx reduction goals established within the New England Governors and Eastern Canadian Premiers “Acid Rain Action Plan”.

Monitoring

Significant resources have been devoted to post TMDL monitoring including additional atmospheric deposition monitoring to better characterize the relative importance of that source to overall loading to the Sound. Land based contribution estimates were also refined through the development of an HSPF watershed model of the drainage basin in Connecticut. Watershed modeling was used to improve understanding of how nitrogen is attenuated in the watershed and is especially relevant to implementation efforts related to BMPs as well as to understanding acceptable trading ratios between point source trading partners.

Lessons Learned: Developing Watershed TMDLs in the Real World[3]

Ultimately, the desirability of developing a watershed TMDL for LIS included technical, environmental, political and programmatic reasons. Technical and environmental, as discussed above, but also political because the impairment cannot be corrected unilaterally by one state. And, each state recognized that their efforts alone wouldn't be sufficient to do the job so there had to be assurance that both CT and NY would proceed equally. Other contributing state reductions are currently under more scrutiny and will be subject of next year's (expected 2009) revised TMDL to provide a more complete and comprehensive plan, building on the recommendations of the current TMDL. Among the reasons for revising the TMDL are a new Systemwide Eutrophication Model (SWEM) as well as new state DO criteria (http://www.ct.gov/dep/lib/dep/water/water_quality_standardsl/wqs.pdf).

Facilitation of complex technical evaluation

One of the primary technical advantages of having developed the LIS TMDL on a watershed scale was having the support of EPA and the LISS to assist with the technical evaluations. According to the state TMDL program, the complex technical evaluations necessary for the LIS TMDL would not likely have been accomplished as well if the states were working independently on the problem. Programmatically, having both states on board and implementing the same level of reduction in both states minimized "finger pointing".

Dealing with obstacles

While there were advantages associated with developing the TMDL on the watershed scale, difficulties and frustrations were also encountered during the process including the sheer magnitude of work necessary to understand the problem and the length of time required to work through the process as well as difficulties associated with navigation of interstate and multimedia issues.

According to state program staff familiar with the LIS TMDL, the magnitude of the required scientific understanding required to understand what needs to be done to restore LIS was probably the biggest obstacle. Costs were high in terms of both time and money. The LISS highlighted hypoxia as a primary water quality issue, supported monitoring and research, and was instrumental in the modeling required to develop a credible and defensible management plan, i.e., the TMDL. It took from 1985 until 2001 for the TMDL to be developed and adopted. Interim plans were developed during that time, but the fact that it took 15 years of work from discovery of hypoxia to a final management plan reflects the complexity of the problem as well as the implementation intricacies of all the negotiations over who does what and to what degree. In addition, input from the regulated community and the public had to be considered. Connecticut began engaging the regulated community, especially municipalities with sewage treatment plants, as early as the late 1980's, and kept them informed about their potential role in solving the problem.

Implementing multimedia and multi-jurisdictional controls

Another significant issue has been trying to impact air emissions through a TMDL, which has no binding on air programs. Better multimedia coordination among EPA's air and water programs has been cited as being needed to fully implement the air deposition reductions that are identified in the TMDL. Additionally, strong EPA support in engaging upstream states with respect to multijurisdictional issues is also necessary for ensuring progress toward the TMDL. For example, a strong EPA voice in the TMDL process can facilitate getting monitoring requirements for out of state sources.

[3] Special thanks to Paul Stacey, Director of Planning and Standards in the Bureau of Water Protection and Land Reuse of CT DEP

References

CTDEP and NYDEC, 2000. A Total Maximum Daily Load Analysis to Achieve Water Quality Standards for Dissolved Oxygen in Long Island Sound.

EPA, 2003. Watershed-Based Permitting Case Study: Final Permit, General Permit for Nitrogen Discharges (Long Island Sound). Fact Sheet #1. (http://www.epa.gov/npdes/pubs/wq_casestudy_factsht1.pdf)

EPA, 2007. Water Quality Trading Toolkit for Permit Writers: Appendix A, Water Quality Trading Program Fact Sheets. pp. A-13 – A-26.

Case Study 4: Lower Fox River Basin and Green Bay, Wisconsin

Watershed TMDL at a Glance

Waterbody:
Lower Fox River (LFR Basin)

***Drainage Area*:**
638 square miles

Parameters:
Phosphorus
Total Suspended Solids (TSS)

Development Status:
Currently in the workplanning and stakeholder engagement process. Next phase will be TMDL development; Draft TMDL due Spring 2009

Developed by:
Wisconsin Department of Natural Resources (TMDL)
Oneida Nation (Watershed Management Plan)

Jurisdictions:
Portions of Brown, Calumet, Outagamie, and Winnebago Counties as well as most of the Oneida Nation Reservation.

***Impaired Segments Listed***:
24 Segments listed as impaired for phosphorus or sediment

Technical Approach:
Undetermined but will likely utilize the existing technical tools already developed for the area such as the Lower Fox River SWAT watershed model, and an optimization model used to evaluate the cost effectiveness of multiple implementation scenarios.

Source Types:
NPS and PS

Background

The Lower Fox River Basin and Green Bay are important environmental and economic resources for the State of Wisconsin and the local community. People have long used the river and bay for transportation, commerce, energy, food, and recreation. Situated on one of the major bird migration routes in North America, the Mississippi flyway, the Lower Fox River and Green Bay environment provides essential habitat for breeding and migratory birds. The terrestrial, wetland, and aquatic habitats in the basin support a wide diversity of songbirds, shorebirds, waterfowl, and birds of prey.

The river and bay also support a nationally known fishery. Green Bay is the largest freshwater estuary in the world; the bay itself is an inflow to Lake Michigan. The wetlands along Green Bay's west shore, as well as the wetlands lining the Lower Fox River that flows into Green Bay, provide critical fish spawning habitat for perch, northern, walleye and the elusive spotted musky. The natural resources of the Lower Fox River Basin and Green Bay are critical to tourism and the local economy. The river and bay support popular recreational activities such as hiking, boating, fishing, snowmobiling, cross-country skiing, and ice fishing. Many local and state parks and wildlife areas are scattered throughout the basin. These areas provide opportunities to enjoy camping, trails, and hunting, and passive nature observation.

The Lower Fox River Basin encompasses approximately 638 square miles in northeastern Wisconsin (Figure 3). Portions of several counties and most of the Onieda Nation Reservation lie within the drainage area. The lower portion of the watershed is designated as an Area of Concern (AOC) under the Great Lakes Water Quality Agreement between the United States and Canada. The AOC consists of the lower 6.9 miles of the Fox River below DePere Dam and a 21 square mile area of southern Green Bay out to Point au Sable and Long Tail Point. In addition to the AOC, the rest of the drainage area of the Lower Fox River Basin contains streams that have been identified on Wisconsin's 303(d) list as impaired by phosphorus and/or sediment due to various sources. As a result of the phosphorus and sediment loading to the River and Lower Green Bay, excess aquatic algal growth contributes to severe depletion of oxygen levels in the waterbodies of the Basin and the Bay, impacting fish and other aquatic life. Sediment also decreases the availability of light to support submerged vegetation which in turn provides habitat and food sources for fish, birds, frogs, turtles, insects and other wildlife. Submerged vegetation also plays an important role in producing oxygen, stabilizing bottom and shoreline sediments, and taking up nutrients that would otherwise support nuisance algae.

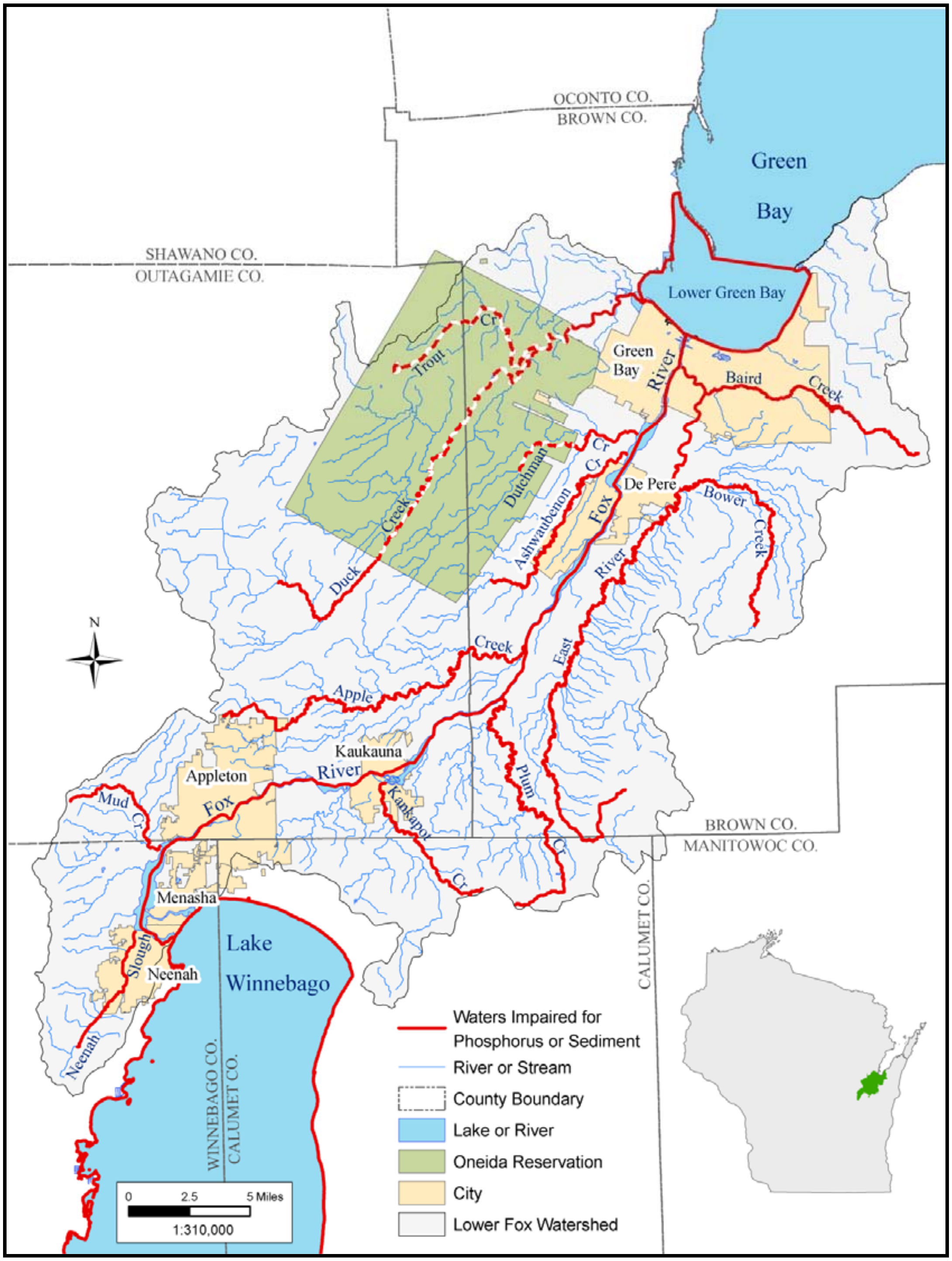


Figure 3. Lower Fox River Basin (Source: CADMUS 2007)

Impairment Listing Information

The approach will be to establish a Phosphorus and Sediment Watershed TMDL for the LFR and Green Bay AOC, as well as a Watershed Management Plan (WMP) for the impaired waters within the boundary of the Oneida Nation Reservation. There are currently 24 impaired segments in the LFR Basin, including the Green Bay AOC, which will be addressed by the TMDL and WMP (Table 11). Section 303(d) of the Clean Water Act requires a TMDL be developed for each pollutant for each listed waterbody. The LFR Basin and Green Bay AOC Watershed TMDL will address impairments through 41 individual TMDLs.

Table 11. Impaired Segments Covered Under the Watershed TMDL for the Lower Fox River and Green Bay AOC

Waterbody	County	Pollutants	Impairments
Apple Creek Segment 1	Brown	Phosphorus, Sediment	Degraded Habitat, Dissolved Oxygen, Temperature
Apple Creek Segment 2	Outagamie	Phosphorus, Sediment	Dissolved Oxygen, Sediment
Ashwaubenon Creek	**Brown**	**Phosphorus, Sediment**	**Degraded Habitat, Dissolved Oxygen**
Baird Creek Segment 1	Brown	Phosphorus, Sediment	Degraded Habitat, Dissolved Oxygen, Temperature
Baird Creek Segment 2	**Brown**	**Phosphorus, Sediment**	**Degraded Habitat, Dissolved Oxygen**
Bower Creek Segment 1	**Brown**	**Phosphorus, Sediment**	**Degraded Habitat**
Bower Creek Segment 2	**Brown**	**Phosphorus, Sediment**	**Degraded Habitat**
Duck Creek Segment 1	Brown	Phosphorus, Sediment	Dissolved Oxygen, Sediment
Duck Creek Segment 2	Outagamie	Phosphorus, Sediment	Dissolved Oxygen, Sediment
Dutchman Creek	Brown	Phosphorus	Dissolved Oxygen
East River	Brown	Phosphorus, Sediment	Degraded Habitat, Dissolved Oxygen, Sediment
East River	Brown	Phosphorus, Sediment	Degraded Habitat, Dissolved Oxygen, Sediment
Fox R. Lower Segment 1 (1)	Outagamie	Phosphorus	Degraded Habitat, Dissolved Oxygen
Fox R. Lower Segment 2 (1)	Brown	Phosphorus	**Degraded Habitat**, Dissolved Oxygen
Fox R. Lower Segment 3 (1)	Brown	Phosphorus, **Sediment**	**Degraded Habitat**, Dissolved Oxygen
Green Bay AOC (inner bay) (1)	Brown	Phosphorus, **Sediment**	**Degraded Habitat**, Dissolved Oxygen
Kankapot Creek Segment 1	Outagamie	**Phosphorus**, Sediment	Degraded Habitat
Kankapot Creek Segment 2	Outagamie	**Phosphorus**, Sediment	Degraded Habitat
Mud Creek Segment 1	Outagamie	**Phosphorus**, Sediment	Degraded Habitat
Mud Creek Segment 2	Outagamie	Sediment	Degraded Habitat
Neenah Slough	Winnebago	Phosphorus	Dissolved Oxygen
Plum Creek Segment 1	Outagamie	**Phosphorus**, Sediment	Degraded Habitat & Temperature
Plum Creek Segment 2	Outagamie	Sediment	Degraded Habitat & Temperature
Plum Creek Segment 3	Outagamie	Sediment	Degraded Habitat & Temperature

Note: Bold indicates proposed additions based on impending 2008 Impaired Waters List

Pollutant Sources

Sources of phosphorus and sediment loading to the LFR Basin and Green Bay AOC include polluted runoff from nonpoint sources, such as the abundance of dairy farms in the area, pastures and crop land, stormwater, rural and urban land, and construction sites, as well as treated effluent from permitted municipal and industrial point source dischargers. Point source facilities have already begun to reduce their discharge of phosphorus as part of their permit requirements established by WDNR. While additional reductions from point source facilities may be needed to restore water quality in the river and bay, reducing phosphorus and sediment loading to the LFR Basin and Green Bay AOC will require significant reductions in polluted runoff from nonpoint sources.

Applicable Standards and Water Quality Targets

Neither Wisconsin nor the Oneida Nation has numeric criteria for phosphorus or TSS. However, a numeric target is needed for the TMDL and WMP in order to calculate reductions in phosphorus and sediment loading necessary to meet water quality objectives and protect designated uses. WDNR has proposed the following numeric targets for the LFR and Green Bay AOC TMDL: mean summer total phosphorus (TP) concentration of 120 μg/L (0.12 mg/L) and mean summer total suspended solids (TSS) concentration of 16 mg/L. The targets chosen will reflect what is both feasible and reasonable to meet water quality restoration goals. Numeric targets for phosphorus and TSS for the impaired tributary streams will be determined by the WDNR and Ad-Hoc Science Team for the LFR Basin by the TMDL Development Phase.

Available Data

There are 25 years of data in this watershed, next draft to include a brief summary.

Stakeholder Process

A number of factors, including the impairment status of the Lower Fox River Basin, the high priority status of the Lower Green Bay AOC, and the availability of significant monitoring data to characterize loading in the watershed, led to area stakeholders to recognize that the Basin offers an excellent opportunity for developing a TMDL and subsequent implementation plan. The effort that is now underway represents a unique approach to TMDL development compared to how many are traditionally done. The process is following a four-phased approach. In Phase I, which is now complete, a preliminary modeling study was performed to develop a framework in which managers can explore optimal watershed management options for restoring water quality in the basin. The primary goal of Phase I was to look at a combination of optimal best management practices (BMPs) for agriculture. This optimization framework will be further expanded upon to include additional agricultural BMPs and coasts, stormwater BMPs and costs, and upgrade costs to point sources during the TMDL development phase of the project. Phase II, which is underway, includes multiple stakeholder involvement efforts. Facilitated stakeholder discussions have been held for both large and small agricultural producers, crop consultants in the basin, and local agency staff. Discussions will continue with the stormwater stakeholders throughout the watershed, as well as elected officials and environmental groups. A basin-wide social indicators survey was sent to 300 dairy farmers with a 58% response rate. Another set of surveys will be sent to a randomly selected portion of the general public in the summer of 2008. The social indicators survey will raise awareness of water quality issues, find out what BMPs are currently being done, help plan for modeling restoration scenerios, and assist in planning for TMDL implementation. Phase III is development of the TMDL. This phase will include defining water quality targets, exploring different restoration scenarios, determining reductions needed for all sources, a draft report, and a final public meeting. Phase IV will include implementation of the TMDL by both point sources (permitted entities) and nonpoint sources (where cost share resources are available). An Implementation Plan will be included in the final TMDL report.

Organizational Structure

Figure 4 illustrates the organizational structure and role of those involved with the TMDL for WDNR and the WMP for the Oneida Nation Reservation. The TMDL development process will be led by WDNR, with guidance from EPA and technical support from a contractor. Several committees have been formed to support the development and implementation of the TMDL and WMP: The Outreach Committee, the Ad-Hoc Science Team, and the Technical Team.

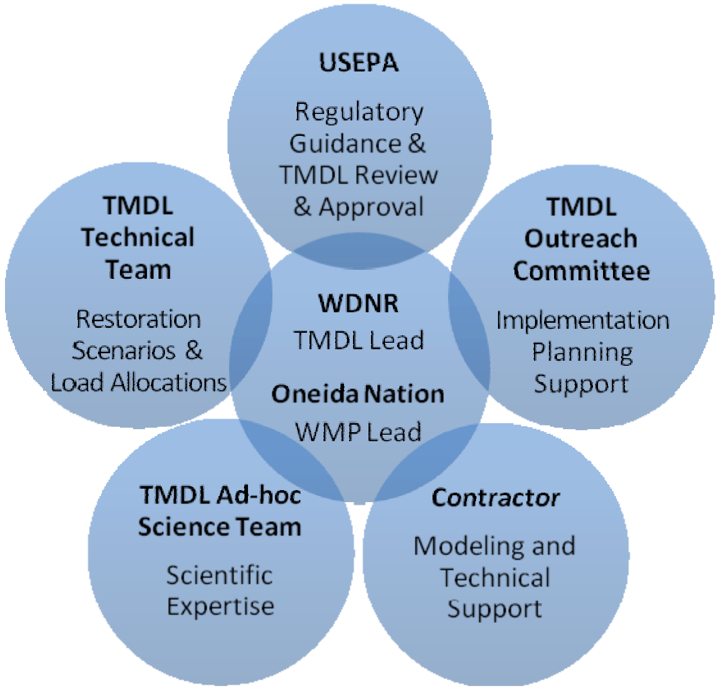


Figure 4. Organizational Structure for the Development of the TMDL and WMP

Outreach Committee

The Outreach Committee will play a key role in public and stakeholder outreach for both development and implementation of the TMDL. Objectives for this committee include but are not limited to: developing key messages, developing and implementing a communication and outreach strategy for TMDL development and implementation, and meeting with key stakeholder groups. The committee will work closely with key stakeholders (agriculture, stormwater, industrial and municipal dischargers, etc.) to determine and analyze Best Management Practice (BMP) scenarios as part of the pollutant load reduction optimization modeling.

Members of the Outreach Committee will be asked to share any information gathered through outreach tools (media, stakeholder meetings, social indicators) with the TMDL Technical Team when considering the feasibility of the allocation and restoration scenarios.

The Outreach Committee includes representatives from WDNR, EPA, UW-Green Bay (UW-GB), UW-Extension, UW-Sea Grant, Oneida Nation, Brown County Land Conservation Department (LCD), Green Bay Metropolitan Sewerage District (GBMSD) and Fox Wolf Watershed Alliance (FWWA).

Established in fall of 2006, the Outreach Committee meets approximately every two months and has already held a series of stakeholder outreach meetings to inform the community about the TMDL, answer questions, and listen to stakeholder concerns. A kick-off meeting to present the TMDL and WMP work plan and proposed numeric targets was held January 23, 2008. The Outreach Committee will continue to assist in organizing two additional community meetings during the TMDL development process: 1) Restoration Scenarios Meeting to review the results of the modeling and discuss feasibility of various BMPs in meeting TMDL targets (Fall 2008); and 2) Public Comment Period Meeting to present the final TMDL (Spring 2009).

Ad-Hoc Science Team

The role of the Ad-Hoc Science Team is to contribute local data and scientific expertise to set the numeric targets and restoration goals of the TMDL. The Ad-Hoc Science Team includes: staff from WDNR, UW-GB, UW-Milwaukee Water Institute, GBSMD, UW-Sea Grant, Oneida Nation and EPA. The Ad-Hoc Science Team has already held a series of discussions to analyze the numeric targets for the TMDL. Data analysis and modeling is currently taking place to define numeric criteria for total suspended solids

(TSS) and phosphorus (P) in the tributary streams. Numeric targets for the Lower Fox River, Green Bay and all the impaired tributaries in the basin, will be established by the beginning of the TMDL development phase. Once the team completes the scientific analyses and determines the numeric targets for the TMDL, this team will no longer be active, but participants may be asked to provide scientific expertise to the Technical Team.

Technical Team

The role of the Technical Team will be to evaluate and comment on various load allocation scenarios and restoration strategies that have been selected by WDNR. WDNR will welcome and consider comments from the technical team when deciding on the final methodology to ensure that the allocation scenario is feasible and will meet water quality standards.

Members were solicited for this team, from those attending various TMDL outreach meetings. However, due to the large number of people interested in participating, WDNR will select members from each key stakeholder group (county land and water conservation departments, crop consultants, point source facilities, agricultural producers, municipalities, etc.). Members with various backgrounds and interests will be chosen to ensure broad representation. Team members will be chosen by the end of July 2008. Participation on this team will require attending a series of meetings with a contractor to discuss results of the modeling and proposed allocation scenarios. While the load allocations and wasteload allocations will be determined by the WDNR, the decision making process will be informed by the allocation scenario chosen by the Technical Team. The Technical Team will also be encouraged to participate in the second Public Outreach meeting to be held in Fall 2008.

Local Watershed Websites

The Lower Fox River Watershed Monitoring Program (LFRWMP) (https://www.uwgb.edu/watershed/about/index.htm The LFRWMP is a multi-year water monitoring program which will provide independent, high-quality data that can be used to make resource decisions to improve water quality and foster habitat restoration within the Fox River Basin. Funded by a grant from Arjo Wiggins Appleton, the program involves coordination between area high school students and teachers, university students and researchers from the University of Wisconsin-Green Bay (UWGB) and the University of Wisconsin-Milwaukee (UWM), the Cofrin Center for Biodiversity, the Green Bay Metropolitan Sewerage District (GBMSD), and the US Geological Survey (USGS).

University of Wisconsin-Extension Basin Education Initiative http://basineducation.uwex.edu/lowerfox/index.htm The UW-Extension Basin Education Initiative with the Wisconsin Department of Natural Resources designs and delivers educational programs, assists organizations, and builds partnerships to promote understanding and stewardship of Wisconsin's natural resources at the watershed and landscape scale.

Wisconsin Department of Natural Resources http://dnr.wi.gov/org/water/wm/wqs/303d/FoxRiverTMDL/ Lower Fox River & Green Bay Area of Concern Total Daily Maximum Load (TMDL)

TMDL Development Approach

The previously calibrated and validated Soil & Water Assessment Tool (SWAT) will be used to develop the TMDL and WMP for the LFR Basin and Green Bay AOC (i.e., to estimate existing loads and calculate necessary load reductions to meet the numeric targets). SWAT is a distributed parameter, daily time-step model that was developed by the U.S. Department of Agriculture - Agricultural Research Service (USDA-ARS) to assess nonpoint source pollution from watersheds and large complex river basins. SWAT simulates hydrologic and related processes to predict the impact of land use management on water, sediment, nutrient, and pesticide export. With SWAT, a large heterogeneous river basin can be divided into hundreds of subwatersheds; thereby, permitting more realistic representations of the specific soil, topography, hydrology, climate and management features of a particular area. Crop and management components within the model permit reasonable representation of the actual cropping, tillage, and nutrient management practices typically used in northeastern Wisconsin.

Modeled output data from SWAT can be easily input to a spreadsheet or database program, thereby making it easier to model large complex watersheds with various management scenarios efficiently. Major processes simulated within the SWAT model include: surface and groundwater hydrology, weather, soil water percolation, crop growth, evapotranspiration, agricultural management, urban and rural management, sedimentation, nutrient cycling and fate, pesticide fate, and water and constituent routing. SWAT also utilizes the QUAL2E sub-model to simulate nutrient transport. A detailed description of SWAT can be found on the SWAT website (http://www.brc.tamus.edu/swat/).

The SWAT model was previously calibrated and validated by Mr. Paul Baumgart (UWGB) in 2005 for use in estimating TP and TSS loading in the LFR Basin. The SWAT model framework that Mr. Baumgart applied to the LFR Basin in 2005 was refined as part of a recent demonstration project (by Cadmus and Mr. Baumgart) and reapplied to estimate the load reduction associated with various combinations of agricultural BMP scenarios for the LFR Basin. A Quality Assurance Project Plan (QAPP) has already been developed for the recalibration and validation of the SWAT model for use in the load allocation modeling analysis for the TMDL and WMP.

SWAT will be used to estimate existing TP and TSS loading to each of the impaired segments in the basin. SWAT will also be used to calculate the tributary/segment specific loading targets and associated load reduction necessary to meet the TMDL and the targets in the WMP. TMDLs will be developed for each impaired segment.

Future efforts will refine SWAT to make use of new data sets of continuous flow and daily loads of TP and TSS from the five Lower Fox River Watershed Monitoring Program (LFRWMP) monitoring stations. The urban stormwater component of the model will be updated to allow for the evaluation of phosphorus and sediment loading MS4 urban areas covered under WPDES Municipal General Permits. MS4 urban loading and non-MS4 urban loading are tracked differently in a TMDL and subject to different regulatory requirements, therefore, it is important to have the ability to evaluate loading from both MS4 urban areas and non-MS4 urban areas. The urban stormwater component of SWAT will also be updated to incorporate data from recent urban stormwater modeling using the Source Loading and Management Model (SLAMM) conducted for MS4s within the LFR Basin. SLAMM is used to simulate pollutant loads and demonstrate compliance with requirements stipulated in **NR 151** for urban areas.

In addition, the streambank erosion sub-model within SWAT will be updated. Previously, this component of the modeling framework had been "turned off" and effectively lumped in with upland sources because 1) county land conservation departments assessed the streambank contributions of TSS and TP during watershed planning and estimated that they were relatively minor compared to upland sources; and 2) actual watershed-wide measurements of streambank contributions were not available to calibrate the model. However, urbanization along tributaries within the LFR Basin is likely to change the hydrologic regime and potentially create unstable streambanks and beds, which could contribute significant loads of TSS and TP to the streams. Data from an ongoing sediment source tracing study of LFR tributaries has recently been made available, and may be used to calibrate the SWAT model. This study, which is being conducted by the UWGB and UW-Milwaukee, utilizes radionuclide analysis of suspended sediments and compares the results to sediment sources, such as streambanks, urban areas, and agricultural fields to estimate the proportional contribution from each source. Existing local estimates of streambank contributions will be augmented with data from similar areas to calibrate the model if we determine that the data from the sediment source tracing study is not enough to support recalibration.

Finally, the SWAT modeling framework will be updated to allow for the simulation of potential load reductions associated with the implementation of potentially restorable wetlands within the basin. Potential wetland restoration sites will be identified using the same methodology used for the Rock River Basin TMDL analysis (WDNR is in the process of documenting the methodology).

Implementation Approach

Define Restoration Goals and Identify Restoration Scenarios

The restoration goals for the TMDL should focus on biological benefits and endpoints for the river and bay (e.g., increased submerged aquatic vegetation). EPA, WDNR, UWGB, and other creditable sources have previously identified approaches and potential restoration goals. WDNR, the Oneida Nation Reservation, the Outreach Committee and the Technical Team will help define the restoration goals for the TMDL and WMP.

WDNR, the Oneida Nation Reservation, and the Outreach Committee will identify all potential restoration scenarios to analyze with the load reduction optimization-modeling framework. Both agricultural and urban stormwater BMPs, as well as point source facility upgrades will be considered. The agricultural BMPs evaluated in the demonstration project will be reevaluated; additional agricultural BMPs will be identified for inclusion in the optimization analysis. WDNR, the Oneida Nation Reservation, and the Outreach Committee will also identify urban stormwater BMPs to include in the optimization analysis.

WDNR, the Oneida Nation Reservation, and the Outreach Committee will discuss BMP options with stakeholders and assess the potential for implementation success based on the BMP's feasibility, acceptability, and sustainability. Many of the BMPs necessary to achieve the phosphorus and sediment reduction goals for the LFR Basin and Green Bay AOC will require voluntary cooperation from landowners. The Outreach Committee has been conducting an assessment to identify socioeconomic indicators to gain a better understanding of the social systems that influence water quality in the LFR Basin and Green Bay AOC. The results of the social indicators work will be used to help gauge the potential effectiveness of the various BMPs that have outreach and behavior change components.

Perform Cost Analysis of Restoration Scenarios

A final list of BMPs and other restoration scenarios will be included in the cost and load reduction optimization analysis. Site-specific (i.e., local) total annual costs associated with implementation of each of the agricultural and urban stormwater BMPs in the LFR Basin will be calculated. This estimate will include all costs associated with the BMP, including implementation expenses and costs associated with incentives (e.g., provided by the government or other agency). Costs will also take into account both initial implementation costs and annual operation and maintenance (O&M) costs. In 1991, the Southeast Wisconsin Regional Planning Commission (SEWRRC) prepared a technical report entitled "Costs of Urban Nonpoint Source Water Pollution Control Measures," which includes estimated costs for urban BMPs. The costs of some of the BMPs in this report (i.e., those selected by WDNR, the Oneida Nation Reservation, and the Outreach Committee) will be updated to reflect current costs.

BMPs have varying lifetimes; therefore all costs will be reduced to their annual values. Annualizing BMP costs provides a means of comparing BMPs by cost and supplying cost values that can be utilized in conjunction with average annual TP and TSS load reduction estimates associated with the BMPs to identify the optimal combination of BMPs. Point source facility upgrades (including O&M costs) will be estimated on costs provided by point sources (time permitting) or calculated based on similar studies throughout the state.

Perform Load Reduction Optimization Analysis

A watershed-level optimization-modeling framework will be used for determining the optimal combinations of BMPs and potential point source facility upgrades for reducing TP and TSS loading in the LFR Basin and Green Bay AOC. Site-specific BMP and point source facility upgrade costs will be used in conjunction with estimated load reductions (from SWAT) associated with implementation of the BMPs and facility upgrades to identify the ten most cost-effective combinations of implementation scenarios that achieve the TMDL targets for TP and TSS. The optimization analysis will be conducted using SWAT in conjunction with a Generic Algorithm Optimization Model (OptiMod), which is a refinement of the Optimization Model previously developed for the demonstration project.

The most cost effective combinations of restoration scenarios that achieve the TMDL targets for TP and TSS will be presented to EPA, WDNR, the Oneida Nation Reservation, the Outreach Group, and the Technical Team who will comment on the scenarios and provide input to WDNR and Oneida Nation. WDNR and Oneida National will choose the final scenario to serve as the basis for the implementation plan for the TMDL and WMP.

Lessons Learned: Developing Watershed TMDLs in the Real World

Start Upstream

Since this watershed is rich with 25 years of data it was a logical place to start with a TMDL project. The Upper Fox and Wolf Basins, above the Lower Fox River covers more land area and has less data . Since 50% of the total load to the Lower Fox River and Green Bay is entering from the Upper Fox and Wolf Basins, TMDLs must be completed in the near future to reach the water quality goals proposed for the Lower Fox River TMDL.

Agency Coordination is Critical

Since this watershed TMDL will include point and nonpoint sources, WDNR realizes the importance of synchronizing the permitting, runoff management, water quality standards, and TMDL development processes. Involving additional agency personnel, particularly at the regional level, is important to the appropriate development and implementation of a TMDL.

Using the Local Hero Approach

WDNR has been lucky to have an active local watershed group, including university professors, spearheading the original efforts for data analysis in the watershed. Involving stakeholders in facilitated discussions and surveys has helped find out what BMPs are currently being implemented, plan for modeling restoration scenarios, and will help pave the way for TMDL implementation. Active public involvement will be a vital part of the development and implementation of the Lower Fox River Basin and Green Bay TMDL. Accomplishing reductions in phosphorus and sediment loadings to the river and bay will require participation from every community member. It is hoped that implementation scenarios will be carried out by individual “local heroes” and “tributary teams” throughout the watershed.

Having lots of data helps, not having numeric criteria is problematic

Having 25 years of water quality data for the watershed has made modeling efforts for the watershed much easier than if significant amount of data collection had been necessary. However, once a model has given an output, not having codified numeric criteria from which to calculate a TMDL, is problematic. WDNR has had to include the additional step of developing watershed specific numeric targets for both phosphorus and TSS in this watershed. Fortunately the plethora of monitoring data in the basin has given WDNR and researchers the opportunity to base site-specific numeric targets on local scientific data.

References

CADMUS, 2007. Final Report: Integrated Watershed Approach Demonstration Project, A Pollutant Reduction Optimization Analysis for the Lower Fox River Basin and the Green Bay Area of Concern

Wisconsin Department of Natural Resources. 1993. Lower Green Bay Remedial Action Plan, 1993. Update for the Lower Green Bay and Fox River Area of Concern. Wisconsin Department of Natural Resources. 152 pp.

Case Study 5: Tidal Potomac and Anacostia PCB TMDL

Watershed TMDL at a Glance

Waterbody:
Tidal reaches of the Potomac and Anacostia Rivers

***Drainage Area*:** The drainage area is divided into (1) direct drainage and (2) non-tidal upstream tributaries. The definition and interpretation of tributary and direct drainage areas have been defined by the Chesapeake Bay Program.

Parameters:
Polychlorinated Biphenyls (Total PCBs)

Development Status:
Approved on October 31, 2007

TMDL Developed by:
Interstate Commission on the Potomac River Basin

Jurisdictions:
Virginia Department of Environmental Quality
District of Columbia Department of the Environment
Maryland Department of the Environment

 # *Impaired Segments Addressed*:
28

Technical Approach:
Linked modeling applications based on various loading estimation methodologies depending on source

Source Types:
NPS and PS

Background and Rationale for Using a Watershed Approach

A total of 28 segments of the tidal Potomac and Anacostia Rivers were placed on the Maryland, Virginia, and District of Columbia's 303(d) lists as being impaired by PCBs (Figure 7). The District of Columbia Potomac PCB listings were covered by a consent decree between the Environmental Protection Agency (EPA) and the U.S. District Court scheduled to be addressed by September 30, 2007. While Maryland and Virginia were not bound by the same deadline, in 2004 the three jurisdictions recognized the importance of consistent methods and agreed to coordinate their PCB TMDL development for the tidal Potomac and Anacostia listings.

A consolidated TMDL effort was expected to minimize anticipated confusion associated with making sense of independent TMDLs completed on different dates, using different models and assumptions, and possibly reaching different conclusions. A single TMDL effort was also deemed to be more cost effective as the three jurisdictions were able to share cost associated with data collection, model development, and stakeholder participation. EPA was closely involved in this project and provided funding for consulting services and model development. The Interstate Commission on the Potomac River Basin (ICPRB) assisted the jurisdictions in the TMDL development effort by providing overall coordination and acting as a technical resource, while consulting services for model development were funded by EPA.

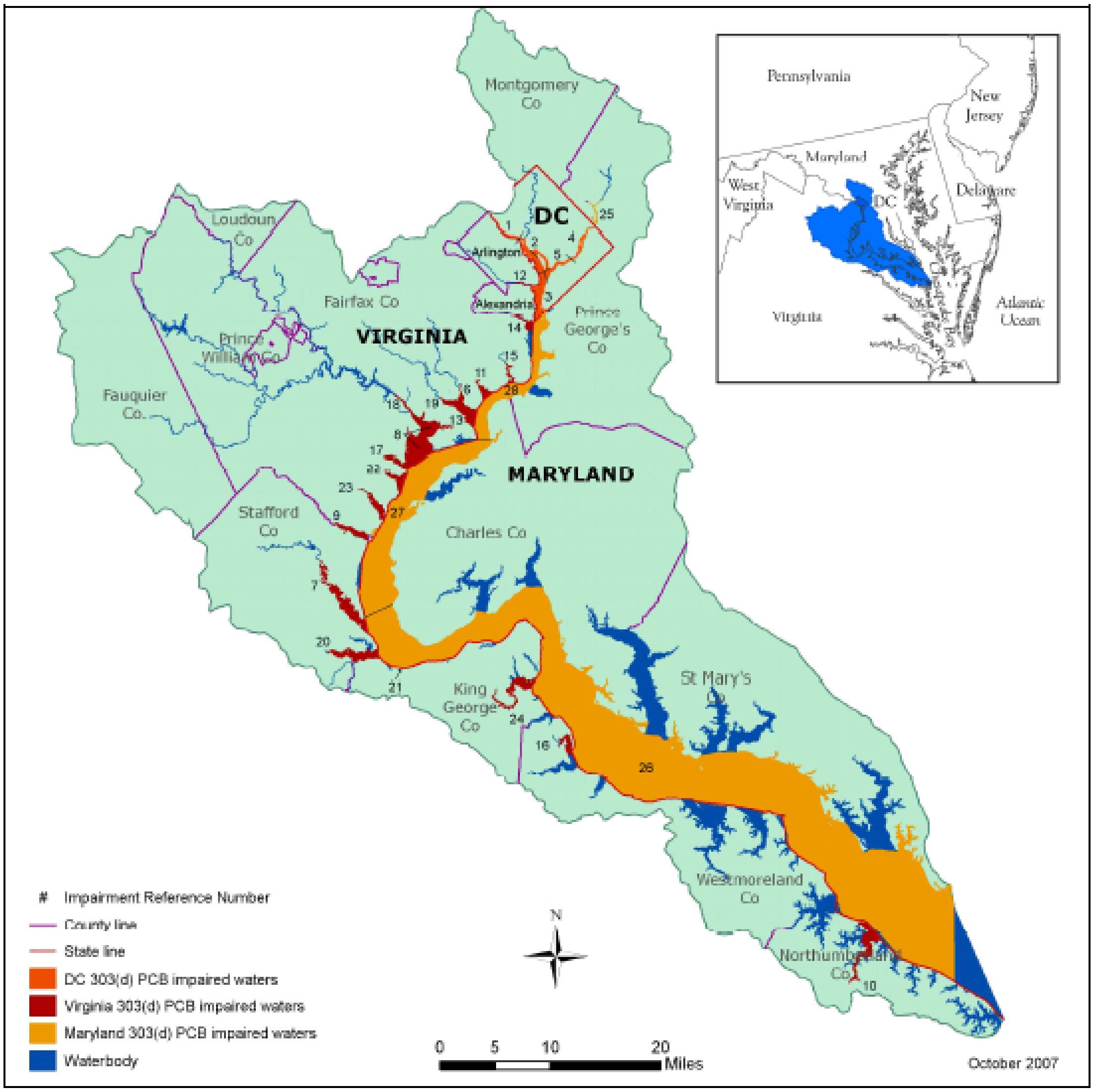


Figure 5. Waters of the Tidal Potomac and Anacostia PCB TMDL

Impairment Listing Information

In all three jurisdictions, a waterbody may be listed as impaired by PCBs based on water column (i.e., violation of the water column criteria) or fish tissue data (i.e., fish tissue threshold exceedance). All of the tidal Potomac and Anacostia segments (Table 12) were placed on the 303(d) list due to elevated fish tissue concentrations.

Some of these segments are also listed for other reasons (e.g., nutrients, sediments, bacteria, and impacts to biological communities). The tidal Potomac and Anacostia PCB TMDL addressed only the PCB listings. The Potomac and Anacostia PCB TMDL replaces a 2003 Anacostia River PCB TMDL developed for the DC portion of the river.

Table 12. PCB impaired waterbodies in the tidal Potomac and Anacostia rivers

	Impaired Waterbody	Juris	Description
1	Upper Potomac	DC	Chain Bridge to Key Bridge
2	Middle Potomac	DC	Key Bridge to Hains Point
3	Lower Potomac	DC	Hains Point to Wilson Bridge (DC/MD border)
4	Upper Anacostia	DC	DC/MD border to Pennsylvania Ave. bridge
5	Lower Anacostia	DC	Pennsyl. Ave. bridge to Potomac River
6	Accotink Bay	VA	In each Virginia embayment, the impairment generally includes all tidal waters within the embayment, from head-of-tide to the Potomac river mainstem. The Potomac River, Fairview Beach, impairment is an area on the mainstem off the beach. See the Virginia 2006 Integrated Assessment report for specific descriptions of the geographic extent of each impairment.
7	Aquia Creek	VA	
8	Belmont Bay / Occoquan Bay VA	VA	
9	Chopawamsic Creek	VA	
10	Coan River	VA	
11	Dogue Creek	VA	
12	Fourmile Run	VA	
13	Gunston Cove	VA	
14	Hooff Run & Hunting Creek	VA	
15	Little Hunting Creek	VA	
16	Monroe Creek	VA	
17	Neabsco Creek	VA	
18	Occoquan River	VA	
19	Pohick Creek / Pohick Bay VA	VA	
20	Potomac Creek	VA	
21	Pot. River, Fairview Beach	VA	
22	Powells Creek	VA	
23	Quantico Creek	VA	
24	Upper Machodoc Creek	VA	
25	Tidal Anacostia	MD	From head of tide on NE and NW Branches of the Anacostia to the DC/MD border
26	*Potomac River Lower	MD	Mouth of the Potomac to Smith Point, Charles County
27	*Potomac River Middle	MD	Smith Point to Pomonkey Point, Charles County
28	*Potomac River Upper	MD	Pomonkey Point to DC/MD line at Wilson Bridge

Note: * Only the tidal portion of these MD 8-digit waters have been listed as impaired for PCBs.

Applicable Standards and Water Quality Targets

The designated uses of the tidal Potomac and Anacostia include primary and secondary contact recreation, protection of aquatic life, and fish consumption. Additionally, the Upper Machodoc Creek is covered by a shellfish water designation.

The PCB listings for all of the tidal Potomac and Anacostia Rivers were based on the exceedence of the jurisdictional fish tissue threshold levels (i.e., human health risk assessment limits for fish consumption). Consequently, the objective of the tidal Potomac and Anacostia PCB TMDL was to identify maximum allowable PCB loads that would not result in "fish consumption" use impairments.

Table 13lists the specific PCB fish tissue thresholds and water quality criteria used by each jurisdiction. The variations among these values are mainly due to different assumptions applied by each jurisdiction with regards to acceptable risk levels, individual weight, exposure duration, and the amount of fish and drinking water intake.

Table 13. Applicable Criteria for the PCBs TMDLs in the Tidal Potomac and Anacostia Rivers

Jurisdiction	Fish Tissue Threshold (ppb)	Water Quality Criteria (ng/L)
DC	20	0.064
MD	88	0.64
VA	54	1.70

Stakeholder Process

The TMDL development process was initiated with the formation of a Steering Committee (SC) and Technical Advisory Committee (TAC). The SC members coordinated activities, guided the TMDL development process, and routinely updated TAC members on the status of the project. Additionally two sets of public meetings were held and public comments were solicited.

Steering Committee

Steering Committee representatives included staff from the District of Columbia Department of the Environment (DCDOE), Maryland Department of the Environment (MDE), Virginia Department of Environmental Quality (VADEQ), the EPA, the Interstate Commission on the Potomac River Basin (ICPRB), LimnoTech, Inc., and the Metropolitan Washington Council of Governments (MWCOG).

Specific roles of the individual Steering Committee members included:

- States: regulatory guidance and decision making, monitoring and funding, internal review and coordination, stakeholder notification.
- EPA: regulatory guidance and decision making, funding,
- ICPRB: coordination, contract management, data analysis, scenario development and TMDL document development, public meeting facilitation.
- MWCOG: expertise and regional perspective.
- Consultant: model development, technical expertise.

The SC members held conference calls on a regular basis (1-4 times a month). Additionally, topic specific workgroups were convened, to provide input on relevant issues. Work groups collaborated on such issues as monitoring, loading estimation methods, modeling, and implementation.

Technical Advisory Committee

Membership of the TAC consisted of institutional stakeholders likely to be affected by the TMDL. These included civic, environmental, and business groups. TAC participation was solicited via broad email notification sent out to the identified stakeholders. The participation list was continually updated.

Six publicly noticed TAC meetings were held between September 2005 and September 2007. The TAC was briefed and asked to provide feedback related to modeling, data analysis, and policy decisions.

Public Information Meetings

Public information meetings were held in each jurisdiction in June 2006 and July 2007. The purpose of these meetings was to provide the public an opportunity to learn about and comment on the activities associated with the Potomac and Anacostia PCB TMDL development. Additionally, a draft TMDL report was made available for public comment on July 17, 2007. Approximately 100 comments were received from 17 organizations.

Available Data

An initial examination of historical PCB data collected by multiple agencies revealed a lack of consistency among the analytical methods and geographic differences in the extent of sampling. In order to overcome these obstacles, the SC restricted initial analysis to a set of commonly reported PCB homologs.

During the course of the project, additional water column and point source discharge samples were collected (between 2005 and 2007) and analyzed using high resolution, congener based laboratory techniques. Point source effluent monitoring included sampling of 15 wastewater treatment plants. Water column samples were collected at the Potomac River at Chain Bridge and 26 other nontidal tributaries.

Pollutant Sources

Three principal data sources were used to develop most of the PCB load estimates: historical PCB data, new PCB samples, and regression-derived PCB data. These sources were supplemented by additional information from the literature.

Table 14 summarizes external PCB loads to the Potomac and Anacostia Rivers and the methodology used to estimate these loads.

Table 14. PCB Sources Considered by the TMDL

Source	Estimation Method
Potomac at Chain Bridge	Loads were generated by applying PCB and carbon regressions with TSS to daily times series of TSS concentration predicted by the LOADEST regression model with USGS flow data [a]
Basin Tributaries [b]	Loads were generated by applying PCB and carbon regressions with total suspended solids (TSS) to daily times series of TSS concentration predicted by the Chesapeake Bay Model (WM5). These loads represent a sum of loads from atmospheric deposition, unidentified contaminated sites, and stormwater runoff (regulated and unregulated)
Direct Drainage	Loads were generated by applying PCB and carbon regressions with TSS to daily times series of TSS concentration predicted by the WM5. These loads represent a sum of atmospheric deposition, loads from small tributaries not specified in the WM5, regulated and unregulated stormwater, unidentified contaminated sites, unspecified point source discharges
WWTPs	Monitoring data (PCB, BOD and flow)
CSOs	Modeled flows and monitoring data
Atmospheric Deposition	Literature values
Contaminated Sites	Contaminated soil data maintained by each jurisdiction. Delivery rate to the nearby waterbody was determined using Revised Universal Soil Loss Equation, Version 2 (RUSLE2)
Bay Boundary	POTPCB model

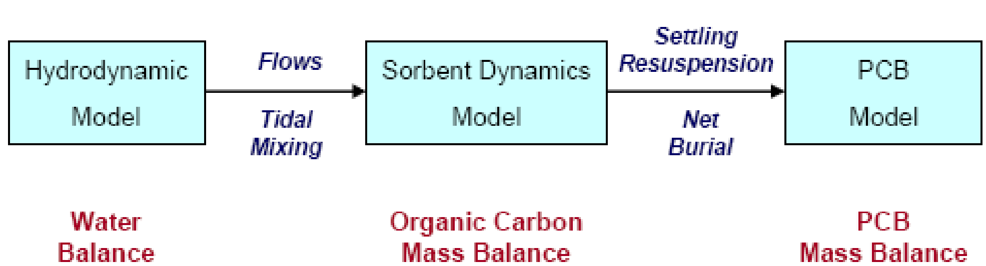
Notes: [a] This method provided better agreement with observed data than the WM5 model.
[b] Specific point sources were not characterized for the upstream loads.

For additional details on the source loading estimations and data and methods used to develop them, see Appendix A of the TMDL Report.

Technical Approach

POTPCB Model

The POTPCB model (Limnotech, Inc. 2007) is a coupled, hydrodynamic, salinity, sorbent dynamics (sediment), and PCB mass balance model for the tidal portions of the Potomac and Anacostia Rivers. It is closely based on a similar linked modeling platform developed for the Delaware River Estuary PCB



TMDL.
Figure 6**Error! Reference source not found.** presents a graphic representation of the modeling framework.

POTPCB provided daily water column and sediment concentrations in each of 257 model segments in response to loading inputs generated externally of the model (see Table 14). The Hydrodynamic model is based on a version of the Dynamic Hydrologic Model (DYNHYD). For sorbent dynamics and PCB mass balance, a version of the Water Quality Analysis Simulation Program 5 (WASP)/Toxic Chemical (TOXI5) was developed.

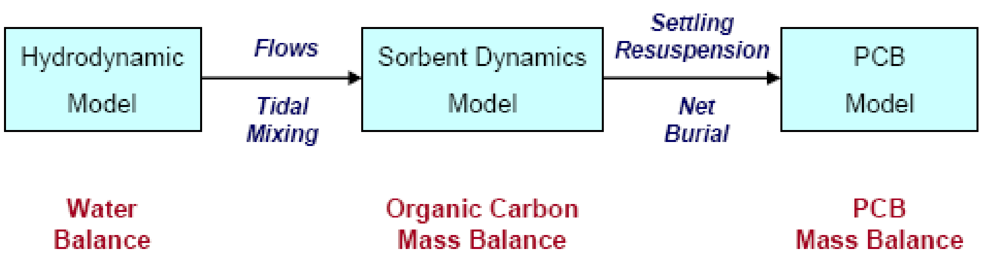


Figure 6. POTPCB Model Framework (Source: Tidal Potomacand Anacostia PCB TMDL)

PCB Targets

While POTPCB model simulates water column and sediment concentrations, it does not predict the associated fish tissue concentrations. Therefore, a method external to the POTPCB model was required to relate water column and sediment PCB concentrations to fish tissue concentrations. For this purpose, species-specific bioaccumulation factors (BAFs) were derived from the observed fish tissue, water column, and surface sediment PCB concentrations. The BAFs were in turn used to establish water quality and sediment targets for the POTPCB model used to determine loading scenarios necessary for achieving desirable fish tissue PCB concentrations.

Table 15 summarizes the water quality targets calculated using species specific bioaccumulation factors. For comparison purposes applicable water column criteria and fish tissue thresholds are also listed.

Table 15. BAF-based TMDL Targets

	Fish Tissue PCB Impairment Threshold (ppb)	PCB Water Quality Criteria (ng/L)	BAF-based Target PCB Water Concentration (ng/L)	BAF-based Target PCB Sediment Concentration (ng/g dry wt)
DC	20	0.064	0.059	2.8
Maryland	88	0.64	0.26	12.0
Virginia	54	1.7	0.064	7.6

As the BAF-based water concentration targets were found to be more stringent that the existing water column criteria, the BAF based targets were used to determine a set of PCB loads that would result in the desirable fish tissue concentrations. The POTPCB model was used to predict water column and sediment concentrations for given loading scenarios, which then were compared against the appropriate targets.

Allocations

TMDL loads were allocated to each of the identified source categories within each impaired segment. This was done as part of a deliberate process starting with a number of diagnostic model runs that provided a general sense of required load reductions to achieve the PCB targets in each impaired segment. The next step included a series of model runs with adjusted loads from specific the source categories in order to arrive at a set of loads that provided quasi-equilibrium PCB concentrations at or below the appropriate targets in each of the model segments.

Wasteload Allocations

For the TMDL, the jurisdictions agreed to apply a consistent approach for WWTPs. Only those WWTPs facilities (22) with the greatest annual flows within the direct drainage of the tidal Potomac and Anacostia Rivers were assigned a WWTP WLA. These WLAs were determined based on the facility design flow multiplied by the applicable water quality target.

The regulated NPDES stormwater allocations within the direct drainage area were expressed as a single stormwater WLA for each impaired waterbody. These allocations were determined by multiplying the direct drainage PCB load for the TMDL scenario by the percent of land classified as developed (i.e., covered by an NPDES stormwater permit). The nontidal tributary regulated and unregulated stormwater loads are included in the LA portion of the TMDL.

Combined Sewer Overflow WLAs were based on daily flows and modeled loads for each outfall (53 in the District and 4 in VA).

Load Allocations

Load allocations include loads from upstream nontidal tributaries, which include upstream point sources, direct drainage nonpoint source runoff, atmospheric deposition to water surface, and runoff from known contaminated sites. Additionally, PCB exchanges with the Chesapeake Bay were considered in the analysisbut isnot tracked and identified in the final TMDLs. Table 14 describes how the nonpoint source load estimates were developed, for additional details, please see the TMDL report.

MOS

While conservative assumptions were used in developing load estimations and in setting up the POTPCB model, an additional explicit margin of safety of 5% was applied to all source categories with an exception of WWTPs.

Daily Load Expression

Fish tissue PCB concentrations and associated human health impacts are reflective of exposure to elevated PCB concentrations over an extended time period. Consequently, the final TMDL allocations were expressed on annual basis. Two additional PCB loading expressions were also provided:

a) average daily loading condition – calculated as the annual load divided by 365;

b) peak one-day loads for the TMDL year – calculated differently for different source categories (for details see Table 16).

Table 16. Methods for Peak One Day Loads

Source	Calculation Method
Tributaries Direct drainage areas CSOs Blue Plains WWTP	Annual maximum daily load in the daily load time series for the TMDL year
Atmospheric deposition Contaminated sites	Annual load divided by 365.
WWTPs (other than Blue Plains)	1.31 x average daily load [a]

[a] A statistical procedure recommended by EPA for identifying daily loads for long term allocations, that relates maximum daily concentrations to a long term average. The procedure is outlined in EPAs 1991 *Technical Support Document for Water Quality-based Toxics Control*.

Overall Reductions

Overall, the PCB TMDL constitutes a 96% reduction of PCBs from the 2005 baseline load of 37,156 grams/year (Figure 7).

Total PCB loads to the tidal Potomac and Anacostia rivers, in g/year

Source category	Baseline (g/year)	TMDL (g/year)	Reduction
Potomac @ Chain Bridge[1]	16,433	329	98%
Lower Basin Tributaries[2]	2,857	407	86%
Direct drainage[3]	10,996	413	96%
WWTP[4]	762	68.2	91%
CSO[5]	3,020	61.2	98%
Atmospheric deposition[6]	3,070	217	93%
Contaminated sites[7]	15.1	10.8	28%
TOTAL[8]	37,156	1,505	96%

[1] The non-tidal Potomac River above Chain Bridge in the District of Columbia. Chain Bridge is the approximate head-of-tide of the tidal Potomac River, or estuary.
[2] The lower basin is that portion of the Potomac River watershed that contributes to the tidal waters, and excludes the watershed above Chain Bridge. The tributaries are the 17 streams in the lower basin defined in the Chesapeake Bay Watershed Model (WM5) as tributaries.
[3] That part of the lower basin watershed that is not in a WM5 defined tributary. Direct drainage areas are located adjacent to the Potomac and Anacostia rivers.
[4] Waste water treatment plant.
[5] Combined sewer overflow system.
[6] Atmospheric PCBs deposited directly on the tidal water surface.
[7] Those sites that have been identified as contaminated by PCBs, some of which have been remediated.
[8] This total does not include changes in the Downstream Boundary condition for reasons explained in Section V(5.2)

Figure 7. Summary of Potomac and Anacostia PCB TMDLs (source Tidal Potomac PCB TMDL)

Implementation

Due to the uncertainty associated with the TMDL loading capacity and load allocations, the three jurisdictions agreed to follow the adaptive implementation guidelines. Collection of additional data, PCB source-tracking, and PCB source minimization and reduction measures will be the focus of the implementation efforts rather than end-of pipe treatment measures.

Potomac and Anacostia PCB TMDL calls for large reductions from a number of upstream nontidal tributaries. While the NPDES permitted point sources in the nontidal tributary have not been assigned a WLA as part of this TMDL effort, it is expected that the upstream facilities will be subject to similar permit provisions as those for facilities with an existing WLA. Additionally, the SC recommended that the jurisdictions, ICPRB, and EPA Region III continue to work together in gathering additional monitoring data to better characterize loadings from non identified sources.

Each of the jurisdictions intends to apply existing programs in the implementation of the PCB TMDL along with follow-up monitoring. All three will utilize high resolution analytical techniques (such as Method 1668A) for sample analysis for surface water, sediment, and permit related monitoring.

Important implementation aspects in the District include implementation of the Long Term Control Plan for CSO Discharges, implementation of its stormwater management plan for MS4 areas, and follow-up monitoring. Authorities in Maryland intend to evaluate the impact of atmospheric deposition on point source loadings including regulated stormwater. Additionally, a monitoring plan is being drafted to evaluate contributions from the upstream nontidal portion of the Potomac and Anacostia watersheds. For WLAs, permitting activities will first address monitoring, followed by minimization and reduction measures. Also, implementation of existing nutrient and sediment TMDLs in the region is expected to result in reductions of PCB loadings. In Virginia, implementation efforts will focus on the impacts of atmospheric deposition to regulated source loadings. The strategy and framework for Virginia's implementation activities is detailed in the *PCB Strategy for the Commonwealth of Virginia*, published in 2004.

Lessons Learned[4]

Participant insights:

Given the complexity associated with the type of pollutant and the interconnected nature of the tidal Potomac subwatersheds, addressing the tidal Potomac and Anacostia PCB listings would have been much more difficult on a jurisdiction by jurisdiction level.

Will additional listings be addressed in a coordinated manner as well?

Maryland and DC have coordinated on other TMDLs developed for the Anacostia River (sediment and nutrient), while the three jurisdictions, EPA, and ICPRB are currently coordinating their work on the PCB TMDL implementation measures.

Additional multi-jurisdictional efforts include: work towards addressing nutrient and sediment impairments in the Chesapeake Bay and a bacteria TMDL for the restricted shellfish harvesting/growing areas of the Pocomoke River.

What were particular difficulties with this approach?

While the TMDL established an allowable PCB load that the watershed can assimilate and still meet water quality standards, the specific ongoing sources are still unknown. The wide historical use of PCBs and the time constraint associated with the consent decree made it difficult to identify ongoing sources on a manageable scale. Thus, the initial stages of implementation will need to focus on further source identification rather than being able to move directly to elimination of the ongoing sources.

Applying a 5% margin of safety to all source categories created an unanticipated situation in which some sources which otherwise would not need to reduce their loads, ended up with a 5% reduction.

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Case Study 6: St. Marys River TMDLs, Indiana

Watershed TMDL at a Glance

Waterbody:
St. Marys and Upper Maumee Rivers

Drainage Area:
8-digit HUC, 814 square miles

Parameters:
E. coli bacteria
Total suspended solids
Nutrients *(total phosphorus)*
Impairments biological communities (IBC)

Development Status:
Approved by EPA Sept. 2006

Developed by:
Indiana DEM

Jurisdictions:
Watershed incorporates all or portions of Adams, Allen, and Wells Counties, as well as City of Fort Wayne

 # Impaired Segments Listed:
TMDL addressed 42 impairments on 34 segments

Technical Approach:
Load Duration Curve

Source Types:
NPS and PS

Background

The St. Marys River watershed is located in northeastern Indiana (Figure 8), covering more than 810 square miles. The river originates in Ohio and flows into Indiana through Adams County. The St. Marys continues in a northwest direction into Allen County where it joins the St. Joseph River at Fort Wayne to form the Maumee River. Land use in the watershed is predominantly agriculture, which represents over 84% of the total land cover. Corn and soybeans comprise the majority of crops produced in the watershed. Other important landuses include urban / residential (7.3%), woodland / forest (7.1%), and wetlands (1.2%). In addition to Fort Wayne, other major communities in the Indiana portion of the St. Marys watershed include Decatur and Berne. Along with the mainstem St. Marys River, this watershed TMDL covers tributaries located in Indiana including Habegger Ditch, Gates Ditch, Blue Creek, Yellow Creek, Martz Ditch, Borum Run, Holthouse Ditch, Kohne Ditch, Gerke Ditch, and Nickelsen Creek.

One of the driving factors for the Indiana Department of Environmental Management (IDEM) to develop a watershed TMDL for the St. Marys was to build on their efforts in preparing a Watershed Restoration Action Strategy (WRAS). The WRAS consisted of two parts: 1) Characterization and Responsibilities, and 2) Concerns and Recommendations. Multiple stakeholders in the watershed were involved in the development of the WRAS. Priority issues identified during the process included data / information collection, targeting areas of concern within the watershed, streambank erosion and stabilization, failing septic systems, and general water quality. Because segments in the St. Marys watershed were on Indiana's §303(d) list, there was an awareness by stakeholders of the potential utility of the TMDL process to address the priority issues. Following publication of the WRAS in 2001, IDEM decided to take advantage of this local interest and initiate development of a broader watershed TMDL for the St. Marys.

Several major stakeholders were also key players in the St. Joseph River Watershed Initiative (SJRWI), a progressive effort to address water quality problems in the basin immediately north of the St. Marys. Included were the Allen County Soil & Water Conservation District, the City of Fort Wayne, the Maumee River Basin Commission, and the Allen County Health District. These groups were very interested in the St. Marys TMDL process, in particular the technical approach that was being contemplated by IDEM to evaluate water quality data. As a result of this interest, these stakeholders became actively engaged in supporting the St. Marys watershed TMDL development effort through major assistance in ambient monitoring and coordinating public involvement activities. For instance, the City of Fort Wayne partnered with IDEM in a collaborative monitoring effort to collect data, which were used in preparation of the TMDL. The Allen County Health Department also provided ambient data from their weekly sampling program conducted over a four year period; information that proved to be quite useful in evaluating conditions and potential sources of E. coli in the St. Marys watershed.

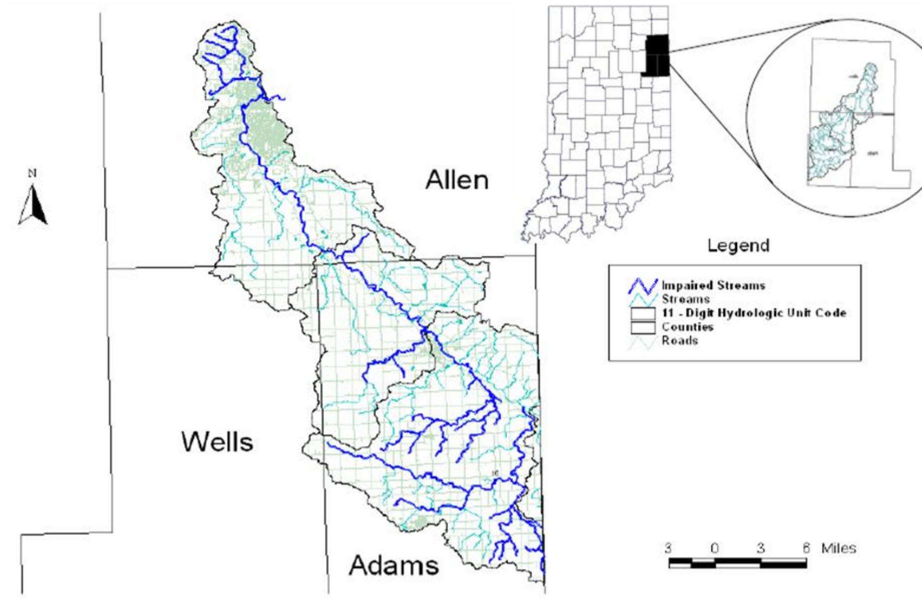

Figure 8. St. Marys River watershed

Impairment Listing Information

Numerous streams in the St. Marys River watershed are identified on Indiana's 2002 and 2004 §303(d) lists as impaired for *E. coli*, impaired biotic communities (IBC), and nutrients. Based on data collected in 2004 by IDEM and the City of Fort Wayne, a reassessment was conducted of the St. Marys watershed. The purpose of the reassessment was to define the extent of the 2004 impairments and in turn confirmed the 2002 listings. The reassessment for the *E. coli* impairment resulted in the addition of the sixteen segments in the St. Marys River watershed to the 2006 §303(d) list. Table 17 summarizes segments and impairments addressed by the St. Marys Watershed TMDL.

In order to assist with the assessment and TMDL development process, the St. Marys River watershed was divided into subwatersheds, a more detailed delineation of smaller catchments. The entire watershed TMDL contains six subwatersheds, which include the mainstem St. Marys, Blue Creek, Yellow Creek, Borum Run, Holthouse Ditch, and Nickelsen Creek.

Table 17. Impaired Segments Addressed by the St. Marys Watershed TMDL.

Waterbody Name	Segment ID Number	Length (mi)	Impairment
St. Marys-Willshire	INA0434_00	2.84	E. coli
St. Marys River	INA0441_00	0.86	E. coli
Blue Creek	INA0442_T1007	11.94	E. coli
Blue Creek	INA0445_T1006	12.28	E. coli, IBC, ammonia, nutrients
Duer Ditch (Adams) and Other Tribs	INA0445_00	9.33	E. coli
Blue Creek Headwaters (Adams)	INA0442_00	8.46	E. coli
Habegger Ditch	INA0443_T1008	5.80	E. coli, IBC, nutrients
Wittmer Ditch, No. 1	INA0443_T1020	2.98	E. coli
Farlow Ditch and Tribs	INA0443-T1019	11.01	E. coli
Gates Ditch	INA0443_T1014	1.17	E. coli

Little Blue Creek	INA0444_00	22.12	E. coli
Borum Run and Tribs	INA0448_00	21.65	E. coli
Yellow Creek	INA0447_00	32.79	E. coli, IBC, nutrients
Martz Creek-Ruppert Ditch and Unnamed Tributaries	INA0447_T1002	9.82	E. coli
Holthouse Ditch-Kohne Ditch	INA0452_00	10.16	E. coli, IBC
St. Marys River	INA0461_T1004 INA0463_T1003 INA0465_T1002 INA0448_T1016 INA0449_T1017 INA0453_T1018 INA0454_T1021	37.70	E. coli
St. Marys River	INA0446_T1015	4.79	E. coli
Unnamed Trib of St. Marys River	INA0454_T1012	2.84	E. coli, IBC
Pleasant Mills and Tribs	INA0446_00	15.30	E. coli
Decatur Tribs	INA0449_00	7.12	E. coli
Gerke/Weber Ditch and Tribs	INA0453_00	17.53	E. coli
Snyder Ditch and Other Tribs	INA0463_00	10.61	E. coli
Junk Ditch	INA0465_00	6.55	E. coli
Spy Run Creek	INA0465_T1011	8.75	E. coli
Unnamed Tributaries to Spy Run Creek	INA0466_T1012	5.08	E. coli
Lowther Neuhaus Ditch	INA0466_T1013	3.03	E. coli
Unnamed Tributary to Lowther Neuhaus Ditch	INA0466_T1014	3.00	E. coli
St. Marys River	INA0466_T1022	0.50	E. coli

Applicable Standards and Water Quality Targets

Beneficial uses and the criteria to protect those uses are identified in Part 327 of the Indiana Administrative Code (IAC). With respect to the St. Marys watershed, full body contact recreation is a designated use *[327 IAC 2-1-3. Sec 3. (a)(1)]*. In addition, all surface waters in the St. Marys watershed must support a well-balanced, warm water aquatic community *[327 IAC 2-1-3. Sec. 3. (a) (2)(A)]*,

For waters in Indiana within the Great Lakes system, numeric criteria have been adopted for *E. coli* bacteria to protect the primary contact recreation use under IAC 2-1-6(a)(3)(d). The criteria, which apply during the recreation season (April 1 – October 31), state that:

> *"E. coli bacteria, using membrane filter (MF) count, shall not exceed one hundred twenty-five (125) per one hundred (100) milliliters as a geometric mean based on not less than five (5) samples equally spaced over a thirty (30) day period nor exceed two hundred thirty-five (235) per one hundred (100) milliliters in any one (1) sample in a thirty (30) day period."*

Narrative criteria were applied to establish numeric targets, which address the impaired biotic communities portion of the St. Marys watershed TMDL. In particular, the relevant narrative criteria state that:

> *"All surface waters at all times and at all places, including waters within the mixing zone, shall meet the minimum conditions of being free from substances, materials, floating debris, oil, or scum attributable to municipal, industrial, agricultural, and other land use practices, or other discharges that do any of the following:…*
>
> *(a)re in concentrations or combinations that will cause or contribute to the growth of aquatic plants or algae to such degree as to create a nuisance, be unsightly, or otherwise impair the designated uses." [327 IAC 2-1-6. Sec. 6. (a) (1)(D)]*
>
> *(a)re in amounts sufficient to be acutely toxic to, or to otherwise severely injure or kill, aquatic life, other animals, plants, or humans." [327 IAC 2-1-6. Sec. 6. (a) (1)(E)]*

Indiana utilized benchmarks to evaluate conditions that may contribute to the biological impairments. Indicators evaluated included total phosphorus, nitrate, dissolved oxygen, pH, algal conditions, and total suspended solids (TSS). IDEM assessed the Index of Biological Integrity (IBI) scores relative to the benchmarks, considering the effect of each indicator on the aquatic ecosystem. Based on a review of all information, IDEM used the benchmarks for total phosphorus (0.3 mg/L), nitrates (10 mg/L), and TSS (30 mg/L) as the numeric TMDL targets, which would address the biological impairments.

Pollutant Sources

The St. Marys watershed contains a mix of both point and nonpoint sources. Source assessment information was analyzed by major subwatershed. Point sources in the St. Marys center on five major categories: municipal wastewater treatment facilities (WWTF), combined sewer overflows (CSO), municipal separate storm sewer systems (MS4), industrial facilities, and confined animal feeding operations (CAFO). Significant nonpoint sources evaluated in the St. Marys watershed TMDL included agriculture, which is the dominant land use, and rural domestic on-site septic systems. Potential contributions from wildlife, especially E. coli, were also evaluated.

Permit files, discharge monitoring reports, land use inventories, air photos, and ambient water quality data were all considered as part of the source assessment process. In addition, IDEM conducted public meetings in the watershed as part of an effort to solicit additional input from stakeholders and other interested groups. Because a large portion of the watershed is in agricultural land use, contributions of E. coli, sediment, and nutrients were looked at closely in the source assessment process. Aerial photos and GIS files were evaluated for significant changes in land use, location of feeding operations relative to receiving waters, and for the distribution of cropping patterns. The presence of CSOs in three communities also prompted a close review of available data regarding these sources.

One concern that emerged from the public information meetings was the potential effect of failing septic systems on streams throughout the watershed. Because of the rural nature of the watershed, the Adams County Health Department conducted studies in 2001, which demonstrated a high likelihood that on-site septic systems represent a major source of E. coli bacteria. Numerous systems were identified, which discharge directly to streams or are directly connected to old agricultural field tiles. In addition, the study identified a number of unsewered communities in the St. Marys watershed, which are neither connected to a municipal treatment plant nor use a complete functioning on-site septic system.

Technical Approach

The St. Marys watershed TMDL used the duration curve framework to link water quality data with the source assessment information. A collaborative monitoring effort on the part of IDEM and the City of Fort Wayne was utilized to generate sufficient ambient data to help identify major sources of concern and effectively target priority areas for subsequent implementation. IDEM sampled fourteen sites, once every other week from March 2004 to October 2004. The City of Ft. Wayne sampled seven of the same sites as IDEM on opposite weeks from July of 2004 through October of 2004

IDEM applied the duration curve framework for the TMDL in an effort to consider the general hydrologic loading conditions of the watershed, and subsequently, to enhance the source assessment process. Pollutant delivery mechanisms likely to exert the greatest influence on receiving waters (e.g., point source discharges, surface runoff) could be matched with potential source areas appropriate for those conditions (e.g., riparian zones, impervious areas, uplands). Patterns associated with certain source categories are often apparent when visually assessing data by flow conditions.

Because the flow duration interval serves as a general indicator of hydrologic loading condition (i.e., wet loading versus dry loading and to what degree), allocations and reduction targets were linked to source areas, delivery mechanisms, and the appropriate set of management practices. The use of duration curve zones (e.g., high flow, moist, mid-range, dry, and low flow) allowed the development of allocation tables, which were used to summarize potential implementation actions that most effectively address water quality concerns.

The analysis was conducted by major subwatershed. Water quality patterns were evaluated for each flow condition. One of the advantages of conducting the subwatershed assessments under the *"umbrella"* of a larger watershed TMDL effort was the ability to consolidate the overall analytical process. This was particularly important in developing estimates of flow on ungaged streams, a critical part of the duration curve method. Furthermore, conducting the overall analysis at the watershed scale enabled the ability to *"cluster"* data sets based on land use similarities. This was particularly useful in evaluating the relative importance of old field tile lines as a delivery mechanism for E. coli from on-site septic systems.

Allocations

Critical source categories receiving allocations for each TMDL are summarized in Table 18. Due to the level of detail at which source allocations were determined, IDEM presented summary allocation tables for LAs and WLAs in the TMDL document. For detailed, source-specific allocations by subbasin, IDEM also developed spreadsheet tables in Microsoft Excel to assist in implementation efforts.

Table 18. Allocated Sources for the St. Marys River Watershed TMDLs

TMDL	Sources receiving LAs [a]	Sources receiving WLAs [a]
E. coli Total phosphorus Nitrate Total suspended solids	Agricultural areas Rural residential areas Woodland / forest areas Background and Other NPS (wildlife)	NPDES permitted facilities (e.g., WWTFs) Combined Sewer Overflows MS4 Stormwater Communities Onsite Sewage Treatment Systems [b] Sanitary Sewer Overflows [b]

[a] Concentration-based TMDL and allocations

[b] Illegal discharges such as those from failing septic systems and straight pipes as well as sanitary sewer overflows received a wasteload allocation of zero.

Implementation

The next phase of this TMDL will be to identify and support the implementation of activities that will bring the St. Marys River watershed in compliance with the *E. coli* criteria, and with the phosphorus, nitrate, and total suspended solids targets. IDEM continues to work with its existing programs on implementation, as well as with local stakeholder groups to pursue best management practices that will result in improvement of the water quality in the St. Marys River watershed. Prior to the TMDL, two 319 grants were awarded to the Adams County Soil and Water Conservation District in 1999 and 2000 to address nutrient management. The information gathered for these grants was useful in building upon existing work in this watershed, which has led to additional 319 grants to fund needed implementation.

More recently, the Allen County Soil and Water Conservation District received a 319 grant to complete a Watershed Management Plan. The Adams County Soil and Water Conservation District and the City of Fort Wayne are both partners in this project. The Watershed Management Plan will be designed to achieve the reductions in pollutant loads called for in the nonpoint source section of the St. Marys/Maumee TMDL. An Implementation Plan will be developed describing in detail all the activities planned during the implementation phase of this project to address the needed reductions.

The Maumee River Basin Commission (including Steuben, Dekalb, Allen, Adams Co) offers a cost-share program for voluntary agricultural land use conversion whereby an agricultural land owner may put in filterstrips, grass buffer zones, French Drains, Wetland Restorations, or Woodland / Reforestation in the floodplain. Though the goal of the program is to reduce flooding, there are water quality benefits.

In addition, a Clean Water Indiana grant has led to the hiring of a local project manager to foster greater adoption and implementation of conservation practices by working with landowners and farmers in the St. Marys and Maumee River watersheds. The focus of this effort is to launch an intensive public education and outreach effort, which creates an awareness of currently available local, state and federal conservation programs. A resource inventory will be developed, which includes water quality conditions and a geo-referenced database of existing conservation practices. The inventory effort will be supported by the Maumee River Watershed Project (MRWP), currently underway by the Ohio Department of Natural

Resources and Ohio NRCS. The inventory will guide the project's efforts by identifying priority areas within the watersheds to maximize environmental benefit. In addition to the public education, technical assistance, and resource inventory assessment efforts, the project will conduct focus group meetings to help identify other local resource concerns that may not be able to be discerned from water quality or related data, such as land-use issues and community development planning. The focus groups will include landowners, farmers, local business owners, local and state agency personnel, local government leaders, as well as concerned citizens. Participants in the focus groups will be encouraged to assist with the development of Watershed Management Plans (WMP) as WMP Steering Committee members.

Lessons Learned

IDEM continues to take advantage of opportunities for large-scale analysis because it allows for a more coordinated response to water quality issues in terms of collecting data, analyzing pollutant sources, and implementing solutions. Critical lessons learned by the program are summarized below.

The value of utilizing local interest cannot be overstated. Incorporating any and all information that can be gathered often builds credibility and trust with local stakeholders. It is important to ensure that stakeholders are engaged in the process without being overwhelmed, as well as to listen to their thoughts, ideas, and perspectives. In addition to meeting regulatory requirements, the TMDL process should strive to fit local needs and interest.

The ability to "cluster" data sets, particularly when several counties and government agencies are involved, maximizes use of available information and enables efficient targeting of priority source areas. Coordinated monitoring and assessment between multiple counties and governmental agencies is time intensive. However, good communication coupled with continued coordination helps ensure stakeholder "buy-in" as the TMDL is developed and sets the stage for a smooth transition into implementation.

Successful implementation of the TMDL is dependant on the involvement/participation of local stakeholders. Initiating the interest, and maintaining that interest in the project is a key element needed to support successful TMDL implementation. Statewide, Indiana has hired five watershed specialists to take the lead on these types of initiatives.

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Case Study 7: Tualatin River TMDLs, Oregon

Watershed TMDL at a Glance

Waterbody:
Tualatin River and tributaries

***Drainage Area*:**
Approximately 710 square miles

Parameters:
Temperature
Dissolved Oxygen
Bacteria
Phosphorus

Development Status:
Revised / Finalized 2001

Developed by:
Oregon DEQ

Jurisdictions:
Watershed incorporates all or portions of 15 cities, including portions of Portland

Impaired Segments Listed:
Temperature: 19
Bacteria: 26
Dissolved Oxygen: 22 plus mainstem
Phosphorus: 8 (chlorophyll a)

Technical Approach*:*
Temperature: Continuous simulation model (Heat Source)
Bacteria: Event based unit load model
Dissolved Oxygen and related parameters: Steady State QUAL2E simulation (tributaries) and dynamic simulation (mainstem) using CE-QUAL-W2

Source Types*:*
NPS and PS

Background

The Tualatin River is a major tributary of the Willamette in the Northwest corner of Oregon. The watershed lies almost entirely within Washington County with small portions in Multnomah, Clackamas and Yamhill Counties. It is approximately 83 miles in length with a flat gradient for most of its length. Major tributaries include Scoggins, Gales, Dairy, Rock and Fanno Creeks. Summer flows are supplemented by releases from two Reservoirs (Scoggins and Barney). The urban areas in the watershed are rapidly growing and are served by four wastewater treatment plants (WWTPs) which are operated by the public utility Clean Water Services (CWS). In addition, CWS also has two industrial stormwater permits and is a co-permittee on a Municipal Separate Storm Sewer permit (MS4) permit. The Tualatin drains urban, agricultural, and forested lands.

The primary driver for developing this TMDL on a watershed-scale was political, as it was one of the first TMDLs developed in Oregon, and was the focus of the initial 1986 lawsuit. Although the litigation was concerned with nuisance algal growth and phosphorus in the lower Tualatin and Lake Oswego, several factors were clear from the start of TMDL development. The dominant nutrient sources during the summer low flow period were two major advanced wastewater treatment facilities operated by the Unified Sewerage Agency (USA) of Washington County (now Clean Water Services, or CWS). However, significant nonpoint source loads from multiple sources (urban stormwater, agriculture, and forest lands) were delivered during major rain events. Also, flows in the Tualatin River are managed by releases from a multiple purpose reservoir (Scoggins) and diversions from the Trask Basin through Barney Reservoir, making water quantity a significant issue. Because of the high visibility the litigation was receiving, and because of major stakeholder interest from multiple parties, the Oregon Department of Environmental Quality (DEQ) decided that developing the TMDL for the entire Tualatin was the only logical path to take. Two major advisory committees were formed; in addition to DEQ sampling & analysis, CWS also operated a large ambient WQ monitoring network in the basin and had a history of data sharing with DEQ. The initial Tualatin experience of developing TMDLs on a watershed basis set the tone for Oregon’s statewide program as it moved forward (including the 2001 revision to the Tualatin TMDL).

Impairment Listing Information

Population growth in the watershed has contributed to water quality decline. In 1988, the Oregon Department of Environmental Quality (DEQ) developed an ammonia TMDL to address problems with low dissolved oxygen (DO) in the mainstem river and total phosphorus TMDL to address high pH and nuisance algal growth occurring in the reservoir like section between river miles 24 and 3.4. The ammonia TMDL was largely addressed through upgrades to the WWTPs in the watershed. The phosphorus TMDL involved both point and nonpoint sources. WWTPs upgraded processes to increase phosphorus removal and BMPs were implemented by Designated Management Agencies (DMAs) throughout the watershed, which resulted in significant decreases in overall phosphorus concentrations in both the mainstem and the tributaries.

While nuisance algal blooms were reduced as a result of implementation measures from the 1988 TMDLs, the watershed is not meeting phosphorus limits set by the TMDL. The Tualatin Basin Policy Advisory Committee was appointed to develop recommendations to DEQ regarding the TMDLs. Concurrently, Oregon updates to the 303(d) list included additional listings for temperature, bacteria, dissolved oxygen, pH, biological criteria, arsenic, iron, and manganese.

In 2001, new TMDLs were issued for the Tualatin watershed, updating the ammonia and phosphorus TMDL from 1988 and instituting new TMDLs for temperature, bacteria and dissolved oxygen (volatile solids). Based on further data analysis and assessment of background conditions in the watershed, TMDLs were deemed not necessary for arsenic, iron, manganese, and low pH. Impairment of biological criteria was deemed to be addressed by temperature and DO TMDLs.

Applicable Standards and Water Quality Targets

Because multiple listings and parameters of concern were involved in the TMDLs for the Tualatin watershed, the array of uses, standards and applicable targets is wide. Oregon DEQ issued a single TMDL report document that discussed the individual TMDLs separately. However, the analysis performed to develop the TMDLs for parameters and impairments that are related (e.g., DO, temperature, phosphorus) was not done separately. For example, to account for all potential factors associated with the DO listing it was necessary to evaluate multiple factors such as pH, phytoplankton growth, temperature, oxygen demanding substances, and nutrient levels. While the DO TMDL specifically identifies loading capacities for ammonia and sediment oxygen demand, the loading capacities for the related parameters of temperature and phosphorus are presented in those TMDLs. Table 19 summarizes the applicable water quality standards and targets of each TMDL analysis.

Table 19. Applicable Standards and TMDL Targets

Temperature	Standard	No measurable increase from anthropogenic activities
	Targets	Multiple, determined by designated use
	Surrogate	Effective shade (for nps loading)
DO [a]	Standard	Numeric, minimum levels specified for salmonid spawning, cold-water, cool-water and warm-water aquatic life
	Targets	salmonid spawning – 11.0 mg/L cold-water – absolute minimum = 8.0 mg/L [b] cool-water - absolute minimum = 6.5 mg/L [c] warm-water - absolute minimum = 5.5 mg/L [d]
Phosphorus [e]	Standard	Nuisance phytoplankton growth rule Numeric pH criteria
	Targets	pH 6.5 - 8.5 Chlorophyll *a* action level = 15 ug/L or that associated with natural phosphorus loading conditions Background phosphorus concentrations Tributaries from 0.04 mg/L – 0.19 mg/L Mainstem from 0.04 mg/L – 0.11 mg/L
Bacteria	Standard	Numeric E. coli; Year-round
	Targets	30-day log mean = 126 organisms / 100 mL (5 sample minimum) Single sample maximum = 406 organisms /100 mL

[a] (related to ammonia, SOD, phosphorus, and temperature)
[b] DEQ Discretion: 30-day mean minimum = 8 mg/L; 7-day mean minimum = 6.5 mg/L; absolute minimum = 6 mg/L
[c] DEQ Discretion: 30-day mean minimum = 6.5 mg/L; 7-day mean minimum = 5 mg/L; absolute minimum = 4 mg/L
[d] DEQ Discretion: 30-day mean minimum = 5.5 mg/L; absolute minimum = 4 mg/L
[e] (related to D.O., pH and chlorophyll *a*)

Pollutant Sources

For each TMDL, pollutant sources include both point and nonpoint sources. Bacteria, DO-related, heat loading and total phosphorus sources all include forestry, agriculture, transportation, rural residential, urban, industrial discharge, and WWTPs. Different methods for developing loading estimations were applied for each pollutant.

Temperature

According to the TMDL, the largest source of heat loading is from nonpoint sources, with anthropogenic nonpoint source heat loading as the dominant pollutant source. NPDES point source loading is relatively small. Nonpoint source thermal loading is attributed to lack of riparian shading (e.g, near-stream vegetation disturbance and removal).

Bacteria

Source assessments conducted for the bacteria TMDL examined run-off related and non-runoff related loading. This analysis indicated that while criteria exceedences occur year-round, higher concentrations are associated with wet weather across the watershed. Based on the data, instream bacteria levels, especially in urban areas are quite high during runoff events, implicating urban runoff as one of the most significant sources of bacteria loading. Ultimate sources of urban loading probably include pet waste, illegal dumping, failing septic systems and sanitary sewer cross connections and overflows.

DO

Factors affecting DO levels instreams of the Tualatin watershed include nitrification, carbonaceous biochemical oxygen demand (CBOD), algal growth, sediment oxygen demand (SOD), and temperature. DEQ conducted an assessment of critical DO factors in each watershed based on beneficial use categorization to identify the most critical sources for control. In Gales Creek, ammonia was identified as a minor contributor to the DO problem while SOD was identified as a significant contributor. Temperature was also identified as a factor. In Fanno Creek, algae, BOD and SOD were considered critical factors to the overall DO levels as was the case for Lower Rock and Beaver Creeks. For Scoggins Creek, the primary source appears to be low DO waters discharged from Scoggins Dam.

The primary pollutants affecting DO levels in the tributaries are solar loading (increased water temperatures) and SOD. Modeling of the mainstem Tualatin suggests that the most important sources of oxygen demand include (in order of importance) SOD, CBOD, algal respiration, zooplankton respiration and nitrogenous biochemical oxygen demand (NBOD). Important sources of the factors listed above include runoff and effluents from WWTPs.

Phosphorus

Important sources of phosphorus are identified as groundwater, which is higher than previously attributed in the original TMDL, WWTPs, only two of which discharge during the summer TMDL period, and runoff from urban, agricultural and forested lands. Other smaller but potential sources include failing septic systems, instream and riparian phosphorus loading under anoxic conditions, tile drains and other permitted point sources.

Roles and Responsibilities

Oregon DEQ was responsible for developing the TMDL. In addition to state funding, a lawsuit against USA in the 1990's regarding compliance issues over their treatment facilities resulted in additional financial resources being made available to support a DEQ Tualatin Coordinator.

Stakeholder Involvement and Implementation

The original TMDL set an expectation for heavy stakeholder involvement. Both Citizen and Technical Advisory Committees were established in the first TMDL. This basic framework carried forward and resulted in recommendations for the revised TMDL.

Technical Approach

As has been mentioned, the analyses performed to develop the Tualatin TMDLs for DO, Phosphorus and Temperature were linked, either through concurrent modeling analysis or through the application of similar assumptions and targets. The bacteria TMDL utilized an event based, unit loading model which uses storm volumes, runoff concentrations for land uses, and bacteria die off rates to predict concentrations in streams. Input data for the bacteria modeling was derived from GIS databases with information on soils, land use, precipitation patterns, watersheds and distance from streams.

In comparison to the bacteria analysis, more complex modeling was performed for the temperature and DO modeling, which incorporated the phosphorus analysis. For the temperature TMDL, a continuous simulation model called Heat Source was developed to identify loading capacities and allocate to sources. DO modeling was conducted using a modified version of the U.S. Army Corps of Engineers model CE-QUAL-W2. The model provides a good fit to the measured data for streamflow, water temperature, and water quality constituents such as chloride, ammonia, nitrate, total phosphorus, orthophosphate, phytoplankton, and dissolved oxygen. The CE-QUAL-W2 model utilized certain temperature related inputs from the Heat Source temperature model. For additional details regarding each of the modeling analyses, the reader is refered to the TMDL report and its supporting appendices. The DO modeling is futher detailed in a USGS report, Modeling Water Quality in the Tualatin River, Oregon, 1991–1997 (Rounds and Wood 2001).

Allocations

Allocations for each of the TMDLs, Temperature, Bacteria, DO and Phosphorus are made for both point and nonpoint sources. Important factors are noted below.

Temperature

While the point source load is not the predominant current source of thermal load to the system (representing approximately 7%), under TMDL conditions, it represents a significant source and thus receives a significant reduction relative to currently permitted levels, approximately 95%. Fifteen facilities received WLAs. Background nonpoint sources were given a load allocation equal to the system potential, which is defined as the median concentration of total phosphorus during non-runoff periods. Anthropogenic nonpoint sources were given a load of zero.

The loading capacity for heat energy as expressed in the TMDL (kcal / day) is of limited value for management activities, thus the TMDL also allocates "other appropriate measures" as provided under EPA regulations [40 CFR 130.2(i)]. As a result, percent effective shade (percent reduction in potential solar radiation load delivered to the water surface) is used to translate the reduction targets into measurable practices (restoration, riparian planting, etc.) that can be expected to meet those targets. Allocations derived for the temperature TMDL were also used in the analysis to derive the DO TMDL.

Bacteria

Allocations during the non-runoff periods are based on the single sample maximum of 406 counts / 100 mL. Combined with reductions in septic system loads, illegal dumping, and CAFO loads, which received allocations of zero, this level of allocation is expected to achieve both the 406 single sample maximum and the 126 counts / 100 mL criterion.

Allocations during the runoff periods are set to a geometric mean of 126 counts / 100 mL as measured at the mouth of each fifth-field watershed. Instream samples taken during storm events provide sufficient data (5 samples or more per storm event) to use this criterion. This criterion is used because the load allocations are derived using event mean concentrations (EMCs) for storm events. The achievement of this loading capacity is also expected to achieve the single sample criterion of 406 / 100 mL. LA and WLAs are specified for the entire year; however specific allocations are identified for the summer (May1 – Oct. 31) and the Winter (Nov.1 – Apr. 30) to reflect seasonal patterns and to coincide with seasonal periods for other TMDLs.

DO

LAs and WLAs for parameters related to DO were derived from model results. Allocations for ammonia and SOD are presented in the DO TMDL, while allocations for temperature and phosphorus are presented in those sections. LA from the previous ammonia TMDL were deemed to be still appropriate; WLAs were updated. SOD reductions were addressed through allocations for settleable volatile solids and total phosphorus. Due to a lack of data in the watershed on levels of settleable volatile solids, DEQ expected to base initial allocations on a similar parameter for which data exist, such as total suspended solids (TSS).

Phosphorus

LAs and WLAs for phosphorus are related to issues addressed in the DO TMDL and will help ensure that large algal blooms on the mainstem are controlled as much as possible, minimizing impacts on SOD from algal detritus. Seasonal LAs and WLAs were assigned to meet the background level loading capacities identified in the TMDL analysis.

Implementation

In Oregon, water quality management plans (WQMP) are designed to reduce pollutant loads to meet TMDLs. A WQMP was developed with strategies for how the Tualatin River TMDLs will be implemented. Portions of the WQMP were developed by the various DMAs who share responsibilities for managing areas within the Tualatin watershed and thus, for assisting with implementation efforts. Critical elements of the WQMP include programs developed in response to the earlier ammonia and phosphorus TMDLs. In addition, structured programs on which DEQ intends to rely for implementation include the NPDES and Water Pollution Control Facility permit programs, local ordinances, and programs within the state’s Departments of Forestry and Agriculture.

A particularly novel and interesting element of the implementation effort has been the state’s effort to authorize water quality trading to achieve portions of the load reductions required in the temperature and DO TMDLs. With the help of grant funding from EPA, Oregon DEQ began developing a prototype trading program with Clean Water Services, which operates four WWTPs and implements an MS4 permit in the watershed. In 2005, DEQ issued CWS a revised NPDES watershed-based permit that combined its formerly separate WWTP and MS4 permits into a single permit.

Watershed Based Permit

The new single permit issued to CWS includes provisions for trading to implement the required WLAs for the DO and temperature TMDLs. The permit establishes the authority for trading and spells out the specifics of DO related trades in an appendix. In addition, it lays out the basics of temperature trading, which were to be augmented in a detailed Temperature Management Plan (TMP) to be developed by the permittee.

DO Trading

Permit provisions allow for CWS to shift loads of oxygen demanding substances between two facilities (the Rock Creek and Durham treatment plants). The permit contains no numeric limits for BOD and ammonia but rather model-derived formulas that define allowable daily and weekly mass loads of ammonia, NBOD and CBOD for the plants. Modeling was performed to determine what levels and combinations of BOD and ammonia can be released from the plants without violating criteria at Oswego Dam, the location where oxygen levels have consistently been lowest. Formulas in the permit cover varying stream conditions, accounting for instream flows, DO levels, months and water temperature.

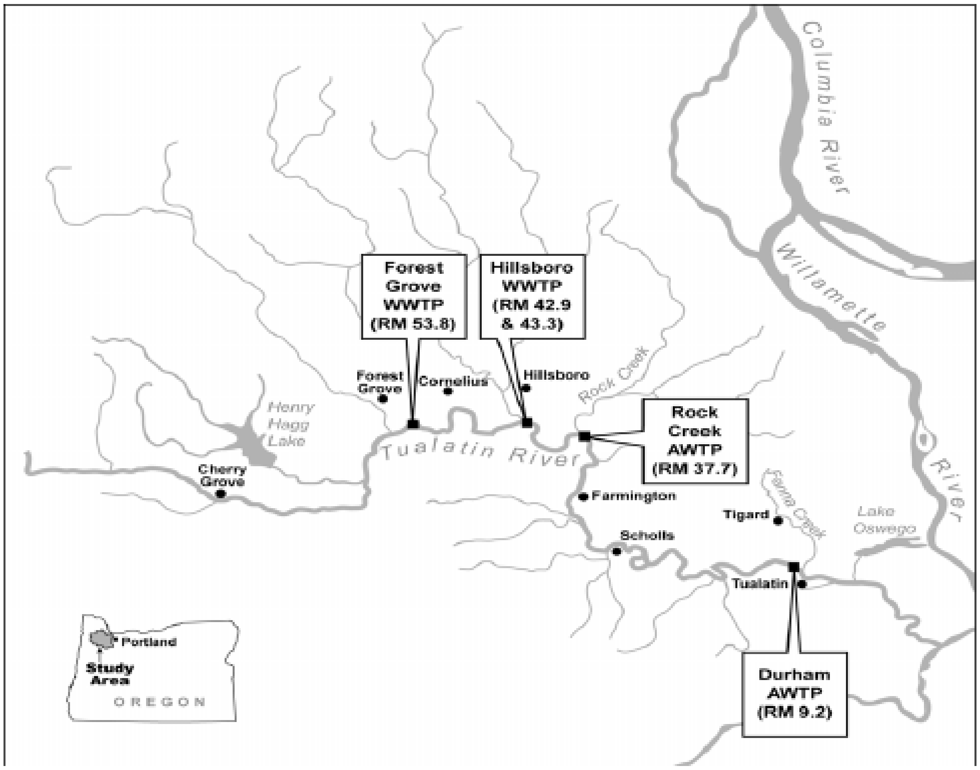

Figure 9. Locations of WWTPs

Temperature

The permit provisions that cover temperature trading include the following options:

- Increase riparian shade with plantings
- Augmenting flows with cooler waters
- Effluent reuse
- Other mechanisms as identified by CWS

In its detailed TMP, the CWS discusses various options available for controlling temperature, some involve trading while others do not. Non-trading options include use of cooling equipment, effluent reuse to irrigate non-food crops, and source control. Trading options include flow augmentation (CWS owns water rights at Scoggins and Barney reservoirs) and riparian shade creation.

With regard to flow augmentation, CWS would receive credits toward its required reductions by releasing reservoir waters into the relatively warm mainstem. The TMP includes a methodology for calculating the impacts of flow augmentation for purposes of compliance.

Credits for shading are generated through programs that provide incentives to landowners to plant shade-producing vegetation along streams. The TMP provides a calculated estimate of the stream miles to be planted each year. Once shade is established, CWS's efforts to demonstrate compliance shift from showing adequate number of surviving plantings to showing how much shade they are producing. Annual report submission will detail the credit trading activities for the previous year. To compensate for the fact that the heat offset will take years to establish through shading, DEQ determined that at the end of 20 years, the load offset must actually be two times the actual excess thermal load.

Based on calculations by CWS, after accounting for heat reductions resulting from flow augmentation, approximately 35 miles of stream must be shaded in the 5 year permit period to reach the offset goal. CWS is implementing the riparian shading program by enhancing US Department of Agriculture's existing Conservation Restoration and Enhancement Program (CREP) which provides financial incentives to landowners to implement restoration projects such as riparian shade plantings. Enhanced CREP cost breakdowns are shown in Table 20.

Table 20. Estimated 5-Year Costs for Enhanced CREP

	Costs	**%**
Clean Water Services	$820,000	37
Partners [a, b]	$1.38 million	63
Five-year cost total	$2.2 million	100

[a] USDA still provides funding for the basic CREP program

[b] Partners include USDA, Oregon Department of Forestry, Oregon Water Trust, Tualatin Soil and Water Conservation District

The total cost of $2.2 million is in stark contrast to estimates for mechanical effluent refrigeration of more than $50 million, plus yearly operations and maintenance costs of $2 million. (Source: Charles Logue, CWS, 2nd National Water Quality Trading Conference, May 2006)

Lessons Learned

The Tualatin provides a good example of how TMDLs can work to improve water quality in a watershed as there have been measurable improving trends in the parameters that have been addressed. It is also a good example of the need for adaptive management and the need to revisit the TMDL and implementation structure, on a periodic basis, in the case of Oregon DEQ, this is about every ten years.

Adaptive Management

Oregon DEQ's experience with the Tualatin TMDLs and implementing a statewide program is that TMDLs are something that need to be revisited about every 10 years. Based on comments from staff involved in the development, implementation and revision of the Tualatin TMDLs, DEQ's watershed TMDL history has seen TMDLs (for the Tualatin) initially developed in 1988, modified in 2001 and which are now being proposed for modification in 2009. DEQ has been trying to work this into its Watershed Approach where they revisit TMDLs in the year prior to permit renewals. DEQ now has the Tualatin Subbasin on a schedule for permit renewal in 2010 and will modify the TMDL in 2009. According to staff, while it would be nice to revisit each TMDL on the 5-year cycle that permits are scheduled to be renewed, they have found that there aren't the resources to do that and a 10-year cycle seems to appropriate to allow time for implementation and development of new information/tools, etc.

Updating the existing TMDL

The process for updating the existing ammonia and phosphorus TMDLs was relatively straightforward and easy. The various DMAs were involved in the collection of the data, were able to see the results and had experience with the implementation. Similarly, environmental groups had a chance to see the data and the results of implementation as well. While there was some controversy around the revision, it was minor compared with the controversy around the new TMDLs - temperature, bacteria and DO in the tributaries.

Between 1988 and 2001, CWS supported ongoing work by USGS to refine the Tualatin mainstem model. Similarly, they continued to invest in expanding and improving the mainstem and tributary models for TMDL updates in 2009. It should be noted that the models were also enhanced for other reasons as well - mainly to help in CWS' efforts to understand and better manage the river through flow augmentation, treatment, etc. Again, this all feeds into the first lesson above, that a 10 year TMDL revisit (adaptive management) appears appropriate as there is new information, new or refined analytical techniques, policy changes, and lessons learned in watershed management that minor or major modifications to the TMDL are often needed.

Particular Difficulties

One specific difficulty related to development of the Tualatin TMDLs, according to staff, is that the Tualatin is often on the leading edge of TMDL development in the state. It often is one of the first subbasins receiving a type of TMDL (e.g., TP, NH3 in 1988, temperature, bacteria, and settleable volatile solids in 2001.) Being one of the first, it becomes the "test case" for working out targets, allocations and working them into permits (including MS4 permits) and NPS implementation mechanisms, which is always challenging. In addition, the presence and continued involvement of a very active environmental watchdog group that has litigated in the past, makes things very challenging. Finally, working WLAs into MS4 permits continues to be a challenge.

Implementation

DEQ's report, *Water Quality Credit Trading in Oregon: A Case Study Report* (Oregon DEQ, date unspecified) identifies several lessons learned since the trading agreement with CWS was finalized. Trade efforts should seek to encourage restoration of contiguous areas to produce a higher value benefit. For the trading program, DEQ offers that providing additional incentives for higher value riparian shading projects might encourage this. Implementation efforts, whether related to trading or not, will tend to be enhanced when high priority areas can be identified and addressed early.

Because the trading program relies on planting trees to provide shade, it is important that those trees be allowed to grow and remain at the site in order to provide the needed shading services. Interestingly, while conservation easement options are provided in the Enhanced CREP program to encourage farmers not to remove trees, landowners are reluctant to relinquish longterm control of their property. Only one farmer participated in a conservation easement, committing only one acre of land.

DEQ also notes that water quality standards and their interpretation in the permit process impacts the achievability of potential trading schemes. The temperature standard under which the trading agreement was negotiated required that a source develop a temperature management plan within the five-year permit cycle. The current stipulation is that the source must meet wasteload allocations within a single permit cycle. As trees cannot be expected to provide the needed amount of shade in 5 years, the current situation would preclude riparian restoration as an option.

Finally, trading can be a way to focus limited resources in areas where they will do the most good. The Tualatin watershed has many miles of deteriorated streams; point sources represent a relatively small portion of the problem. Requiring point sources simply to reduce their loads at the discharge point misses the real problem, which is that riparian areas all over the watershed are deteriorated.

Implementation work related to bacteria has been tied to continuing to sewer unsewered areas, correct problems with aging infrastructure, and implementing MS4 storm water permits. Additional work has been done to do DNA testing of bacteria to determine the source - avian sources were found to be a high contributor in some areas. Additionally, further work has been done by CWS on the influence of flow on the low DO concentration found in tributaries with some work investigating ways to get additional flow in the tributaries and resultant changes in the DO. DEQ will be exploring ways to make the tributary DO TMDL more flow based.

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Case Study 8: Virgin River TMDLs, Utah

Watershed TMDL at a Glance

Waterbody:
Virgin River

Drainage Area:
2,800 square miles

Parameters:
total dissolved solids, temperature, total phosphorus, and dissolved oxygen

Development Status:
Approved by EPA on September 20, 2004

Developed by:
Utah Department of Environmental Quality
Washington County Water Conservancy District

Jurisdictions:
Utah's portion of the watershed drains portions of 3 counties

 # *Impaired Segments Addressed:*
2002 303(d) List included 8 impaired streams

Technical Approach:
Streams – Load Duration Curve
Reservoirs – BATHTUB
Urban Runoff – Simple Method

Source Types:
PS and NPS

Background

The Virgin River watershed, part of the larger Lower Colorado River–Lake Mead watershed, occupies approximately 2,800 square miles within Utah's borders (Figure 10). The majority of the watershed (approximately 76 percent) is in Washington County, while 19 percent is in Kane County and 5 percent is in Iron County. The principal drainage for the watershed is provided by the Virgin River and its tributaries: the East Fork Virgin River, North Fork Virgin River, North Creek, La Verkin Creek, Ash Creek, Fort Pearce Wash, Santa Clara River, and Beaver Dam Wash. Although permanent flow is observed year round in the Virgin River and its major tributaries, the majority of the watershed is drained by intermittent streams that are dry most of the year. The watershed contains artificial canals and ditches, as well as diversions and reservoirs, for agricultural irrigation and drinking water supplies. The major land uses in the watershed include shrubland and forest and the Bureau of Land Management is responsible for managing 43 percent of the land in the Virgin River watershed. Only 23 percent of the land in the watershed is privately owned, with agricultural and residential land uses each approximately one percent of the total watershed land uses. However, accessibility to larger metropolitan areas in surrounding states and favorable climate conditions are causing the watershed to experience rapid population growth.

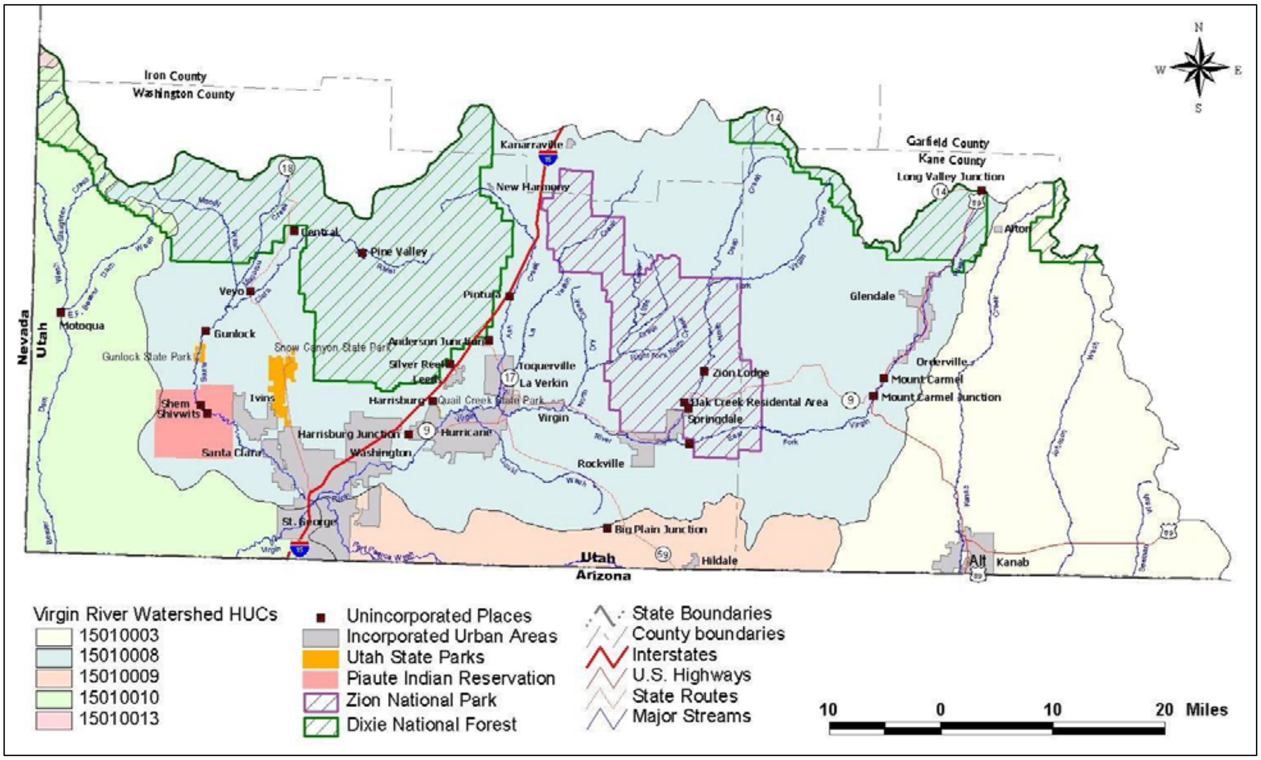

Figure 10. Virgin River Watershed, Utah

In Utah, the development of TMDLs is integrated within a larger watershed management framework that emphasizes a common-sense approach aimed at protecting and restoring water quality. Key elements of this approach include:

- Water quality monitoring and assessment
- Local stakeholder leadership
- Problem targeting and prioritization
- Integrated solutions that coordinate multiple agencies and interest groups.

Stakeholder involvement for the TMDL development process tapped into an existing watershed stakeholder group referred to as the Virgin River Watershed Advisory Committee (VRWAC). The VRWAC initiated watershed management planning activities in 1998, including conducting public outreach and involvement activities to educate watershed stakeholders on issues related to water quality, water quantity, land use, and groundwater. In 2002, the VRWAC decided to take a more comprehensive approach to watershed management planning and hired a consultant to facilitate the development of the locally-led watershed management plan, a drinking water source protection plan for the three surface water intakes in the watershed, as well as TMDLs for impaired segments. As a result, stakeholder involvement in the Virgin River watershed TMDL development process was also integrated with other watershed management activities.

Impairment Listing Information

Various segments of the Virgin River are listed on Utah's 2002 Section 303(d) list of impaired waters for total dissolved solids, dissolved oxygen, temperature, and total phosphorus. The beneficial uses that are listed as impaired include cold water aquatic life (3A), other aquatic life (3C), and agriculture (4). Several of the listings are due to naturally high concentrations of TDS and therefore the adoption of site-specific criteria are being recommended as part of the Total Maximum Daily Load (TMDL) development process. Other listings (i.e., for high temperatures) were made in error and are being corrected.

Beaver Dam Wash, from Motoqua to the Utah/Nevada state line, is listed on Utah's 2002 303(d) list as impaired for temperature for the beneficial use of cold water game fish and other cold water aquatic life

(3A). However, DWQ believes that high water temperatures are naturally occurring and the impairment is due to an incorrect beneficial use designation, rather than an actual water quality impairment.

Applicable Standards and Water Quality Targets

Designated Use	Description	TDS	Temperature	Dissolved Oxygen[1]	Selenium	TP Pollution Indicator
3A	Cold water aquatic life	—	Max.: 20 ºC Max. change: 2 ºC	30 day avg: 6.5 7 day avg: 9.5/5.0 1 day avg: 8.0/4.0	4 day avg: 4.86(μg/L) 1 hour avg: 20 (μg/L)	0.025 mg/L (max) for lakes
3B	Warm water aquatic life	—	Max.: 27 ºC Max. change: 4 ºC	30 day avg: 5.5 7 day avg: 6.0/4.0 1 day avg: 5.0/3.0	4 day avg: 4.86 (μg/L) 1 hour avg: 20 (μg/L)	0.025 mg/L (max) for lakes
3C	Other aquatic life	—	Max.: 27 ºC Max. change: 4 ºC	30-day avg: 5.0 1 day avg: 3.0	4 day avg: 4.86 (μg/L) 1 hour avg: 20 (μg/L)	
4	Agricultural use	1200 mg/L (max)			0.05 mg/L (Max)	—

Pollutant Sources

Pollutant sources contributing to impairments in the Virgin River watershed include both point and nonpoint sources. Field assessments supplemented with an aerial reconnaissance and photo analysis facilitated a better understanding of pollutant sources in the watershed. Sources identified through the field assessments included animal feeding operations (AFOs), wastewater lagoons, industrial sources, areas of disturbance, streambank erosion, agricultural practices, agricultural return flows, sand and gravel operations, and natural sources. Other sources contributing to impairments in the watershed include septic systems, urban wet weather and dry weather flows, and geothermal activities. Different methods were applied for developing loading estimations for pollutants associated with each source category.

Total Dissolved Solids

The TMDL identifies a variety of factors affecting total dissolved solids include natural erosion, geology, geothermal, stormwater runoff, AFOs, irrigation return flow, reservoirs, streambank erosion, exotic vegetation, and sand and gravel mining. According to the TMDL, TDS loads in North Creek, a segment of the Santa Clara River (from Gunlock Reservoir to the confluence of the Virgin River), and the lower Virgin River are primarily due to natural erosion, geology, and geothermal sources. Anthropogenic nonpoint and point sources are relatively small percentages of the overall load.

Temperature

According to the TMDL, factors affecting heat loading include natural conditions and reservoir management. The aerial and ground-based field assessment revealed a healthy riparian stream corridor and natural channel geomorphology for the Santa Clara River segment listed as impaired due to temperature. largest source of heat loading is from nonpoint sources, with anthropogenic nonpoint source heat loading as the dominant pollutant source. NPDES point source loading is relatively small. Nonpoint source thermal loading is attributed to lack of riparian shading (e.g, near-stream vegetation disturbance and removal). For the Beaver Dam Wash subwatershed, DWQ conducted a specific vegetative cover and temperature data analysis in to determine if the appropriate beneficial use was assigned to this waterbody.

Selenium

According to the TMDL, the largest source of selenium in the listed segment of the Santa Clara River is from streambank erosion, with additional significant contributions from irrigation return flows. NPDES point source loading from permitted stormwater sources is relatively small.

Total Phosphorus and Dissolved Oxygen

According to the TMDL, streambank erosion, livestock, and failing septic systems are the predominant sources of total phosphorus for the Baker Dam and Gunlock Reservoirs. Internal loading is also a significant source for Gunlock Reservoir. Streambank erosion is due to upstream sand and gravel mining operations. The TMDL does not attribute any of the phosphorus load to point sources.

TMDL Development Approach

The technical approaches to develop the Virgin River watershed TMDLs varied based on type of impaired waterbody. For streams, a statistical approach to linking sources and water quality was chosen rather than a watershed model due to modeling challenges associated with diversions, canals, and irrigation pathways that have altered the natural flow of the Virgin River, as well as seasonal snowmelt events. The statistical approach used to calculate the TMDLs for impaired stream segments in the Virgin River watershed included the following steps:

1. A flow duration curve for each segment was developed using the available flow data. This was done by generating a flow frequency table that consisted of ranking all of the observed flows from the least observed flow to the greatest observed flow and plotting those points.
2. The flow curve was translated into a load duration (or TMDL) curve by multiplying each flow by the water quality standard and a conversion factor and plotting the resulting points.
3. Each water quality sample was converted to a daily load by multiplying the sample concentration by the corresponding average daily flow on the day the sample was taken. The load was then plotted on the TMDL graph.
4. Points plotting above the curve represent deviations from the water quality standard and unallowable loads. Those plotting below the curve represent compliance with standards and represent allowable daily loads.
5. The area beneath the TMDL curve is the loading capacity of the stream. The difference between this area and the area representing current loading conditions is the load that must be reduced to meet water quality standards.
6. Average annual loads were calculated by using a weighted-average approach based on the total number of days associated with each flow percentile.

Data used for the load duration curve approach includes daily flow records for USGS gages and water quality data collected by DWQ. Where the period of records for the USGS flow gage and the DWQ water quality station do not coincide with each other, DWQ instantaneous flow values supplemented the USGS daily flow records for use in the load duration analysis.

The load duration curve approach is not appropriate for calculating loading capacities for reservoirs. Therefore, the BATHTUB model was selected to develop total phosphorus TMDLs for Gunlock and Baker Dam reservoirs. For Gunlock Reservoir, the BATHTUB model facilitated determining the internal total phosphorus loading. The phosphorus sedimentation term in BATHTUB is net sedimentation–that is, it represents the rate of phosphorus settling minus the rate of resuspension/regeneration from the sediment. The TMDL analysis interpreted internal loading as the difference between an estimate of phosphorus deposition based on a phosphorus budget model (Chapra, 1997) and the BATHTUB net sedimentation rate.

Stakeholder coordination in the TMDL development process occurred through VRWAC activities planned and implemented to support comprehensive watershed management activities, including the development of a locally-led watershed management plan and drinking water source protection plans for three surface water intakes. Stakeholders contributed to the development of the Virgin River watershed TMDLs through their participation in several meetings at key junctures in the project:

- Project Kickoff Meeting on June 11, 2002
- Field Survey Meeting on October 10, 2002
- Key Issues Public Meetings on July 9th and 10th, 2003
- TMDL Overview and Status Report Meeting on October 27, 2003

Allocations

The TMDL report for the Virgin River watershed TMDLs presents allocations for each of the impaired segments. The source assessment and data analysis for several of the listed segments in the Virgin River watershed revealed that exceedances of water quality standards for several parameters (i.e., temperature and total dissolved solids) are due to natural causes. As a result, the analysis conducted through this watershed TMDL approach resulted in DWQ either delisting or not recommending a TMDL for specific segments. For some segments, DWQ recommended site-specific standards. A summary of the recommendations made in the final TMDL report is provided below for specific segments.

Beaver Dam Wash Temperature Listing

The TMDL report includes the results of DWQ's vegetative cover and temperature data analysis. Through the analysis, DWQ determined that the high water temperatures in Beaver Dam Wash are naturally occurring and the listing was due to an incorrect beneficial use designation, rather than an actual water quality impairment. As a result, DWQ removed this segment from the 303(d) list.

North Creek Total Dissolved Solids Listing

Review of the available data for this subwatershed revealed that most sources of TDS are naturally occurring and very few are anthropogenic. Through the analysis, DWQ recommended the development of a site-specific standard of 2,035 mg/L (the 90th percentile of data for North Creek). Although the recommendation is to remove North Creek from 303(d) list, the TMDL report does recommend some implementation activities to address the small percentage of anthropogenic-related load.

Santa Clara River Total Dissolved Solids and Temperature Listings

The available temperature data for the Santa Clara River subwatershed revealed that a temperature TMDL was not warranted; only four percent of the recent samples exceeded the standard of 27 ºC, which is within the allowable (ten percent) frequency of exceedances for aquatic life beneficial use support classes. Therefore, DWQ recommended removing this waterbody from the 303(d) list for temperature. Allocations for TDS and selenium were made for both point and nonpoint sources, although nonpoint sources (streambank erosion, irrigation return flows) and upstream sources were found to have the most significant contributions. A 24 percent reduction in annual TDS loads and a 9 percent reduction in selenium loads is necessary to achieve water quality standards. Urban stormwater and dry weather flows received the wasteload allocation for both TDS and selenium.

Baker Dam and Gunlock Reservoir Total Phosphorus and Dissolved Oxygen Listings

The TMDL analysis using the BATHTUB model revealed that approximately a 70 percent reduction in total phosphorus loads to Baker Dam Reservoir is necessary to meet the 0.025 mg/L target, which is predicted to result in meeting the dissolved oxygen standards. For Gunlock Reservoir, the BATHTUB model determined that a 32 percent reduction in total phosphorus loads is necessary. The primary sources of total phosphorus to both Baker Dam and Gunlock Reservoirs are livestock and failing septic systems, indicated in part by the dissolved form of total phosphorus. The wasteload allocation is zero for both reservoirs because there are no point sources.

Virgin River Total Dissolved Solids Listing

The recommendations for a portion of the Virgin River are similar to those for North Creek. Review of the available data for the Virgin River below Pah Tempe Springs, a natural source of salts and other minerals, indicate that the statewide TDS water quality standard is not achievable and that a site-specific standard would be more appropriate. A TDS concentration of 2,360 mg/L, rather than 1,200 mg/L, is considered to represent natural background conditions and is proposed as the site-specific criterion for the Virgin River below Pah Tempe Springs to the Utah/Arizona border. The TMDL analysis used the recommended site-specific criterion to determine the need for load reductions in the lower Virgin River. Based on the analysis with the site-specific criterion, the TMDL recommends a 5 percent reduction in annual TDS loads. The St. George wastewater treatment plant received the wasteload allocation. Because a majority of the load comes from nonpoint sources (streambank erosion, irrigation return flow), nonpoint sources received a larger load allocation.

Implementation

Because the Virgin River watershed TMDLs were developed as part of a comprehensive watershed management approach, implementation recommendations to achieve the pollutant load reductions appear in both the TMDL report and the locally-led Virgin River Watershed Management Plan.

Section 6 of the final TMDL report provides a detailed analysis of potential BMPs that stakeholders could implement to achieve the load reductions for impaired segments in the Virgin River watershed. Figure 6-1 in the TMDL report provides a graphical overview of the Virgin River watershed and the load reductions necessary to achieve water quality standards. Appendix C of the TMDL report contains detailed fact sheets best management practices (BMPs), including a description of the practice and the expected pollutant load reductions. Tables in Section 6 of the TMDL report use the information from Appendix C to present recommended sets of BMPs that could be implemented together to achieve the necessary pollutant load reductions.

Lessons Learned

Utah's TMDL program is watershed-based in that TMDL analyses consider all contributing sources and the process attempts to involve all affected stakeholders. The TMDLs for the impaired segments in the Virgin River watershed were approached on a watershed-basis because there was a critical mass of listed waters that were inter-related due to similar land-use, geology, and hydrology, as well as affected stakeholders. Addressing these impairments on a watershed-basis provided significant savings in staff and stakeholder time and resources.

Using a watershed approach allowed DWQ to characterize the watershed once and provided a more holistic perspective on water quality issues. For example, because TDS was so prevalent in the listed streams throughout the watershed, finding it in several places provided additional support that TDS loads were due to natural sources and not site-specific anthropogenic sources.

Although DWQ ensures coordination among programs on all TMDLs, this project was unique in that it had a high level of involvement from watershed stakeholders, particularly the Washington County Water Conservancy District (WCWCD). The District provided funding and leadership for many of the comprehensive watershed management activities, including development of the locally-led watershed management plan and the drinking water source protection plans, that generated a large amount of stakeholder participation. Through the VRWAC, stakeholders raised issues for consideration that aren't typically considered, including water resource developments and detailed information on anticipated land use changes.

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