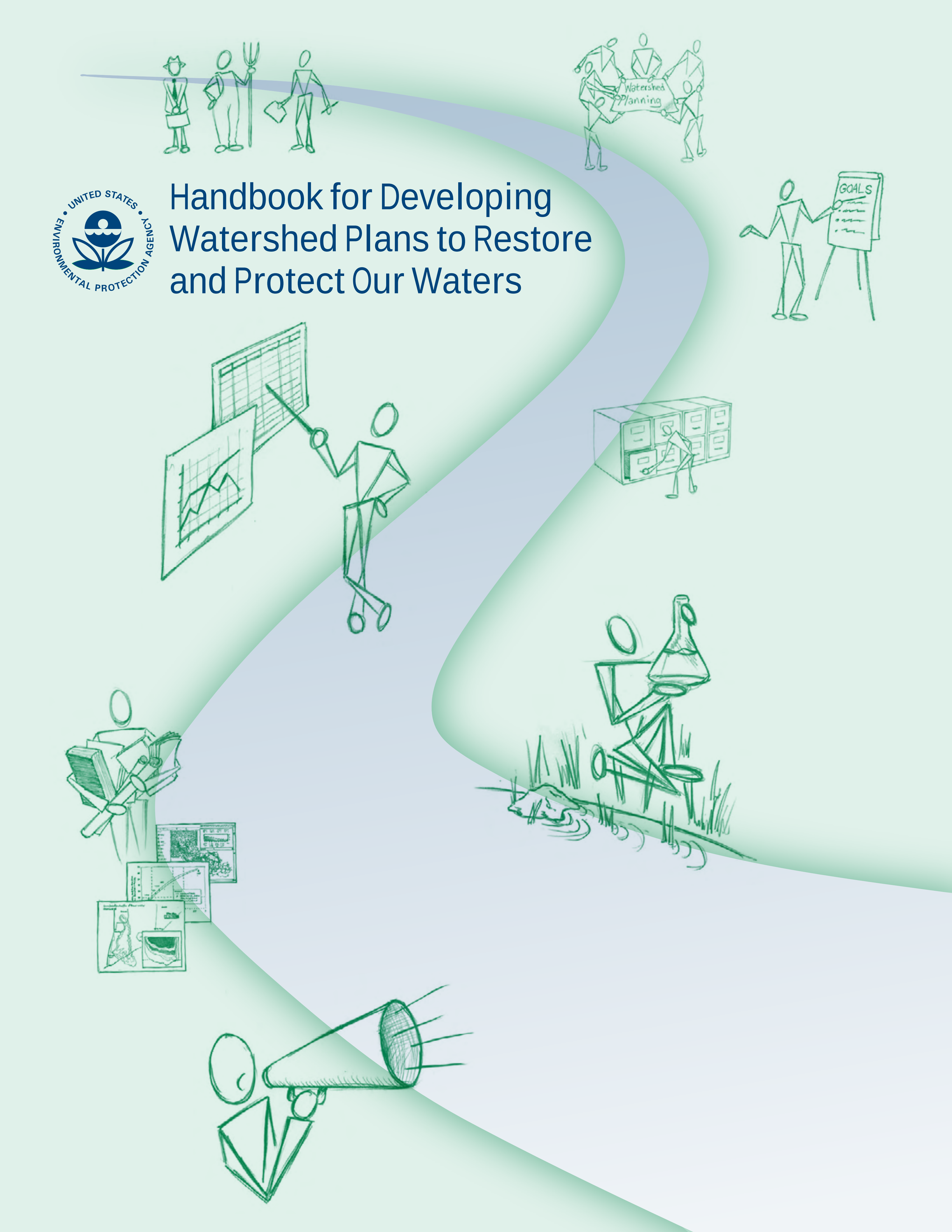
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Handbook for Developing Watershed Plans to Restore and Protect Our Waters



Disclaimer

This document provides guidance to states, territories, authorized tribes, local governments, watershed organizations, and the public regarding technical tools and sources of information for developing watershed based plans to improve and protect water quality. This document 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, states, territories, authorized tribes, local governments, watershed organizations, or the public and may not apply to a particular situation based upon the circumstances. EPA, state, territory, local government, and authorized tribe decision makers retain the discretion to adopt approaches on a case-by-case basis that differ from this guidance. The use of non-mandatory words like "should," "could," "would," "may," "might," "recommend," "encourage," "expect," and "can" in this guidance means solely that something is suggested or recommended, and not that it is legally required, or that the suggestion or recommendation imposes legally binding requirements, or that following the suggestions or recommendations necessarily creates an expectation of EPA approval.

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Office of Water
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Handbook for Developing Watershed Plans to Restore and Protect Our Waters

Contents

Figures

Tables

Acronyms and Abbreviations

There are dozens of acronyms and abbreviations used throughout this handbook. Refer back to this list to help you navigate through the alphabet soup.

ADB . . . . Assessment Database

ADID . . . . advance identification

AFO . . . . animal feeding operation

AGNPS . . . . Agricultural Non-Point Source model

AnnAGNPS . . . . Annualized Agricultural Non-Point Source model

AIEO . . . . American Indian Environmental Office

ARS . . . . Agricultural Research Service

ASIWPCA . . . . Association of State and Interstate Water Pollution Control Administrators

AU . . . . assessment unit

AVIRIS . . . . airborne visible/infrared imaging spectrometer

AVS . . . . acid-volatile sulfide

BASINS . . . . Better Assessment Science Integrating Point and Nonpoint Sources

BEACH . . . . Beaches Environmental Assessment and Coastal Health

BEHI . . . . Bank Erosion Hazard Index

BLM . . . . [U.S.] Bureau of Land Management

BMP . . . . best management practice

BOR . . . . [U.S.] Bureau of Reclamation

CADDIS . . . . Causal Analysis/Diagnosis Decision Information System

CAEDYM . . . . Computational Aquatic Ecosystem Dynamics Model

CAFO . . . . concentrated animal feeding operation

CBOD . . . . carbonaceous biological oxygen demand

C-CAP . . . . Coastal Change Analysis Program

CCMP . . . . comprehensive conservation and management plan

cfs . . . . cubic feet per second

CH3D IMS . . . . Curvilinear grid Hydrodynamics 3D—Integrated Modeling System

CH3D SED . . . . Curvilinear Hydrodynamics 3D—Sediment Transport

CN .... curve number

CNE.............. curve number equation

CNMP .... conservation nutrient management plan

COD .... chemical oxygen demand

CRC.............. Cooperative Research Center

CREM .... Council for Regulatory Environmental Modeling

CREP............ Conservation Reserve Enhancement Program

CRM .... crop residue management

CRP .... Conservation Reserve Program

CSC .... Coastal Services Center

CSO.............. combined sewer overflow

CSP .... Conservation Security Program

CSREES .... Cooperative State Research, Education, and Extension Service

CSTR .... continuously stirred tank reactor

CTG .... composite theme grid

CTIC............. Conservation Technology Information Center

CWA .... Clean Water Act

CZARA........... Coastal Zone Act Reauthorization Amendments

DEM .... digital elevation model

DIAS/IDLMAS .... Dynamic Information Architecture System/Integrated Dynamic Landscape Analysis and Modeling System

DLG .... digital line graphs

DO............... dissolved oxygen

DOI .... [U.S.] Department of the Interior

DOT .... [U.S.] Department of Transportation

DQO .... data quality objective

DRG .... digital raster graphic

ECOMSED........ Estuary and Coastal Ocean Model with Sediment Transport

EDAS .... Ecological Data Application System

EDNA .... Elevation Derivatives for National Application

EFDC . . . . Environmental Fluid Dynamics Code

EMAP . . . . Environmental Monitoring and Assessment Program

EMC . . . . event mean concentration

EPA . . . . [U.S.] Environmental Protection Agency

EPIC . . . . Erosion Productivity Impact Calculator

EQIP . . . . Environmental Quality Incentives Program

ESA . . . . Endangered Species Act

ETM . . . . enhanced thematic mapper

FEMA . . . . Federal Emergency Management Agency

FGDC . . . . Federal Geographic Data Committee

FHWA . . . . Federal Highway Administration

FSA . . . . Farm Service Agency

GAP . . . . Gap Analysis Project

GIRAS . . . . Geographic Information Retrieval and Analysis System

GIS . . . . geographic information system

GISPLM . . . . GIS-Based Phosphorus Loading Model

GLEAMS . . . . Groundwater Loading Effects of Agricultural Management Systems

GLLVHT . . . . Generalized, Longitudinal-Lateral-Vertical Hydrodynamic and Transport

GPS . . . . global positioning system

GRP . . . . Grasslands Reserve Program

GSSHA . . . . Gridded Surface Subsurface Hydrologic Analysis

GWLF . . . . Generalized Watershed Loading Functions

HBI . . . . Hilsenhoff Biotic Index

HCP . . . . habitat conservation plan

HEC-6 . . . . Hydraulic Engineering Center-Scour and Deposition in Rivers and Reservoirs

HEC-6T . . . . Hydraulic Engineering Center-Sedimentation in Stream Networks

HEC-HMS . . . . Hydraulic Engineering Center-Hydrologic Modeling System

HEC-RAS . . . . Hydraulic Engineering Center-River Analysis System

HSCTM-2D . . . . Hydrodynamic, Sediment and Contaminant Transport Model

HSPF . . . . Hydrologic Simulation Program–Fortran

HUC . . . . hydrologic unit code

IBI . . . . index of biotic integrity

IDEAL . . . . Integrated Design and Evaluation Assessment of Loadings

I/E . . . . information/education

IMP . . . . integrated management practices

IPM . . . . integrated pest management

kg/ha/yr . . . . kilograms per hectare per year

kg/yr . . . . kilograms per year

KINEROS2 . . . . Kinematic Runoff and Erosion Model, v2

lb/d . . . . pounds per day

LID . . . . low impact development

LIDAR . . . . light detection and ranging

LSPC . . . . Loading Simulation Program in C++

LULC . . . . land use/land cover

MDC . . . . minimal detectable change

mg/L . . . . milligrams per liter

MINTEQA2 . . . . Metal Speciation Equilibrium Model for Surface and Ground Water

MQO . . . . measurement quality objective

MRLC . . . . Multi-resolution Land Characteristics

MS4 . . . . municipal separate storm sewer systems

MSGP . . . . multi-sector general permit

MUIR . . . . map unit interpretation record

MUSIC . . . . Model for Urban Stormwater Improvement Conceptualization

MVUE . . . . Minimum Variance Unbiased Estimator

NASA . . . . National Aeronautics and Space Administration

NAWQA . . . . National Water-Quality Assessment

NCDC . . . . National Climatic Data Center

NDVI . . . . normalized difference vegetation index

NED . . . . National Elevation Dataset

NEIPCC . . . . New England Interstate Pollution Control Commission

NEMI . . . . National Environmental Methods Index

NEP . . . . National Estuary Program

NGO . . . . non-governmental organization

NHD . . . . National Hydrography Dataset

NIR . . . . near-infrared

NLCD . . . . National Land Cover Dataset

NLFA . . . . National Listing of Fish Advisories

NOAA . . . . National Oceanic and Atmospheric Administration

NPDES . . . . National Pollutant Discharge Elimination System

NPS . . . . nonpoint source

NRCS . . . . Natural Resources Conservation Service

NRI . . . . National Resources Inventory

NSFC . . . . National Small Flows Clearinghouse

NSI . . . . National Sediment Inventory

NTTS . . . . National TMDL Tracking System

NTU . . . . nephelometric turbidity unit

NWI . . . . National Wetlands Inventory

NWIS . . . . National Water Information System

O&M . . . . operation and maintenance

OMB . . . . [U.S.] Office of Management and Budget

ORSANCO . . . . Ohio River Valley Water Sanitation Commission

OSM . . . . Office of Surface Mining

P8-UCM . . . . Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds—Urban Catchment Model

PAH . . . . polycyclic aromatic hydrocarbon

PBMS . . . . Performance-Based Methods System

PCS . . . . Permit Compliance System

PGC-BMP . . . . Prince George's County Best Management Practice Module

POTW . . . . publicly owned treatment works

PSA . . . . public service announcement

QAPP . . . . quality assurance project plan

QA/QC . . . . quality assurance/quality control

QHEI . . . . Qualitative Habitat Evaluation Index

QUAL2E . . . . Enhanced Stream Water Quality Model

RBP . . . . Rapid Bioassessment Protocol

REMM . . . . Riparian Ecosystem Management Model

RF1 . . . . Reach File Version 1

RF2 . . . . Reach File Version 2

RF3-Alpha . . . . Reach File Version 3 - Alpha

RMP . . . . resource management plan

RPD . . . . relative percent difference

RSAT . . . . Rapid Stream Assessment Technique

RUSLE . . . . Revised Universal Soil Loss Equation

SAMP . . . . Special Area Management Plan

SAP . . . . sampling and analysis plan

SAR . . . . synthetic aperture radar

SCS . . . . Soil Conservation Service

SDWA . . . . Safe Drinking Water Act

SED3D . . . . Three-dimensional Numerical Model of Hydrodynamics and Sediment Transport in Lakes and Estuaries

SEM . . . . simultaneously extracted metals

SET . . . . Site Evaluation Tool

SLAMM . . . . Source Loading and Management Model

SOP . . . . standard operating procedure

SPARROW . . . . Spatially Referenced Regression on Watershed Attributes

SRF . . . . State Revolving Fund

SSO . . . . sanitary sewer overflow

SSURGO . . . . Soil Survey Geographic Database

STATSGO .... State Soil Geographic Database
STEPL .... Spreadsheet Tool for Estimating Pollutant Load
STORET .... Storage and Retrieval
STORM .... Storage, Treatment, Overflow, Runoff Model
SVAP .... Stream Visual Assessment Protocol
SWA .... source water assessment
SWAP .... Source Water Assessment Program
SWAT .... Soil and Water Assessment Tool
SWCD .... Soil and Water Conservation District
SWCP .... soil and water conservation plan
SWMM .... Storm Water Management Model
SWP .... source water protection
SWPP .... source water protection plan
SWPPP .... stormwater pollution prevention plan
TCEQ .... Texas Commission on Environmental Quality
TDS .... total dissolved solids
TIGER .... Topologically Integrated Geographic Encoding and Referencing
TKN .... total Kjeldahl nitrogen
TM .... thematic mapper
TMDL .... Total Maximum Daily Load
TOC .... total organic carbon
TP .... total phosphorus
TSI .... Carlson’s Trophic Status Index
TSP .... technical service provider
TSS .... total suspended solids
USACE .... U.S. Army Corps of Engineers
µS/cm .... microsiemens per centimeter
USDA .... U.S. Department of Agriculture
USFWS .... U.S. Fish and Wildlife Service
USGS .... U.S. Geological Survey

USLE . . . . Universal Soil Loss Equation

UTM . . . . universal transverse mercator

VAFSWM . . . . Virginia Field Scale Wetland Model

VFSMOD . . . . Vegetative Filter Strip Model

VSAP . . . . Visual Stream Assessment Protocol

WAMView . . . . Watershed Assessment Model with an ArcView Interface

WARMF . . . . Watershed Analysis Risk Management Framework

WASP . . . . Water Quality Analysis Simulation Program

WATERS . . . . Watershed Assessment, Tracking and Environmental Results System

WATERSHEDSS . . WATER, Soil, and Hydro-Environmental Decision Support System

WBD . . . . watershed boundary dataset

WCS . . . . Watershed Characterization System

WEPP . . . . Water Erosion Prediction Project

WHP . . . . wellhead protection

WinHSPF . . . . Interactive Windows Interface to HSPF

WMS . . . . Watershed Modeling System

WQS . . . . water quality standard

WRAS . . . . Watershed Restoration Action Strategy

WRDA . . . . Water Resources Development Act

WWTP . . . . wastewater treatment plant

1. Introduction

Chapter Highlights

- Purpose of handbook
- Intended audience
- Chapter summaries
- Tips for using the handbook

Read this chapter if...

- You want to know if this handbook is intended for you
- You want an overview of all the chapters
- You want tips on how to skip around to various sections in the handbook

1.1 What Is the Purpose of This Handbook?

This handbook provides information on developing and implementing watershed management plans that help to restore and protect water quality. A watershed is the area of land that contributes runoff to a lake, river, stream, wetland, estuary, or bay. A watershed management plan defines and addresses existing or future water quality problems from both point sources and nonpoint sources of pollutants. Experience over the past decade has shown that effective watershed management includes active participation from stakeholders, analysis and quantification of the specific causes and sources of water quality problems, identification of measurable water quality goals, and implementation of specific actions needed to solve those problems.

What is a watershed?

A **watershed** is the area of land that contributes runoff to a lake, river, stream, wetland, estuary, or bay.

Don't be daunted by the size of this handbook! Although it is comprehensive in terms of providing resources and tools for each step of the watershed planning process, it is laid out in an easy-to-read format with shortcuts and road maps along the way so you can flip to specific sections for more in-depth information. You might not need to read all the sections if you have already completed some stages of the watershed planning process. Read the highlights at the beginning of each chapter to determine whether you can skip to the next section.

Watershed plans are a means to resolve and prevent water quality problems that result from both point source and nonpoint source problems. Although the primary focus of this handbook is on waters listed as impaired under section 303(d) of the Clean Water Act, watershed plans are intended both to provide an analytic framework to restore water quality in impaired waters and to protect water quality in other waters adversely affected or threatened by point source and nonpoint source pollution.

This handbook is intended to serve as the basis for developing and implementing watershed plans to meet water quality standards and protect water resources. Although watershed plans are useful for all watersheds to protect and restore water resources, as well as to meet other community resource goals, they are critical for impaired or threatened waterbodies. The most recent national water quality assessment reported that 40 to 50 percent of the nation's assessed waterbodies are impaired or threatened. This handbook is designed to provide a framework to help you develop a scientifically defensible plan that will lead to measurable results and an overall improvement in the water quality and watershed conditions that are important to your community.

Developing watershed plans does not have to be an exhaustive, expensive endeavor. This handbook shows you how to effectively and efficiently collect the information you need to answer the right questions. The level of effort you expend preparing a watershed plan will depend on several factors, such as the available information, the size of the watershed, and the pollutants of concern.

Federal, state, and local organizations have developed many watershed guides. EPA intends for this handbook to *supplement*, rather than *replace*, those guides. Appendix A includes a list of some watershed planning guides for your reference.

1.1.1 How Is This Handbook Different from Other Guides?

This handbook is more rigorous and goes into greater detail than most watershed planning guides. It describes processes and tools used to *quantify* existing pollutant loads, *develop estimates* of load reductions needed to meet water quality criteria, and *identify* the management measures appropriate for achieving the needed load reductions.

Using these tools will enable you to then develop effective management measures to reduce the loads. The handbook also provides tools to *track progress* once you implement the plan to ensure that the management measures are helping to improve water quality.

1.1.2 Who Should Use This Handbook?

We have designed this handbook to be used by agencies and organizations that develop watershed management plans. It is specifically intended for those working in a watershed where there are impaired or threatened waters. Recognizing that a certain level of technical expertise is required to develop watershed plans, EPA has included information in this handbook on how to engage and involve a wide variety of professionals and other interested parties in plan development. To use this handbook effectively, you should have a basic level of understanding about watersheds, their processes, and the major components of a watershed management plan. If your watershed issues are technically complex, you might have to enlist the support of experienced professionals like engineers, hydrologists, statisticians, biologists, and database managers that have a variety of skills and can provide specific information for your watershed plan.

The primary audiences that will benefit from this handbook are the following:

Watershed organizations that are developing new plans, updating existing plans to meet funding requirements, or considering other watershed issues.

Local agencies that are developing or updating a watershed plan or need references to research a particular subject related to watershed planning.

State and tribal environmental agencies that are developing and reviewing watershed plans, participating as stakeholders on watershed planning committees, or providing guidance to watershed associations.

Federal environmental agencies that have similar planning programs to help identify overlapping activities, provide sources of data, and offer other kinds of financial and technical assistance.

A waterbody is **impaired** if it does not attain the water quality criteria associated with its designated use(s). **Threatened** waters are those that meet standards but exhibit a declining trend in water quality such that they will likely exceed standards in the near future.

1.1.3 What If We Already Have a Watershed Plan?

EPA recognizes that many states and local groups already have in place or are developing watershed plans and strategies at varying levels of scale, scope, and specificity that might contribute significantly to the process of developing and implementing watershed plans using the approach outlined in this handbook.

These existing plans and strategies should be adapted as appropriate or used as building blocks for developing and implementing watershed plans that contain the nine minimum elements that EPA recommends including in watershed plans that address impaired or threatened waterbodies. This can be accomplished by adapting existing plans to include the

Table 1-1. Relationship of Chapters to the Watershed Planning Process

Chapter		Steps in Watershed Planning and Implementation Process
1	Introduction	
2	Overview of Watershed Planning Process	
3	Build Partnerships	Build Partnerships
4	Define Scope of Watershed Planning Effort	Characterize the Watershed
5	Gather Existing Data and Create an Inventory	
6	Identify Data Gaps and Collect Additional Data if Needed	
7	Analyze Data to Characterize the Watershed and Pollutant Sources	
8	Estimate Pollutant Loads	
9	Set Goals and Identify Load Reductions	Set Goals and Identify Solutions
10	Identify Possible Management Strategies	
11	Evaluate Options and Select Final Management Strategies	
12	Design Implementation Program and Assemble Watershed Plan	Design Implementation Program
13	Implement Watershed Plan and Measure Progress	Implement Watershed Plan
		Measure Progress and Make Adjustments

omitted components, incorporating by reference existing assessments or other information in a newly developed plan, or merging existing information into an updated plan that includes all the basic components.

Where existing plans and strategies have been developed at a basin-wide or other large geographic scale, they usually need to be refined at the smaller watershed scale to provide the information needed to develop a watershed plan. The assessment, monitoring, and other data collection requirements for larger basin studies typically are not as detailed as those for watershed plans or assessments generated for site-level work plans.

1.2 What's Inside?

The handbook is divided into 13 chapters that move through the watershed planning and implementation process (table 1-1). Each chapter includes information that addresses the key issues for each step, along with highlights to illustrate how to apply these concepts to your own situation. In addition, the appendices provide more detailed information on additional resources and worksheets that can be used as part of your watershed planning efforts.

1.2.1 Chapter Overviews

Chapter 1: Introduction includes the purpose of the handbook, intended audiences, and guidelines on how to use the information provided.

Chapter 2: Overview of Watershed Planning Process provides an overview of the watershed planning process and highlights common features of typical watershed planning processes.

Chapter 3: Build Partnerships provides guidance on initial activities to organize and involve interested parties, such as identifying stakeholders, integrating other key programs, and conducting outreach.

Chapter 4: Define Scope of Watershed Planning Effort discusses the preliminary activities you undertake to start scoping out your planning effort. It includes information on defining issues of concern, developing preliminary goals, and identifying indicators to assess current conditions.

Chapter 5: Gather Existing Data and Create an Inventory discusses the first step in watershed characterization—gathering existing information and creating a data inventory. It includes collecting information from existing reports and datasets.

Chapter 6: Identify Data Gaps and Collect Additional Data if Needed discusses how to identify data gaps and collect additional data if needed. This chapter includes a discussion on quality assurance/quality control procedures and the development of sampling plans.

Chapter 7: Analyze Data to Characterize the Watershed and Pollutant Sources discusses the primary data analyses needed to identify problems and support development of the plan. It includes information on the types of data analyses that can be conducted and the tools used. It also discusses how to link the impairments to the causes and sources of pollutant loads.

Chapter 8: Estimate Pollutant Loads provides guidance on using watershed models and other tools to estimate pollutant loads. It discusses computer models, identifies the types of models available, and tells how to select appropriate models for your watershed study.

Chapter 9: Set Goals and Identify Load Reductions discusses how to set management and water quality goals, develop management objectives, and determine the load reductions needed to meet the goals. It provides guidance for identifying critical areas to which management efforts can be targeted.

Chapter 10: Identify Possible Management Strategies gives an overview of various management measures that might be selected, discusses how to identify existing management efforts in the watershed, and provides considerations for selecting management options.

Chapter 11: Evaluate Options and Select Final Management Strategies discusses how to screen and research candidate management options, evaluate possible scenarios, and select the final management measures to be included in your watershed management plan.

Chapter 12: Design Implementation Program and Assemble Watershed Plan provides guidance on establishing milestones and implementation schedules and identifying the technical and financial resources needed to implement the plan, including information/education (I/E) activities and monitoring and evaluation components. It discusses how to use various analyses and products to assemble and document the watershed plan.

Chapter 13: Implement Watershed Plan and Measure Progress provides guidance on using adaptive management techniques to make changes to your watershed plan and on analyzing the monitoring data to determine whether milestones are being met. It also provides guidance on using a watershed plan to develop annual work plans.

1.2.2 Appendices and Additional Resources

Appendix A: Resources is an expanded list of resources provided to guide you to more detailed information on various aspects of the watershed planning process.

Appendix B: Worksheets provides a complete set of all the worksheets and checklists included in the handbook as full-size sheets that you can photocopy and use with your planning group.

Look for This Handbook on the Web!

You can download a pdf version of this document at **www.epa.gov/owow/nps/pubs.html**.

Appendix C: List of State Nonpoint Source and Watershed Planning Contacts can help get you in touch with people that can help in your watershed planning effort.

A ***Glossary*** is provided after appendix B to define key terms used in the handbook.

A ***Bibliography*** that lists the sources used to prepare the handbook is included.

1.3 How to Use This Handbook

Although there is no cookie-cutter approach to developing a watershed plan, plans that seek to identify and address threats or impairments to water quality have some common elements. This handbook provides various tools for you to consider when developing your watershed plan and includes many Web links for more in-depth information on particular topics. The document is structured so you can proceed step by step through the watershed planning process or can go directly to a section that highlights a specific technical tool for use in your watershed planning effort.

Some common themes are repeated throughout the handbook to reinforce the concepts presented, provide shortcuts, and help you to focus your efforts. These tips are identified by the following icons:

Nine Elements of Watershed Plans. One of the purposes of this handbook is to show how the nine elements presented in the Clean Water Act section 319 guidelines are used to develop effective watershed plans for threatened and impaired waters. Many organizations already have plans that include some of these elements but might require additional information on other elements. Note that most of the nine elements are presented in chapters 10–13.

Targeting Your Efforts. Although the handbook includes various options to be considered in each step of the watershed planning process, planners must target their efforts to move the process forward to achieve measurable progress in reducing specific pollutant loads. You might already have a good idea of the problems in your watershed and want to identify targeted management measures to address them. Or perhaps your watershed has only one pollutant of concern. The icon highlights places in the planning process where it makes sense to target your efforts so you can focus your resources to identify the most likely problems and solutions for your watershed.

Watershed planning is not an exact science. Often we have to make decisions based on our best professional judgment to move the process forward. There are, however, several places along the way where you should stop and assess what you know, what information you have, and what additional information you need. If you see the stop sign, , take a minute to read the information to make sure you're going down the right path with the right information.

This icon indicates where the topic is discussed elsewhere in the document, or where more information is provided in the text, the Resources appendix (appendix A), other documents, or the Internet.

Worksheets and Checklists. Worksheets and checklists are provided throughout the handbook to help you work through the watershed planning process with the stakeholders. The worksheets are noted with a . A complete set is provided in appendix B to facilitate photocopying.

Handbook Road Map

2. Overview of Watershed Planning Process

Chapter Highlights

- Using a watershed approach
- Common features in watershed planning
- Steps in the watershed planning process
- Watershed planning for impaired waters
- Common watershed impairments
- Summary of nine minimum elements to be included in a watershed plan for impaired waters

Read this chapter if...

- You are unfamiliar with watershed planning concepts
- You want to know more about water quality standards
- You don't know the most common water quality impairments in the United States
- You want a list of the nine minimum elements to be included in section 319-funded watershed plans

2.1 Why Use a Watershed Approach to Manage Water Resources?

Since the late 1980s, watershed organizations, tribes, and federal and state agencies have moved toward managing water quality through a watershed approach. A *watershed approach* is a flexible framework for managing water resource quality and quantity within specified drainage areas, or watersheds. This approach includes stakeholder involvement and management actions supported by sound science and appropriate technology. The *watershed planning process* works within this framework by using a series of cooperative, iterative steps to characterize existing conditions, identify and prioritize problems, define management objectives, develop protection or remediation strategies, and implement and adapt selected actions as necessary. The outcomes of this process are documented or referenced in a watershed plan. A *watershed plan* is a strategy that provides assessment and management information for a geographically defined watershed, including the analyses, actions, participants, and resources related to developing and implementing the plan. The development of watershed plans requires a certain level of technical expertise and the participation of a variety of people with diverse skills and knowledge.

What Is an Impaired Waterbody?

EPA defines an impaired waterbody as a waterbody that does not meet water quality criteria that support its designated use. The criteria might be numeric and specify concentration, duration, and recurrence intervals for various parameters, or they might be narrative and describe required conditions such as the absence of scum, sludge, odors, or toxic substances.

If the waterbody is impaired, it is placed on the section 303(d) list. For each pollutant listed, the state or tribe must develop a restoration target called a Total Maximum Daily Load (TMDL).

Using a watershed approach to restore impaired waterbodies is beneficial because it addresses the problems in a holistic manner and the stakeholders in the watershed are actively involved in selecting the management strategies that will be implemented to solve the problems. Nonpoint source pollution poses the greatest threat to water quality and is the most significant source of water quality impairment in the nation. Therefore, EPA is working with states, tribes, and watershed groups to realign its programs and strengthen support for watershed-based environmental protection programs. Such programs feature local stakeholders joining forces to develop and implement watershed plans that make sense for the conditions found in local communities. Specific features of the watershed approach are explained below.

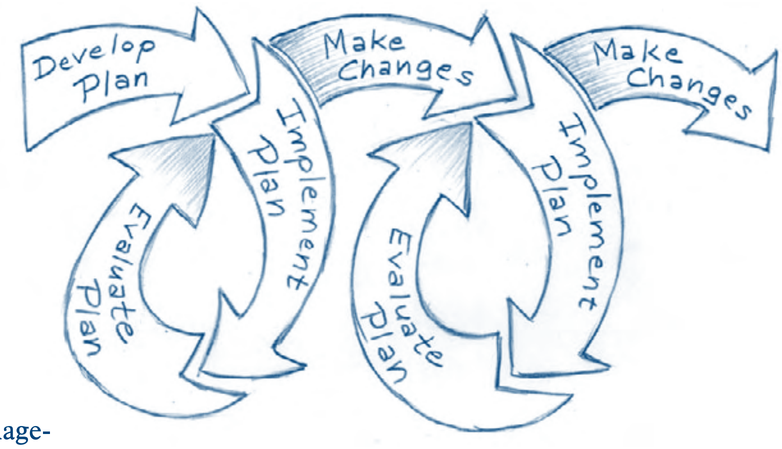
2.2 Common Features of the Watershed Planning Process

Although each watershed plan emphasizes different issues and reflects unique goals and management strategies, some common features are included in every watershed planning process. The watershed planning process is iterative, holistic, geographically defined, integrated, and collaborative.

Watershed Planning

Appendix A includes a selected list of watershed guides published by various state and federal agencies. These guides might help you to fulfill state-specific requirements or provide more in-depth information on specific issues.

States are encouraged to develop statewide watershed planning frameworks that integrate and coordinate plans for large drainage areas. Plans for larger basins should contain general or summarized quantitative analyses of current water quality problems (e.g., pollutant loads) and the load reductions or other benefits expected from the implementation of best management practices (BMPs). The level of detail for these large-basin plans will not be as refined as those for smaller watersheds, but an overview of current pollutant loads and future load reductions expected from BMPs is helpful in providing some sense of the scope of the problem(s) in the basin and the level of effort needed to restore or protect water quality. The level of detail would be further refined for subbasins or watersheds, to provide more specific information for project work plans.



2.2.1 Watershed Planning Is an Iterative and Adaptive Process

EPA recognizes that the processes involved in watershed assessment, planning, and management are iterative and that targeted actions might not result in complete success during the first or second cycle. It is expected, however, that through adjustments made during the management cycles, water quality improvements can be documented and continuous progress toward attaining water quality standards can be achieved. Watershed plans should address all the sources and causes of waterbody impairments and threats; that is, the plans should address not only the sources of the immediate water quality impairment but also any pollutants and sources of pollutants that need to be addressed to ensure the long-term health of the watershed.

EPA recognizes the difficulty in obtaining watershed-related information with precision and acknowledges that a balanced approach is needed to address this concern. On one hand, it is absolutely critical that watershed planners make a reasonable effort to identify significant pollutant sources, specify the management measures that will most effectively address those sources, and broadly estimate the expected load reductions that will result. Without this analytic framework to provide focus and direction, it is much less likely that projects implemented under the plan can efficiently and effectively address the nonpoint sources of water quality impairments.

On the other hand, EPA recognizes that even if reasonable steps are taken to obtain and analyze relevant data, the information available during the planning stage (within reasonable time and cost constraints) might be limited. Preliminary information and loading estimates might need to be updated over time, accompanied by midcourse corrections in the watershed plan and the activities it promotes. In many cases, several years of implementation might be needed for a project to achieve its goals. EPA fully intends that the watershed planning process described in this handbook be implemented in a dynamic and adaptive manner to ensure that implementation of the plan can proceed even though some of the information in the watershed plan is imperfect and might need to be modified over time as better information becomes available.

Remember...

Although watershed plans are recommended to implement TMDLs, they should be developed holistically to consider other impairments and threats in the watershed. TMDLs might focus on specific waterbody segments, sources, or pollutants, whereas the watershed plan should incorporate the pollutant- and site-specific TMDL into the larger context of the watershed, including

- Additional water quality threats
- Additional pollutants
- Additional sources
- Threatened waterbodies
- Synergistic effects
- Water quantity issues
- Development pressures
- Habitat protection
- Wetland restoration/creation
- Source water protection

2.2.2 Watershed Planning Is a Holistic Process

EPA supports the implementation of holistic watershed plans because this approach usually provides the most technically sound and economically efficient means of addressing water quality problems and is strengthened through the involvement of stakeholders that might have broader concerns than solely attainment of water quality standards (e.g., water supply, aesthetics). A holistic approach addresses all the beneficial uses of a waterbody, the criteria needed to protect the use, and the strategies required to restore water quality or prevent degradation. This approach will help to expedite cooperative, integrated water resource planning and successful implementation of needed management, thereby facilitating the restoration of water quality. For example, watershed plans that incorporate a full range of other resource management activities, such as source water protection for drinking water, forest or rangeland management planning, agricultural resource management systems, and parkland or greenspace management will be better able to address the various challenges and opportunities related to water resource restoration or protection.

Why Watershed Plans Fail

The Center for Watershed Protection conducted a broad assessment of the value of planning documents in protecting water resources and identified a number of reasons why some plans had failed:

- Planning activities were conducted at too great a scale.
- The plan was a one-time study rather than a long-term management process.
- Stakeholder involvement and local ownership were lacking.
- The plan skirted land use/management issues in the watershed.
- The document was too long or complex.
- The recommendations were too general.
- The plan failed to identify and address conflicts.

2.2.3 Watershed Planning Is Geographically Defined

By definition, watershed planning focuses on a watershed, a geographic area that is defined by a drainage basin. A watershed plan should address a geographic area large enough to ensure that implementing the plan will address all the major sources and causes of impairments and threats to the waterbody under review. Although there is no rigorous definition or delineation of this concept, the general intent is to avoid a focus on single waterbody segments or other narrowly defined areas that do not provide an opportunity for addressing watershed stressors in a rational, efficient, and economical manner. At the same time, the scale should not be so large that it hampers the ability to conduct detailed analyses or minimizes the probability of involvement by key stakeholders and successful implementation. If you select a scale that is too broad, you might be able only to conduct cursory assessments and will not be able to accurately link the impacts back to the sources and causes.

Plans that bundle subwatersheds with similar sets of problems or address a common stressor (e.g., sediment, nutrients) across multiple related watersheds can be particularly useful in terms of planning and implementation efficiency and the strategic use of administrative resources. ↳ Chapters 4 and 7 provide more specific guidance on defining the geographic extent of your planning effort.

Plans That You Might Want to Integrate into Your Watershed Planning Activities

- Source water assessments
- TMDL implementation plans
- Stormwater management plans
- Resource management plans
- Master plans
- Facility plans
- Wetland assessments
- Wildlife action plans
- Aquatic GAP analyses

2.2.4 Watershed Planning Should Be Integrated with Other Planning Efforts

It is likely that many federal, state, tribal, and local planning efforts are occurring simultaneously with your watershed planning effort. At a minimum, you should be aware of these programs; ideally, you should integrate them into your watershed planning effort through stakeholder participation, data sharing, and implementation of management measures. ↳ Chapter 3 provides a summary of specific programs that have a planning component or conduct related activities that you might want to integrate with your watershed planning effort. You might also want to include staff from these programs as partners in developing your watershed plan. This approach can help in gaining additional technical expertise, leveraging resources, and sharing responsibilities for implementation.

2.2.5 Watershed Planning Is a Collaborative and Participatory Process

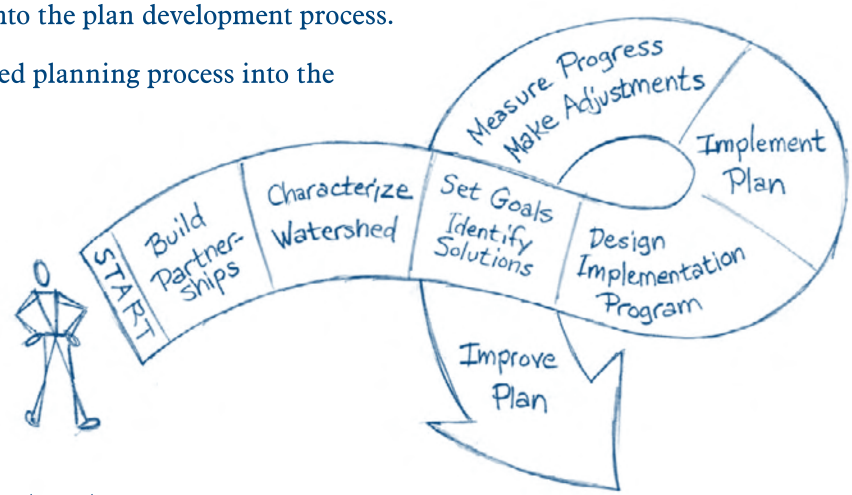
One of the key characteristics of the watershed planning process is that it is participatory. The Center for Watershed Protection conducted research that showed that implementation of a watershed plan has the greatest chance of success when stakeholders are brought into the process at the very beginning of the watershed planning effort (CWP 1996). This finding is supported by the fact that implementation of the plan usually rests with members of the community, and if they are involved up front and see that their concerns are addressed, they will be more likely to participate in developing management options and supporting plan implementation. Chapter 3 discusses how to involve stakeholders to enhance the watershed planning process and implementation of the plan.

2.3 Steps in the Watershed Planning and Implementation Process

The parts of the watershed planning process can be illustrated in a number of ways, such as steps, phases, or portions of a circle. In general, all watershed planning efforts follow a similar path from identifying the problems to, ultimately, implementing actions to achieve the established goals. Many groups find that informal scoping and information collection prior to plan development provides valuable input during the early phase of planning. Scoping activities include pre-planning data review and discussions with stakeholders that can help to define the planning area, identify other stakeholders, and help to solicit opinions and advice on how to proceed before launching into the plan development process.

This handbook organizes the watershed planning process into the following major steps:

1. Build partnerships.
2. Characterize the watershed to identify problems.
3. Set goals and identify solutions.
4. Design an implementation program.
5. Implement the watershed plan.
6. Measure progress and make adjustments.



Within each step, several activities are conducted before moving on to the next step. Many of these activities are repeated in different steps. For example, information/education (I/E) activities occur in the first step when building partnerships but also occur throughout the process, especially when implementing the plan.

It can be daunting to begin the planning process and consider the scope of work needed to implement watershed restoration and/or protection measures. Many groups have found that tackling smaller projects and tasks early in the planning process can help to engage stakeholders and demonstrate progress, creating a sense of momentum that leads to long-term success.

Figure 2-1 shows some of the activities and tools used in each step of the watershed plan development and implementation process. The figure provides a road map for the watershed planning process, as well as a road map for this document. You might want to refer back to it from time to time to find out where you are in the process and where you need to go. Note that

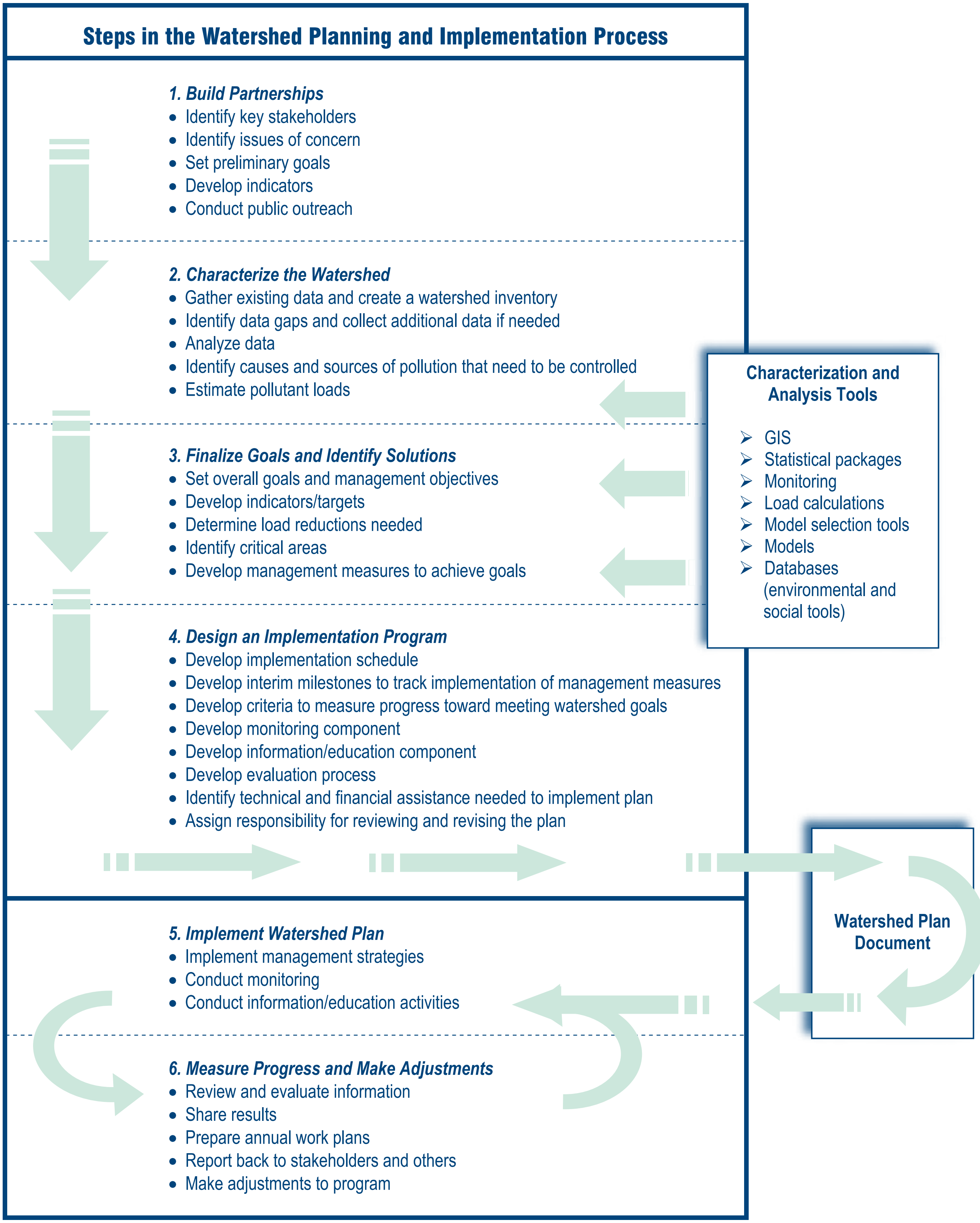


Figure 2-1. Steps in the Watershed Planning Process

steps 1 through 4 feed into the development of the plan, but the watershed planning process continues with plan implementation. Once the plan is implemented, annual work plans are prepared, monitoring activities are conducted to quantitatively measure progress toward meeting water quality goals, and plan adjustments based on evaluation information received (and other inputs, such as changes in resources or watershed conditions) are continually made.

2.4 Watershed Planning for Impaired Waters

EPA recognizes the need to focus on developing and implementing watershed plans for waters that are impaired in whole or in part by nonpoint sources. For these waterbodies it is imperative to select on-the-ground management measures and practices that will reduce pollutant loads and contribute in measurable ways to restoring of impaired waters to meet water quality standards.

What Are Loads?

Pollutant load refers to the amount of pollutants entering a waterbody. Loads are usually expressed in terms of a weight and a time frame, such as pounds per day (lb/d).

Much of this handbook focuses on how to identify pollutant loads and how to determine the load reductions needed to meet water quality goals.

2.4.1 What Are the Most Common Impairments?

Waterbodies can be impaired by one source or a combination of sources. Across the country, a wide variety of waters are listed as impaired by a range of pollutants. Based on the most recent state 303(d) lists, there are more than 38,000 impaired waters in the United States and more than 63,000 associated impairments.[1] Pathogens, metals, nutrients, and sediment are the most common pollutants included on state lists, and the top 10 listed impairments account for over 75 percent of the total listings in the nation (table 2-1). Since January 1, 1996, EPA has approved almost 25,000 TMDLs, accounting for approximately 64 percent of the nationwide listings.

Table 2-1. Top Ten 303(d) List Impairments in the United States (August 14, 2007)

General Impairment[a]	Number Reported	Percent Reported	Cumulative Percent
Pathogens	8,558	13.5	13.5%
Mercury	8,555	13.5	26.9%
Sediment	6,749	10.6	37.5%
Metals (other than mercury)	6,368	10.0	47.5%
Nutrients	5,617	8.8	56.3%
Oxygen depletion	4,540	7.1	63.5%
pH	3,376	5.3	68.8%
Cause unknown - biological integrity	2,867	4.5	73.3%
Temperature	2,852	4.5	77.8%
Habitat alteration	2,246	3.5	81.3%

[a] "General impairment" might represent several associated pollutants or impairment listings. For example, the metals category includes 30 specific pollutants or related listings (e.g., iron, lead, contaminated sediments).
Source: EPA's National Section 303(d) List Fact Sheet (**http://oaspub.epa.gov/waters/national_rept.control**).

Most watershed plans address some combination of these major pollutants: pathogens, metals, nutrients, sediment, and thermal impacts. The next several chapters of the handbook highlight various types of data and analysis tools that you can use to support watershed plan development. Knowing the major impairments might help you to focus your data collection efforts and determine what types of analyses to conduct.

[1] Data were accessed on August 14, 2007, and are based on a review of the most recent state data available. The state lists included in the national summary range from 1998 to 2002. The national summary of 303(d) listings is available at **http://oaspub.epa.gov/waters/national_rept.control**.

What Is a TMDL?

If a waterbody is impaired, it is placed on the 303(d) list. For each impaired waterbody, a state or tribe must develop an accounting of loads that would result in the waterbody's meeting water quality standards. This is called a Total Maximum Daily Load (TMDL).

A TMDL is the amount, or load, of a specific pollutant that a waterbody can assimilate and still meet the water quality standards. The load is allocated among the current pollutant sources (point, nonpoint, and background sources), a margin of safety, and sometimes future growth.

The typical steps for developing a TMDL include the following:

1. Identify linkages between water quality problems and pollutant sources.
2. Estimate total acceptable loading rate that achieves water quality standards.
3. Allocate acceptable loading rates between sources.
4. Package the TMDL for EPA approval.

To provide a better understanding of the major pollutants contributing to waterbody impairments, the typical sources of pollutants and the associated impacts on waterbodies and their designated uses are summarized in table 2-2. This summary provides a starting point for you to think about the types of data you'll collect and analyses you'll conduct to characterize watershed conditions.

When collecting and analyzing your data, it's also important to keep in mind the entire watershed and the general problems and goals. For example, some of the watershed problems might not be those officially recognized as impairments on the 303(d) lists. Broader issues like wetland degradation and adequate source water protection should also be priorities in your watershed. Source water protection is important for both sustaining good water quality and quantity and sustaining biological integrity.

Although watershed plans should be holistic and include information on the broad array of attributes, problems, and protection strategies needed in a watershed, plans that include impaired waters should also contain quantified estimates of current (and sometimes future) problem pollutant loads and reductions designed to achieve water quality standards and other watershed goals. Nonpoint source TMDLs and watershed plans that address quantifiable loading estimates and load reduction strategies provide the analytic link between actions on the ground and attainment of water quality standards. To strengthen this link, the load reductions should be separated by source category to enable you to identify the specific actions and locations of management strategies as part of your implementation efforts. In the absence of such a framework, it's difficult to develop and implement a watershed plan that can be expected to achieve water quality standards or other environmental goals, or to determine the causes of failure when nonpoint source projects do not result in expected water quality improvements.

The watershed planning process described in this handbook emphasizes the restoration (and considers protection) of nonpoint source-affected waters through the development of an analytic framework that accommodates waters with or without approved TMDLs.

2.4.2 Watershed Planning Where a TMDL Has Been Developed

States may use a portion of the funding they receive under section 319 of the Clean Water Act to develop TMDLs and to develop and implement watershed plans that are consistent with those TMDLs. In addition, states may develop and implement watershed plans in advance of TMDLs where none exist. In cases where a TMDL for affected waters has already been developed and approved or is being developed, the watershed plan should be crafted to achieve the load reductions called for in the TMDL.

2.4.3 Watershed Planning in the Absence of a TMDL

If a TMDL has not yet been developed, the plan should be designed to attain water quality standards if possible, in addition to other environmental goals. If implementation of the watershed plan successfully addresses water quality impairments, a TMDL may not be needed (see **www.epa.gov/owow/tmdl/2006IRG**). EPA encourages states to include in

Table 2-2. Summary of Common Pollutants and Sources

Pollutant	Potential Sources		Impacts on Waterbody Uses
	Point Sources	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	• Primarily human health risks • Risk of illness from ingestion or from contact with contaminated water through recreation • Increased cost of treatment of drinking water supplies • Shellfish bed closures
Metals	• Urban runoff • WWTPs • CSO/SSOs • Landfills • Industrial facilities • Mine discharges	• Abandoned mine drainage • Hazardous waste sites (unknown or partially treated sources) • Marinas • Atmospheric deposition	• Aquatic life impairments (e.g., reduced fish populations due to acute/chronic concentrations or contaminated sediment) • Drinking water supplies (elevated concentrations in source water) • Fish contamination (e.g., mercury)
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	• Aquatic life impairments (e.g., effects from excess plant growth, low DO) • Direct drinking water supply impacts (e.g., dangers to human health from high levels of nitrates) • Indirect drinking water supply impacts (e.g., effects from excess plant growth clogging drinking water facility filters) • Recreational impacts (indirect impacts from excess plant growth on fisheries, boat/swimming access, appearance, and odors) • Human health impacts
Sediment	• WWTPs • Urban stormwater systems	• Agriculture (cropland and pastureland erosion) • Silviculture and timber harvesting • Rangeland erosion • Excessive streambank erosion • Construction • Roads • Urban runoff • Landslides • Abandoned mine drainage • Stream channel modification	• Fills pools used for refuge and rearing • Fills interstitial spaces between gravel (reduces spawning habitat by trapping emerging fish and reducing oxygen exchange) • When suspended, prevents fish from seeing food and can clog gills; high levels of suspended sediment can cause fish to avoid the stream • Taste/odor problems in drinking water • Impairs swimming/boating because of physical alteration of the channel • Indirect impacts on recreational fishing
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	• Causes lethal effects when temperature exceeds tolerance limit • Increases metabolism (results in higher oxygen demand for aquatic organisms) • Increases food requirements • Decreases growth rates and DO • Influences timing of migration • Increases sensitivity to disease • Increases rates of photosynthesis (increases algal growth, depletes oxygen through plant decomposition) • Causes excess plant growth

Note: WWTP = wastewater treatment plant; CSO = combined sewer overflow; SSO = sanitary sewer overflow; CAFO = concentrated animal feeding operation; DO = dissolved oxygen.

> **Watershed Plans to Protect Unimpaired Waters**
>
> In some cases, stakeholders might want to protect waters that are affected by nonpoint source pollution but are not included on the 303(d) list. Of particular concern are high-quality waters that are threatened by changing land uses when unique and valuable aquatic resources (e.g., habitat for salmon migration, spawning, and rearing) are at serious risk of irreparable harm. Watershed project sponsors can use the tools presented in this handbook to develop watershed plans for waters that are not impaired by nonpoint source pollution to ensure that they remain unimpaired.

their watershed plans all the significant causes and sources of waterbody impairments and threats; i.e., watershed plans should address not only the sources of water quality impairment but also any pollutants and sources of pollution that need to be addressed to ensure the long-term health of the watershed. If a TMDL is later completed and approved, the plan might need to be modified to make it consistent with the TMDL. EPA continues to encourage the development of TMDLs or, where applicable, sets of such TMDLs on a watershed basis. Figure 2-2 illustrates the potential relationships between TMDLs and watershed plans.

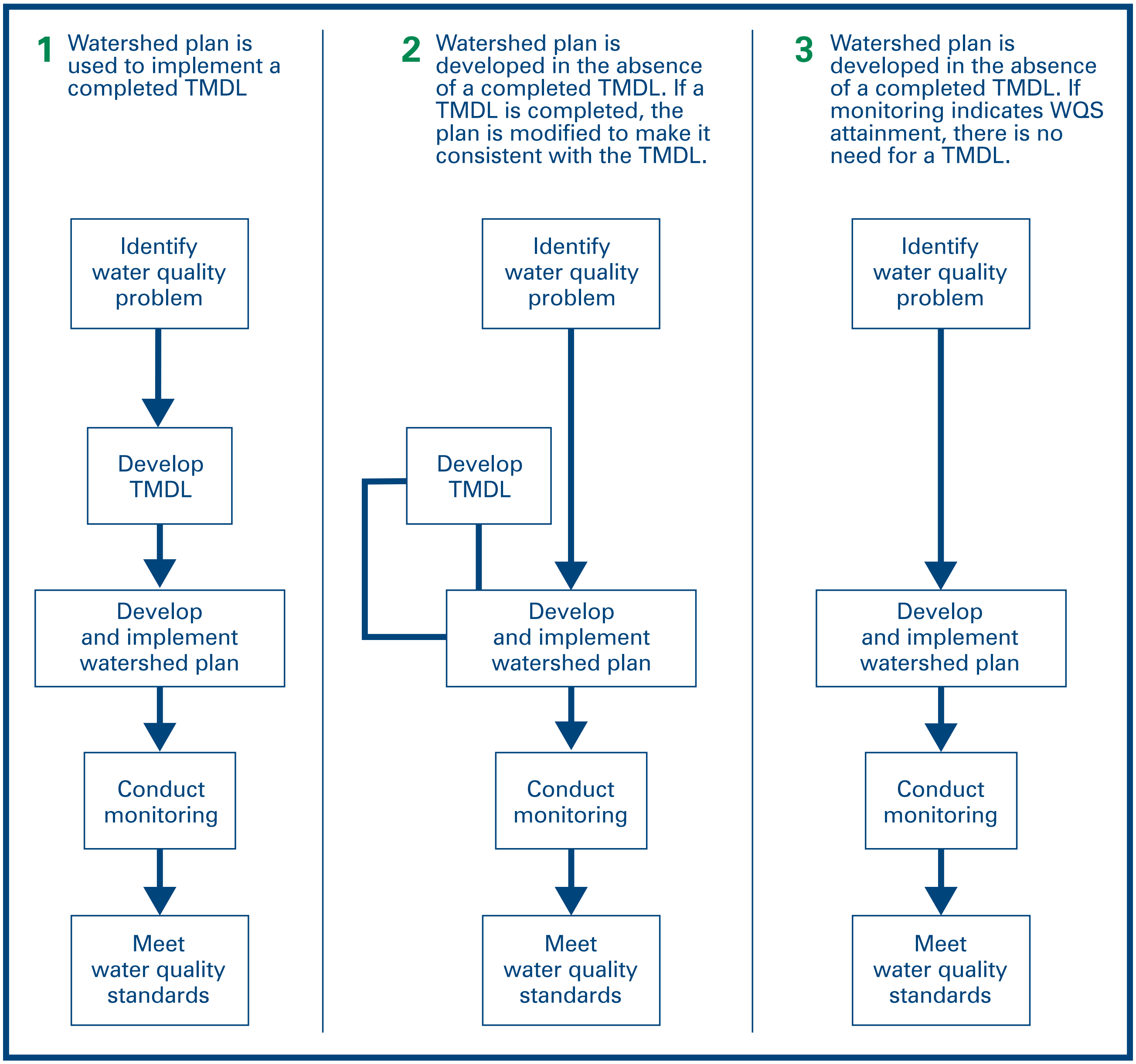
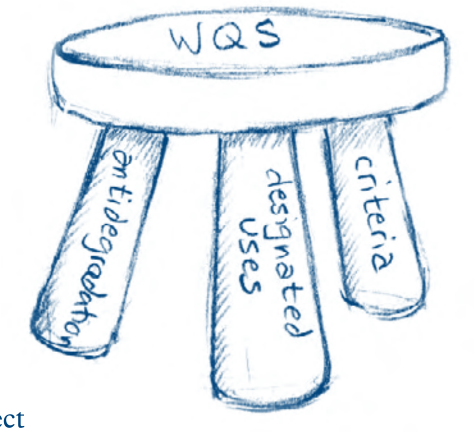


Figure 2-2. Potential Relationships Between TMDLs and Watershed Plans

2.5 Including Water Quality Standards in Goal Setting

Each watershed management plan will address different issues and include unique goals and site-specific management strategies to achieve those goals. All plans should also include attainment of water quality standards for surface waters in the management area. Because water quality standards are the foundation of EPA's water quality protection efforts, this handbook includes a brief description of what they are and how they're used in watershed management programs.



2.5.1 What Are Water Quality Standards and Why Are They Important?

An important cornerstone of the Clean Water Act is the requirement that states, tribes, and territories adopt water quality standards to protect public health, support wildlife, and enhance the quality of life within their jurisdictions. Water quality standards serve as the basis for assessing waters, establishing TMDLs, and setting attainment limits in NPDES permits. Attaining these standards helps to ensure that waters will remain useful to both humans and aquatic life. Standards also drive water quality restoration activities because they help to determine which waterbodies must be addressed, what level of restoration is necessary, and which activities need to be modified to ensure that the waterbody meets its minimum standards.

Standards are developed by designating one or more beneficial uses for each waterbody and establishing a set of criteria that protect those uses. Standards also include an antidegradation policy.

2.5.2 How Are Water Quality Standards Set?

Water quality standards are composed of three elements:

- Designated (beneficial) uses
- Numeric and narrative criteria
- Antidegradation policies

Example Designated Uses

- Growth and propagation of fish
- Water contact recreation
- Drinking water
- Agricultural water supply
- Industrial supply
- Wildlife
- Swimming

Designated Uses

Designated or beneficial uses are descriptions of water quality expectations or water quality goals. A designated use is a legally recognized description of a desired use of the waterbody, such as aquatic life support, body contact recreation, fish consumption, or public drinking water supply. These are uses that the state or authorized tribe wants the waterbody to be healthy enough to support fully.

State and tribal governments are primarily responsible for designating uses of waterbodies within their jurisdictions. Some water quality agencies have many use designations and differentiate among various categories of uses for aquatic life support, irrigation, and even cultural uses for tribal waters. Other agencies designate uses by broad categories or classes, with uses requiring similar water quality conditions grouped under each class.

Water Quality Criteria

Criteria define the levels, pollutant/constituent concentrations, or narrative statement reflecting the condition of the waterbody that supports its designated use(s). Criteria describe physical, chemical, and biological attributes or conditions as numeric (e.g., concentrations of certain chemicals) or narrative (e.g., no objectionable scum, sludge, odors) water quality components. Together, the various criteria for a particular designated use paint a picture of the water quality necessary to support the use. EPA, states, and tribes establish water quality criteria for various waterbody uses as part of their water quality standards.

Numeric Criteria

EPA, states, and tribes have set numeric criteria or limits for many common water quality parameters, such as concentrations of bacteria, suspended sediment, algae, dissolved metals, minimum/maximum temperatures, and so on. Numeric criteria for protecting aquatic life are often expressed as a concentration minimum or maximum for certain parameters and include an averaging period and a frequency or recurrence interval. For example, a criterion for a parameter of concern might state that concentrations of the parameter must not exceed 5 parts per million, averaged from five samples collected within a 30-day period, and recurring more than once in a 3-year period.

Criteria for protecting human health may be derived from epidemiological studies and laboratory studies of pollutant exposure involving species like rats and mice. Numeric criteria established to prevent *chronic* conditions are more strict than those focusing on *acute* exposure to parameters of concern.

What's the Difference Between Numeric and Narrative Criteria?

It's important to note that numeric criteria are invaluable when setting specific, measurable goals for waterbody cleanup plans because they provide a very clear indication of when water quality meets the criteria. However, federal, state, and tribal numeric criteria development is complex and expensive in terms of time and resources. Narrative criteria provide a means to convey the context, conditions, and full intent of water quality protection efforts in the absence of numeric criteria development and monitoring efforts.

Narrative Criteria

Narrative criteria are nonnumeric descriptions of desirable or undesirable water quality conditions. An example of a narrative criterion is "All waters will be free from sludge; floating debris; oil and scum; color- and odor-producing materials; substances that are harmful to human, animal, or aquatic life; and nutrients in concentrations that may cause algal blooms."

Biocriteria

A comprehensive assessment of a waterbody might include a description of its biological characteristics. Biological criteria, or "biocriteria," have been developed to quantitatively describe a waterbody with a healthy community of fish and associated aquatic organisms. Components of biocriteria include the presence and seasonality of key indicator species; the abundance, diversity, and structure of the aquatic community; and the habitat conditions these organisms require. Monitoring of these biological indicators provides a simple and often inexpensive way to screen waters that are supporting their uses without a lot of expensive chemical and other testing. In addition, biological assessments can capture the impacts of intense, short-term pollution that might go undetected under conventional chemical testing. Even if states have not yet adopted official biocriteria for their waters, biological sampling can be an important part of watershed monitoring to show progress in meeting load reductions and attaining narrative criteria.

Antidegradation Policies and Implementation Methods

The antidegradation requirements cited in federal, state, and tribal water quality standards provide an excellent and widely used approach for protecting waters threatened by human activities that might cause a lowering of water quality. Under these provisions, which are required under the Clean Water Act, a public agency designated as the federally delegated water quality authority must adopt both an antidegradation policy and identify methods for implementing the policy. The policy must protect existing waterbody uses (40 CFR 131.12(a)(1)). There are two other parts, or tiers, of the antidegradation policy. Under Tier II, waters that exceed quality levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water must be protected unless the delegated water quality agency (1) determines that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located and (2) meets relevant public participation and intergovernmental coordination provisions of the state or tribal continuing planning process. The antidegradation policy must also ensure that the quality of all outstanding national resource waters is maintained and protected (Tier III).

Implementation methods or procedures for antidegradation policies usually include antidegradation reviews for all new or expanded regulated activities that might lower water quality, such as wastewater treatment, stormwater, CAFO, and other discharges subject to National Pollutant Discharge Elimination System (NPDES) permits; activities governed by Clean Water Act section 404 "dredge and fill" permits; and other activities regulated by federal, state, tribal, or other authorities. In the past, permit approval processes for these activities focused mostly on whether they would maintain water quality to meet existing uses (40 CFR 131.12(a)(1)). However, the Tier II antidegradation provisions require that higher-quality waters be protected unless there is a demonstration of necessity and if there is important economic or social development in the area in which the waters are located, and public participation and intergovernmental coordination requirements are met. States often include, as a part of the Tier II review, requirements to examine possible alternatives to proposed activities that would lower water quality, as well as an analysis of the costs associated with the alternatives.

Full Text of the Federal Antidegradation Regulations at 40 CFR, Chapter I, Section 131.12:

(a) The State shall develop and adopt a statewide antidegradation policy and identify the methods for implementing such policy pursuant to this subpart. The antidegradation policy and implementation methods shall, at a minimum, be consistent with the following:

(1) Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

(2) Where the quality of the waters exceed levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water, that quality shall be maintained and protected unless the State finds, after full satisfaction of the intergovernmental coordination and public participation provisions of the State's continuing planning process, that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. In allowing such degradation or lower water quality, the State shall assure water quality adequate to protect existing uses fully. Further, the State shall assure that there shall be achieved the highest statutory and regulatory requirements for all new and existing point sources and all cost-effective and reasonable best management practices for nonpoint source control.

(3) Where high quality waters constitute an outstanding National resource, such as waters of National and State parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected.

(4) In those cases where potential water quality impairment associated with a thermal discharge is involved, the antidegradation policy and implementing method shall be consistent with section 316 of the Act.

http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&rgn=div5&view=text&node=40:21.0.1.1.18&idno=40#40:21.0.1.1.18.2.16.3

For more in-depth descriptions of water quality standards and criteria, go to **www.epa.gov/waterscience/standards**.

2.6 Nine Minimum Elements to Be Included in a Watershed Plan for Impaired Waters Funded Using Incremental Section 319 Funds

Although many different components may be included in a watershed plan, EPA has identified nine key elements that are critical for achieving improvements in water quality. (Go to **www.epa.gov/owow/nps/cwact.html** for a copy of the FY 2004 *Guidelines for the Award of Section 319 Nonpoint Source Grants to States and Territories*).

What Does This Mean?

Shows you where one or more of the nine minimum elements are specifically discussed.

EPA requires that these nine elements be addressed in watershed plans funded with incremental Clean Water Act section 319 funds and strongly recommends that they be included in all other watershed plans intended to address water quality impairments. In general, state water quality or natural resource agencies and EPA will review watershed plans that provide the basis for section 319-funded projects. Although there is no formal requirement for EPA to approve watershed plans, the plans must address the nine elements discussed below if they are developed in support of a section 319-funded project.

In many cases, state and local groups have already developed watershed plans for their rivers, lakes, streams, wetlands, estuaries, and coastal waters. If these existing plans contain the nine key elements listed below, they can be used to support section 319 work plans that contain projects extracted from the plan. If the existing plans do not address the nine elements, they can still provide a valuable framework for producing updated plans. For example, some watershed management plans contain information on hydrology, topography, soils, climate, land uses, water quality problems, and management practices needed to address water quality problems but have no quantitative analysis of current pollutant loads or load reductions that could be achieved by implementing targeted management practices. In this case, the plan could be amended by adding this information and other key elements not contained in the original plan. If separate documents support the plan and the nine elements listed below but are too lengthy to be included in the watershed plan, they can be summarized and referenced in the appropriate sections of the plan. EPA supports this overall approach—building on prior efforts and incorporating related information—as an efficient, effective response to the need for comprehensive watershed plans that address impaired and threatened waters.

Figure 2-3 highlights where the nine key elements fit into the overall watershed planning process. Once the plan has been developed, plan sponsors can select specific management actions included in the plan to develop work plans for nonpoint source section 319 support and to apply for funding to implement those actions (chapter 12).

The nine elements are provided below, listed in the order in which they appear in the guidelines. Although they are listed as *a* through *i*, they do not necessarily take place sequentially. For example, element *d* asks for a description of the technical and financial assistance that will be needed to implement the watershed plan, but this can be done only after you have addressed elements *e* and *i*.

Explanations are provided with each element to show you what to include in your watershed plan. In addition, chapters where the specific element is discussed in detail are referenced.

Nine Elements of Watershed Plans

a. Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan. Sources that need to be controlled should be identified at the significant subcategory level along with estimates of the extent to which they are present in the watershed (e.g., X number of dairy cattle feedlots needing upgrading, including a rough estimate of the number of cattle per facility; Y acres of row crops needing improved nutrient management or sediment control; or Z linear miles of eroded streambank needing remediation).
(↳ Chapters 5, 6, and 7.)

What does this mean?

Your watershed plan should include a map of the watershed that locates the major causes and sources of impairment. To address these impairments, you will set goals that will include (at a minimum) meeting the appropriate water quality standards for pollutants that threaten or impair the physical, chemical, or biological integrity of the watershed covered in the plan.

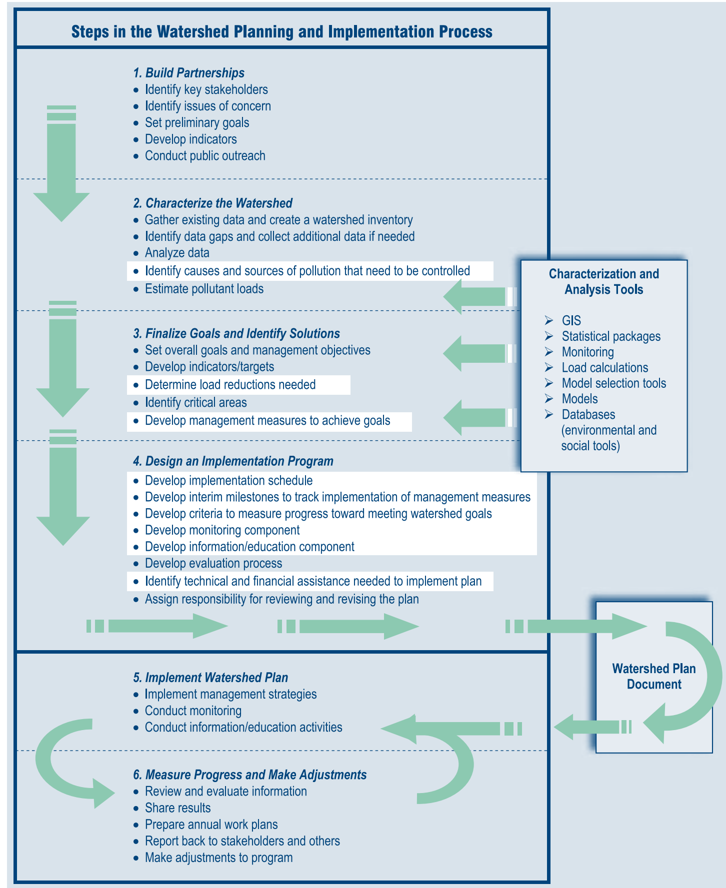


Figure 2-3. Incorporating the Nine Minimum Elements into Your Watershed Plan

This element will usually include an accounting of the significant point and nonpoint sources in addition to the natural background levels that make up the pollutant loads causing problems in the watershed. If a TMDL exists, this element may be adequately addressed. If not, you will need to conduct a similar analysis to do this. The analytical methods may include mapping, modeling, monitoring, and field assessments to make the link between the sources of pollution and the extent to which they cause the water to exceed relevant water quality standards.

b. An estimate of the load reductions expected from management measures.

What does this mean?

On the basis of the existing source loads estimated for element *a*, you will similarly determine the reductions needed to meet the water quality standards. You will then identify various management measures (see element *c* below) that will help to reduce the pollutant loads and estimate the load reductions expected as a result of these management measures to be implemented, recognizing the difficulty in precisely predicting the performance of management measures over time.

Estimates should be provided at the same level as that required in the scale and scope component in paragraph *a* (e.g., the total load reduction expected for dairy cattle feedlots, row crops, or eroded streambanks). For waters for which EPA has approved or established

TMDLs, the plan should identify and incorporate the TMDLs. Applicable loads for downstream waters should be included so that water delivered to a downstream or adjacent segment does not exceed the water quality standards for the pollutant of concern at the water segment boundary. The estimate should account for reductions in pollutant loads from point and nonpoint sources identified in the TMDL as necessary to attain the applicable water quality standards. (↳ Chapters 8 and 9.)

c. A description of the nonpoint source management measures that will need to be implemented to achieve load reductions in paragraph 2, and a description of the critical areas in which those measures will be needed to implement this plan.

What does this mean?

The plan should describe the management measures that need to be implemented to achieve the load reductions estimated under element *b*, as well as to achieve any additional pollution prevention goals called out in the watershed plan (e.g., habitat conservation and protection). Pollutant loads will vary even within land use types, so the plan should also identify the critical areas in which those measures will be needed to implement the plan. This description should be detailed enough to guide implementation activities and can be greatly enhanced by identifying on a map priority areas and practices. (↳ Chapters 7, 8, 9, 10, and 11.)

d. 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.

What does this mean?

You should estimate the financial and technical assistance needed to implement the entire plan. This includes implementation and long-term operation and maintenance of management measures, I/E activities, monitoring, and evaluation activities. You should also document which relevant authorities might play a role in implementing the plan. Plan sponsors should consider the use of federal, state, local, and private funds or resources that might be available to assist in implementing the plan. Shortfalls between needs and available resources should be identified and addressed in the plan. (↳ Chapter 12.)

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

What does this mean?

The plan should include an I/E component that identifies the education and outreach activities or actions that will be used to implement the plan. These I/E activities may support the adoption and long-term operation and maintenance of management practices and support stakeholder involvement efforts. (↳ Chapters 3 and 12.)

f. Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.

What does this mean?

You should include a schedule for implementing the management measures outlined in your watershed plan. The schedule should reflect the milestones you develop in *g*. (↳ Chapter 12.)

*g. A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented. (**Chapter 12.**)*

What does this mean?

You'll develop interim, measurable milestones to measure progress in implementing the management measures for your watershed plan. These milestones will measure the implementation of the management measures, such as whether they are being implemented on schedule, whereas element *h* (see below) will measure the effectiveness of the management measures, for example, by documenting improvements in water quality.

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 toward attaining water quality standards.

What does this mean?

As projects are implemented in the watershed, you will need water quality benchmarks to track progress. The *criteria* in element *h* (not to be confused with *water quality criteria* in state regulations) are the benchmarks or waypoints to measure against through monitoring. These interim targets can be direct measurements (e.g., fecal coliform concentrations) or indirect indicators of load reduction (e.g., number of beach closings). You should also indicate how you'll determine whether the watershed plan needs to be revised if interim targets are not met. These revisions could involve changing management practices, updating the loading analyses, and reassessing the time it takes for pollution concentrations to respond to treatment. (Chapters 12 and 13.)

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

What does this mean?

The watershed plan should include a monitoring component to determine whether progress is being made toward attaining or maintaining the applicable water quality standards. The monitoring program should be fully integrated with the established schedule and interim milestone criteria identified above. The monitoring component should be designed to determine whether loading reductions are being achieved over time and substantial progress in meeting water quality standards is being made. Watershed-scale monitoring can be used to measure the effects of multiple programs, projects, and trends over time. Instream monitoring does not have to be conducted for individual BMPs unless that type of monitoring is particularly relevant to the project. (Chapters 6, 12, and 13.)

The remainder of this handbook proceeds through the watershed planning process, addressing these elements in detail to show you how to develop and implement watershed plans that will achieve water quality and other environmental goals.

The level of detail (figure 2-4) needed to address the nine key elements of watershed management plans listed above will vary in proportion to the homogeneity or similarity of land use types and variety and complexity of pollution sources. Urban and suburban watersheds will therefore generally be planned and implemented at a smaller scale than watersheds with large areas of a similar rural character. Similarly, existing watershed plans and strategies for larger river basins often focus on flood control, navigation, recreation, and water supply but contain only summary information on existing pollutant loads. They often generally identify only source areas and types of management practices. In such cases, smaller subbasin and

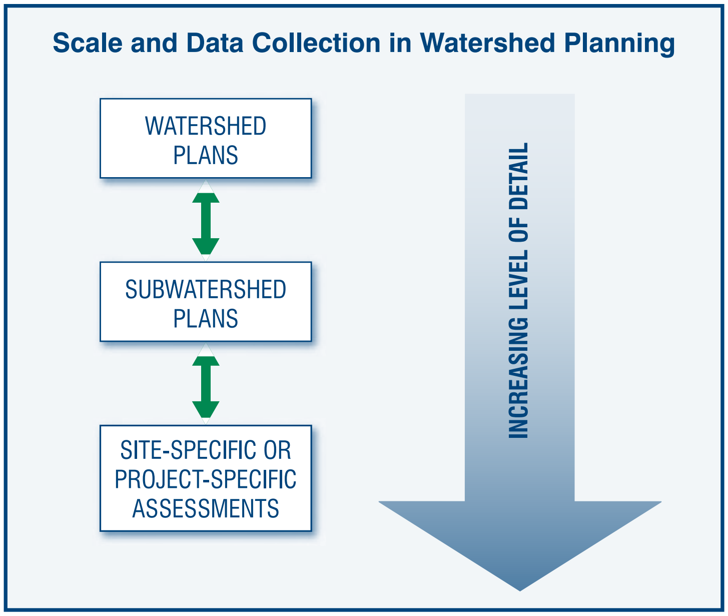


Figure 2-4. Level of Detail for Watershed Management Plans

watershed plans and work plans developed for nonpoint source management grants, point sources, and other stormwater management can be the vehicles for providing the necessary management details. A major purpose of this manual is to help watershed managers find planning tools and data for managing watersheds at an appropriate scale so that problems and solutions can be targeted effectively.

3. Build Partnerships

Chapter Highlights

- Identifying driving forces
- Identifying stakeholders
- Keeping stakeholders engaged
- Integrating with key local, state, tribal, and federal programs
- Initiating outreach activities

Read this chapter if...

- You want to find out what kinds of stakeholders should be involved in developing your watershed plan
- You want to get stakeholders involved early in the process
- You don't know what kinds of programs you should integrate into your planning efforts

3.1 Why Do I Need Partners?

Bringing together people, policies, priorities, and resources through a watershed approach blends science and regulatory responsibilities with social and economic considerations. The very nature of working at a watershed level means you should work with at least one partner to improve watershed conditions. In addition, watershed planning is often too complex and too expensive for one person or organization to tackle alone. Weaving partners into the process can strengthen the end result by bringing in new ideas and input and by increasing public understanding of the problems and, more important, public commitment to the solutions. Partnerships also help to identify and coordinate existing and planned efforts. For example, a watershed organization might be interested in developing a volunteer monitoring program but is unaware that the local parks department is working on a similar program. Researching and identifying partners can help to avoid reinventing the wheel or wasting time and money.

Budgets can be unpredictable, and resources for watershed improvement efforts, such as fencing cows out of streams, are limited. Resources like technical assistance, mapping abilities, and funding are always strained, but working with partners might provide some of the resources that can get your effort closer to its goals more efficiently.

Before you begin to identify and recruit potential partners, you should ask yourself, "Why are we developing a watershed plan?" To answer that question, you should identify the driving forces behind the need for the watershed plan.

Dealing with Multiple Political Jurisdictions in a Watershed

There are very few watershed in a single county and few large rivers in a single state. Coordinating watershed planning and management in multiple political jurisdictions can be difficult, but encouraging stakeholders to focus on the water resource under study and opportunities to cooperate can help to address water quality impairments or threats. Engaging the technical and field staff of federal, state, tribal, county, and local agencies in gathering data and identifying the full range of management options can help to create a collaborative, coordinated approach that can be built upon and further refined by elected officials, managers, and citizens.

3.2 Identify Driving Forces

Watershed plans can be initiated for various reasons and by various organizations. For example, a local agency might want to develop a watershed plan to comply with new federal and state water quality regulations. Or perhaps a watershed organization wants to develop a watershed plan to help coordinate future land-use planning efforts to protect sensitive environmental areas in the community. It could also be that preliminary data collection has identified some specific problems. EPA acknowledges that watershed plans are appropriate tools for both restoring waters that are impaired and protecting waters that are threatened. Plans are also appropriate for those wishing to better coordinate water resources activities, use resources more efficiently, and integrate various required activities, such as protecting source water, implementing Total Maximum Daily Loads (TMDLs), managing forests and other lands, or complying with stormwater regulations. It's important to identify the driving forces motivating you to develop a watershed plan. These forces will set the foundation for developing your plan's goals and objectives. The typical watershed planning drivers are described below.

3.2.1 Regulatory Issues

Water resource or other regulations sometimes require a planning or management document that contains some or all of the elements required in a watershed plan. Communities pursuing efficient, effective approaches to planning often initiate a comprehensive watershed planning effort to streamline multiple planning tasks, like the following:

- Clean Water Act section 303(d) requirements for developing (TMDLs)
- Clean Water Act section 319 grant requirements
- Federal and state National Pollutant Discharge Elimination System (NPDES) Phase II stormwater permit regulations
- NPDES discharge permit requirements
- Source water protection requirements under the Safe Drinking Water Act
- National Estuary Program and coastal zone conservation/management plan requirements
- Federal and state source water assessment and protection program regulations
- Baseline and monitoring studies to implement federal and state antidegradation policies
- Endangered Species Act requirements

Hydromodification, Flows, and Watershed Management

It should be noted that altering river and stream flows through dams and diversions can have a major influence on the ability of such waters to sustain native fish populations, manage internal sediment loads, control flooding, and handle other physical, chemical, and biological issues. Flows are managed by state water agencies, interstate compacts, dam operators, and other entities identified under federal and state laws. For detailed information on dealing with flow and other conditions affecting the ecological integrity of surface waters (e.g.,hydromodification), go to **www.epa.gov/owow/nps/hydromod/pdf/hydro_guide.pdf** and **www.epa.gov/owow/wetlands/restore/principles.html**.

3.2.2 Government Initiatives

Dozens of federal, state, and local initiatives target geographic areas like the Chesapeake Bay or the Great Lakes, or attempt to focus on one aspect of a management program, such as the following:

- EPA-supported, geographically targeted programs (e.g., Chesapeake Bay, Great Lakes)
- U.S. Department of Agriculture (USDA) initiatives (e.g., 2002 Farm Bill program, Forest Service planning)
- Other federal water resource initiatives (e.g., those sponsored by the Bureau of Land Management, the Bureau of Reclamation, and the National Oceanic and Atmospheric Administration)

River Compacts and Watershed Management

Beginning with the Colorado River Compact of 1922, Congress has approved about two dozen river management compacts in an attempt to equitably allocate and manage the waters of interstate rivers. The allocation formulas and management objectives in the river compacts vary, but for the most part they seek to protect existing uses and water rights. River compacts can provide a good framework for coordinating multiple watershed plans in large river basins. For more information on river compacts, visit **www.fws.gov/laws/lawsdigest/interstatecompacts.htm**.

- Congressional mandates (e.g., Comprehensive Wildlife Conservation Strategies required of wildlife management agencies in each state)
- Stream or river restoration planning (e.g., by cities, counties, states)
- River authority and other state-enabled (or required) watershed planning initiatives (e.g., intra- or interstate river compacts)
- State initiatives like Pennsylvania's Growing Greener program or Michigan's Clean Michigan Initiative

3.2.3 Community-Driven Issues

Often the decision to develop a watershed plan comes from within the community. People have a desire to protect what they have or to restore water resources for future generations. Some compelling issues include the following:

- Flood protection
- Increased development pressures
- Recreation/aesthetics (e.g., river walks, boating, fishing, swimming)
- Protection of high-quality streams or wetlands
- Post-disaster efforts
- Protection of drinking water sources

If you're reading this document, you might be part of the group that is leading the development of a watershed plan. In general, the leader's role involves identifying and engaging other stakeholders that should be participating in plan development and implementation. Section 3.3 discusses the importance of stakeholder involvement and provides some information on how to identify and involve stakeholders.

Fire Helps to Energize Watershed Planning Efforts

The Pajarito Plateau Watershed Partnership (PPWP) began in 1998 in response to a draft watershed management plan prepared by the Los Alamos National Laboratory (LANL). The development of LANL's plan did not initially include the stakeholders in the hydrologic watershed. Instead, the plan was for LANL's property. LANL decided to work with the stakeholders, including tribes, Los Alamos County, the Forest Service, the National Park Service, and others, to develop a complete watershed plan. As the plan was developed, however, the partnership began to have trouble keeping the group engaged. Some stakeholders lost interest, and others limited their participation.

It wasn't until after a controlled burn went out of control in May 2000 and burned almost 50,000 acres of the watershed that the group found a common purpose—post-fire rehabilitation. The group has received section 319 grant money for rehabilitation activities, such as seeding, reforestation, and trail maintenance, throughout the watershed. A watershed assessment was completed, and the group has shifted its focus to sediment erosion issues in one subwatershed.

For more information, see the PPWP Web site at **www.volunteertaskforce.org/ppwatershed/default.htm**.

3.3 Identify and Engage Stakeholders

Successful development and implementation of a watershed plan depends primarily on the commitment and involvement of community members. Therefore, it is critical to build partnerships with key interested parties at the outset of the watershed planning effort. People and organizations that have a stake in the outcome of the watershed plan are called stakeholders. Stakeholders are those who make and implement decisions, those who are affected by the decisions made, and those who have the ability to assist or impede implementation of the decisions. It's essential that all of these categories of potential stakeholders—not just those that volunteer to participate—are identified and included. Key stakeholders also include those that can contribute resources and assistance to the watershed planning effort and those that work on similar programs that can be integrated into a larger effort. Keep in mind that stakeholders are more likely to get involved if you can show them a clear benefit to their participation.

> Before you start identifying stakeholders, find out if your state has developed a watershed planning guide. You might find useful information that will help you to identify the relevant stakeholders and programs for your watershed planning effort.

3.3.1 Identify Categories of Stakeholders

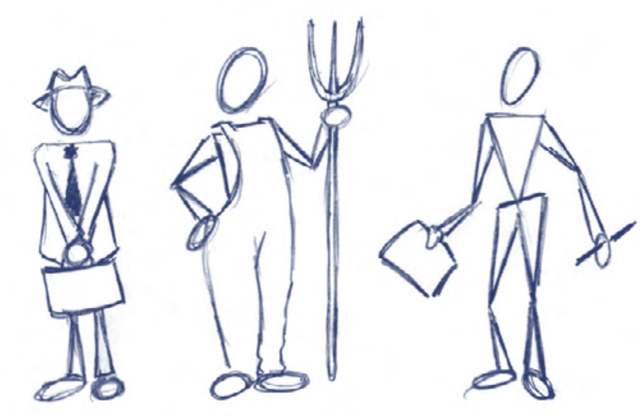
It is daunting to try to identify all the players that could be involved in the watershed planning effort. The makeup of the stakeholder group will depend on the size of the watershed (to ensure adequate geographic representation), as well as the key issues or concerns. In general, there are at least five categories of participants to consider when identifying stakeholders:

- Stakeholders that will be responsible for implementing the watershed plan
- Stakeholders that will be affected by implementation of the watershed plan
- Stakeholders that can provide information on the issues and concerns in the watershed
- Stakeholders that have knowledge of existing programs or plans that you might want to integrate into your plan
- Stakeholders that can provide technical and financial assistance in developing and implementing the plan

> **Unconventional Partners**
>
> The staff of the American Samoan Coastal Program created a Religious Consciousness Project to help spread the word about the islands' environmental problems. For years, program staff had tried unsuccessfully to get village mayors involved in efforts to protect coastal water resources. Through the project, program staff offered to present information on water quality, population growth, and nonpoint source pollution during church gatherings. As a result of the church partnership, a village mayors workshop was held, ultimately leading to the start of a new water quality project focusing on water resource education.

As a starting point, consider involving these entities:

- Landowners
- County or regional representatives
- Local municipal representatives
- State and federal agencies
- American Indian tribes
- Business and industry representatives
- Citizen groups



- Community service organizations
- Religious organizations
- Universities, colleges, and schools
- Environmental and conservation groups
- Soil and water conservation districts
- Irrigation districts

The development of the stakeholder group is an iterative process. Don't worry about whether you have complete representation at the outset. Once the stakeholders convene, you can ask them if there are any gaps in representation.

Section 3.4 provides more detailed information on possible local, state, tribal, and federal program partners that you might want to include in your stakeholder group.

3.3.2 Determine Stakeholders' Roles and Responsibilities

Before contacting potential stakeholders, you should ask yourself the following questions and have at least a rough idea of the answers. This exercise will help you to determine the level of effort needed for the stakeholder process and will provide initial guidance to stakeholders.

- What is the role of the stakeholders?
- How will decisions be made?
- Are stakeholders expected to develop any work products?
- What is the estimated time commitment for participation?

Begin by contacting the people and organizations that have an interest in water quality or might become partners that can assist you with the watershed planning process. Consider who would be the most appropriate person to contact the potential partner. Those who might have a stake in the watershed plan should be encouraged to share their concerns and offer suggestions for possible solutions. By involving stakeholders in the initial stages of project development, you'll increase the probability of long-term success through trust, commitment, and personal investment.

Worksheet 3-1 Stakeholder Skills and Resources Checklist

Skills in Stakeholder Group

- Accounting
- Graphic design
- Computer support
- Fund-raising
- Public relations
- Technical expertise (e.g., geographic information systems, water sampling)
- Facilitation

Resources Available

- Contacts with media
- Access to volunteers
- Access to datasets
- Connections to local organizations
- Access to meeting facilities
- Access to equipment (please describe)
- Access to field trip locations

3.3.3 Provide a Structure to Facilitate Stakeholder Participation

Once you've identified and contacted stakeholders, you'll organize them to help prepare and implement a watershed plan. Stakeholder groups range from informal, ad hoc groups to highly organized committees. The method you choose will likely depend on the makeup of the stakeholders willing to participate, the time and financial resources available, and your capabilities with respect to facilitating the plan development effort. The following examples provide some indication of the range of options available for stakeholder participation.

Decisionmakers. The governing boards of some state river authorities require representation from a broad array of public agencies and private entities, including business interests, recreational organizations, and environmental groups. Giving decision-making power to stakeholders often increases the amount of analysis and time needed to make decisions, but it can provide a venue for generating needed support and resources for watershed planning and management activities.

Advisors. Many watershed planning initiatives involve stakeholders as part of a steering committee or advisory group. Although stakeholders do not have the power to make and enforce decisions, they can create momentum and support for moving the process forward in the directions they choose if they are somewhat united and cooperative in their approach.

Supporters. Sometimes stakeholders are invited to participate because of their ability to provide technical, financial, or other support to the watershed planning process. Under this approach, watershed planners seek out stakeholders that have assessment data, access to monitoring or project volunteers, educational or outreach networks, or other assets that can be used to enhance the watershed plan. For example, the U.S. Geological Survey (USGS) might be invited to provide water quality monitoring data, such as flow data from the many gauging stations across the country.

Ohio Builds Strong and Effective Watershed Groups

Ohio has adopted a program philosophy that strong and effective local watershed stakeholder groups are necessary to develop and implement integrated watershed plans. According to Ohio, the key to watershed organization capacity-building is active stakeholders that provide technical knowledge, financial ability, networking ability, organizational skills, and legitimacy (decisionmakers with the authority to implement and support problem and solution statements and recommended action items).

Additional information about Ohio's philosophy for strong and effective watershed groups is available at **www.epa.state.oh.us/dsw/nps/NPSMP/WAP/WAPccsustainable.html**.

3.3.4 Identify Stakeholders' Skills and Resources

For the group of stakeholders that have agreed to participate in the planning effort, determine what resources and skills are collectively available to support the planning phases. A wide range of technical and "people" skills are needed for most planning initiatives. Stakeholders might have access to datasets, funding sources, volunteers, specialized technical expertise, and communication vehicles. Use Worksheet 3-1 to determine your stakeholders' skills and resources. A full-size worksheet is provided in appendix B.

Ways to Engage and Involve Stakeholders

At Home

- Reading brochures
- Visiting a Web site
- Completing a survey
- Adopting practices that conserve water and protect water quality at home or at work
- Reviewing documents

Out in the Community

- Managing practice tours and watershed fairs
- Conducting coffee shop discussions
- Making educational presentations

Action-oriented Activities

- Stenciling, stormdraining
- Monitoring volunteer work
- Stream cleanup

3.3.5 Encourage Participation and Involvement

As stakeholders begin to show an interest, you'll likely note that the type and degree of effort that individuals or organizations are willing to put forth will vary. Some stakeholders will want to be directly involved in the detailed technical process of planning, whereas others will simply want to be periodically updated on progress and asked for feedback. Still others won't want to plan at all, but instead will want to know what they can do now to take actions that will make a difference. In other words, you'll likely be faced with managing planners, advisors, doers, and watchers. A key step, therefore, involves organizing the effort to help stakeholders plug in at the level that is most comfortable for them and taps their strengths.

If you're not talking about issues that are important to the stakeholders, they'll be less likely to participate in the process. Here are some tips to remember when working with stakeholders to help ensure their long-term participation and support.

Focus on issues important to the stakeholders. If they can't see how their issues will be addressed in the watershed plan, you need to change the plan or clearly show them where their issues are addressed.

Be honest. Much of the process is about trust, and to build trust you must be honest with the stakeholders. That's why it's important to tell them how decisions will be made. If their role is advisory, that's OK, but they should know up front that they will not be involved in the decision-making process.

Start early. Involve stakeholders as soon as possible in the watershed planning process. This approach also helps to build trust by showing them that you have not developed a draft document and just want them to review it. They will help to shape goals, identify problems, and develop possible management strategies for the watershed.

Recognize differences early in the process. It's OK if everyone does not agree on various issues. For example, not all data compiled by some stakeholders, such as tribes, will be shared with a group if there are cultural concerns to be considered. If you ignore these differences, you'll lose credibility and any trust that the stakeholders had in the process.

Communicate clearly and often. The watershed planning process is long and complex. Don't leave stakeholders behind by failing to communicate with them using terms familiar to them. Regular communication and updates can be done through Web sites, newsletters, fact sheets, and newspaper inserts. Also remember that sometimes it will take time before

More on Working with Stakeholders

- To find more detailed information on forming watershed stakeholder groups, keeping a group motivated, conducting outreach, resolving conflict, and making decisions using consensus, download a pdf version of *Getting In Step: Engaging and Involving Stakeholders in Your Watershed* from **www.epa.gov/owow/watershed/outreach/documents**.
- The Conservation Technology Information Center (CTIC) has developed a series of documents to help you know your watershed. This information clearinghouse for watershed coordinators helps to ensure measurable progress toward local goals. The clearinghouse is available at **www2.ctic.purdue.edu/kyw/kyw.html**.

Facilitating Stakeholder Groups

Any watershed coordinator learns quickly that he or she needs to be a good facilitator, find one in the stakeholder group, or hire one. Outside facilitators (third-party persons not connected directly to the sponsoring agency or other stakeholders at the table) are usually best. The facilitator should be perceived as a neutral party who will not contribute his or her ideas to the group. The facilitator should be objective and maintain a broad perspective but should also challenge assumptions, act as a catalyst, generate optimism, and help the group connect with similar efforts. It's important to make sure that the stakeholders feel comfortable with the facilitator.

It's important also that the facilitator have strong facilitation skills like understanding productive meeting room layouts, knowing the different ways decisions can be made, understanding how to help settle conflicts and how to move people with conflicting views toward consensus, and being able to manage time well and keep the discussion on point during meetings.

reluctant stakeholders come to the table, so you need to have a means of communicating with them and keeping them up-to-date. When they do decide to participate in the process, they'll already be well informed.

Team-Building Exercise for Stakeholders

At the first stakeholder meeting, give each person a blank sheet of paper. Tell everyone to "draw a map of your community." Many will want more guidance on what to do, but just repeat the initial instructions.

When the participants are finished, ask them to exchange papers with each other. Then ask the group the following questions:

- What does this map tell you about this person's community?
- What appears to be the "center" of the community? What are its boundaries?
- What does this map suggest about this person's perception of the environmental character of the community?
- Who included people, water resources, roads, trees, administrative buildings?

This exercise helps the stakeholders to get to know each other and to start getting a feeling of their values and how they use the resources in the community.

—Adapted from *Community and the Environment: A Guide to Understanding a Sense of Place*, available at **www.epa.gov/CARE/library/community_culture.pdf**.

3.3.6 Initiate Outreach Activities to Build Awareness and Gain Partners

Information/education (I/E) activities are key to building support for the watershed planning effort, as well as helping to implement the plan. I/E activities (also called outreach) are needed at the very beginning of the watershed planning effort to make potential partners and stakeholders aware of the issues, recruit them to participate, and educate them on the watershed planning process. Often a separate outreach and education committee is created under the umbrella of the watershed planning team. This committee can help develop related materials and a strategy for integrating I/E into the overall watershed planning effort. Eventually, outreach will be most successful if individual stakeholders reach out to their constituents or peer groups about actions that need to be taken to improve and maintain water quality. The education committee can help support this effort by developing materials for stakeholders to use to educate their constituents. Chapter 12 provides more detail on the I/E component.

Developing and distributing effective messages through outreach materials and activities is one the most important components of getting partners and stakeholders engaged in the watershed planning and implementation processes. Outreach materials and activities should be designed to raise public awareness, educate people on wise management practices, and motivate people to participate in the decisionmaking process or in the implementation of actions to restore and protect water quality. To achieve these objectives, you should communicate effectively with a wide range of audiences or groups. At the outset of your watershed planning effort, you might consider developing an informational brochure and a slide presentation for your stakeholder group that explains current issues in the watershed and the need to develop a watershed plan. Once the stakeholder group convenes, it can tailor these materials and determine the preferred formats for disseminating information to various audiences. Remember that your I/E activities should be targeted to specific audiences and will change over time as you develop and implement your watershed plan.

Watershed plan organizers might need to sponsor a broad spectrum of activities to engage and involve most of the stakeholders effectively. People differ widely in how much time and energy they're willing to expend on community-based activities. Some people might want simply to be informed about what's going on in their community, whereas others might want a voice in the management decisions made and how they're implemented. A program that offers many different types of participation opportunities that involve varying levels of effort is likely to attract more willing participants.

3.4 Integrate Local, State, Tribal, and Federal Programs into Your Watershed Planning Effort

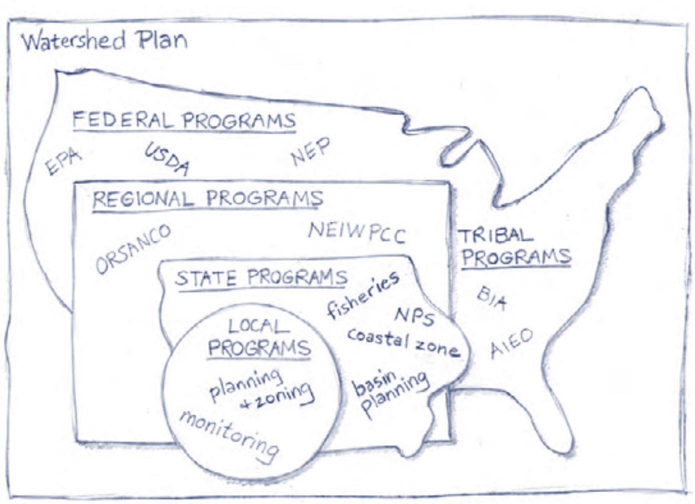
Because developing and implementing watershed plans usually involves a combination of at least some local, state, tribal, and federal partners, it's important to identify any potential programs and activities that might be relevant to your watershed planning effort and determine whether representatives from these programs should participate in your stakeholder group. Many such programs have planning components, collect monitoring data, implement controls, or develop regulations that you might want to incorporate into your watershed plan. In addition, some states have developed multiagency partnerships for the support of monitoring and management practice implementation, which local groups can access. Including partners from these organizations in the watershed management process can help to ensure that any available datasets are identified and that any potential funding opportunities are noted.

Examples of Local Programs and Organizations

- Stormwater management programs
- Parks and recreation departments
- Local elected officials and councils
- Planning and zoning programs
- Soil and water conservation districts
- Cooperative extension
- Solid waste programs
- Water and sewer programs
- Watershed organizations
- Volunteer monitoring programs

The various local, state, tribal, and federal programs that might provide personnel and resources to strengthen your stakeholder group, as well as technical assistance in developing your watershed plan, are briefly described below. Chapter 5 provides more detail on specific datasets that might be available from these programs.

You're not expected to involve all of these programs, but you should be aware of them if they address issues and concerns that are important to your planning effort.



Start at the local level and then broaden your search to include state and tribal programs. Then research which federal programs are relevant to your watershed planning effort. Most likely, the federal programs will already be represented to some extent at the state level. If these programs exist at both the state and local levels, they are included here under the Local Programs heading because the local offices probably have the information most relevant to your watershed.

3.4.1 Local Programs

Because implementing the watershed plan will largely rest with local communities, it's critical that they be involved from the beginning. They usually have the most to gain by participating and the most up-to-date information on the structure of the community. In addition, some of the most powerful tools for watershed plan implementation, such as zoning and regional planning, reside at the local level. *Local* might mean city, county, or township; some states have all three. It's important to learn how the various local governments assign responsibility for environmental protection.

Local Elected Officials

Local elected officials and local agency staff should be closely involved in the plan development and implementation process. Although responsibilities vary among localities, most local government officials are responsible for establishing priorities for local programs and services, establishing legislative and administrative policies through the adoption of ordinances and resolutions, establishing the annual budget, appropriating funds, and setting tax rates. There are also opportunities to make others aware of the watershed management planning process through local government newsletters and presentations at board meetings, which are often televised on local cable television networks.

Local Cooperative Extension Offices

The county cooperative extension offices are part of a state cooperative extension network run through academic institutions. Extension agents conduct research, develop educational programs, and provide technical assistance on a broad range of problems from traditional agricultural management and production issues to farm business management, soil and water conservation, land and water quality, the safe use of pesticides, integrated pest management, nutrient management, models, forestry and wildlife, and commercial and consumer horticulture. ↳ A link to local extension offices is available from the Cooperative State Research, Education, and Extension Service at **www.csrees.usda.gov/Extension/index.html**.

Soil and Water Conservation Districts and NRCS Offices

Most rural counties have local Natural Resources Conservation Service (NRCS) offices and soil and water conservation districts (SWCDs), sometimes referred to simply as conservation districts. These districts and NRCS provide leadership, technical assistance, information, and education to the counties on proper soil stewardship, agricultural conservation methods, water quality protection, nonpoint source pollution, streambank stabilization, stream health, conservation planning (e.g., developing conservation plans), and various other topics related to watershed planning. Local SWCDs also offer volunteer opportunities for citizens, and they can often provide topographic, aerial, and floodplain maps; established erosion and sediment control programs; educational programs; information on the installation and maintenance of management practices; and financial assistance for installing management practices. ↳ Go to **www.nacdnet.org** for a directory of all SWCD locations; NRCS contact information is posted at **www.nrcs.usda.gov/about/organization/regions.html**.

A Mix of Top-down and Bottom-up Efforts

Involvement and leadership from both stakeholders and public agencies are vital ingredients for successful watershed management. The University of Wisconsin found in its Four Corners Watershed Innovators Initiative that "there is a myth that the watershed movement consists of spontaneous 'bottom-up' local efforts that find alternatives to the rigidity of intransigent bureaucracies and one-size-fits-all solutions." Researchers noted that although local support and the energy and resources of watershed groups are vital, "the governmental role is generally critical to successful watershed approaches, particularly if plans and solutions proposed by watershed groups are to be implemented."

Parks and Recreation Department

Local parks and recreation departments are responsible for maintaining recreational facilities and parks in a locality. They manage recreational facilities like boat ramps, nature trails, and swimming pools. They often have support groups that focus on a particular park or topic, such as the trail development or bird-watching activities. These groups can provide insight as to the values of the community in terms of natural resources.

Planning and Zoning Programs

Among the most effective tools available to communities to manage their water resources are planning and zoning. For example, local or regional planning and zoning programs can play a particularly significant role in establishing critical watershed protection areas through overlay zoning; identifying critical water resource areas (e.g., wetlands, springs); and designating protective areas such as vegetated buffers and hydrologic reserves. Professionals in these local programs can provide valuable information on the economic development plans of the region and help to identify current policies to manage growth. The zoning programs are usually linked to a community's overall master plan, so be sure to obtain a copy of the master plan.

Make sure you use local resources to find helpful information about planning and zoning programs for your community. Chapter 5 provides information on developing ordinances as part of your management program, including model language, and information included in master plans.

Regional Planning Councils

Many urban areas have regional councils represented by the participating local governments. These organizations focus on various issues, such as land use planning and the environment. For example, the Southeast Michigan Council of Governments (**www.semcog.org**) represents seven counties, and staff work to support local environmental planning initiatives like watershed management. These organizations can provide valuable resources and expertise useful in your watershed planning effort.

Solid Waste Programs

Many local governments have solid waste programs that address the disposal of solid waste and yard waste. They might also handle the recycling, illegal dumping, and household hazardous waste programs that you might want to incorporate into your outreach activities during the plan implementation phase.

Stormwater Management Programs

The NPDES stormwater permitting program for Phase I and Phase II cities provides one of the most direct links between local government activities and watershed planning/management. Under the stormwater program, communities must comply with permit requirements for identifying and addressing water quality problems caused by polluted urban runoff from sources like streets and parking lots, construction sites, and outfall pipes. Watershed planning programs can provide important guidance to constituent cities on what types of pollutants or stressors need to be addressed by their stormwater programs, what resources are available, and what other cities are doing. Additional information about the two phases of the NPDES stormwater program is available at **http://cfpub.epa.gov/npdes/stormwater/swphases.cfm**.

Volunteer Monitoring Programs

Across the country, volunteers monitor the condition of streams, rivers, lakes, reservoirs, estuaries, coastal waters, wetlands, and wells. Volunteer monitoring programs are organized and supported in many different ways. Projects might be entirely independent or associated with state, interstate, local, or federal agencies; environmental organizations; or schools and universities. If there is an active volunteer monitoring program in your community, it can be a valuable resource in terms of data collection and a means to educate others about watershed issues and concerns. To find out if your community has a volunteer monitoring program, refer to EPA's *Directory of Environmental Monitoring Programs* at **www.epa.gov/owow/monitoring/volunteer**.

Water and Sewer Programs

Most local governments provide water supply and wastewater treatment services for residents. They can help determine whether there are source water protection areas in the watershed and locate water supply and wastewater discharges. They might have a water conservation program that you could incorporate into your watershed outreach program.

Source Water Protection and Watershed Management

Under the 1996 amendments to the federal Safe Drinking Water Act, states must conduct source water assessments and produce studies or reports that provide basic information about the drinking water in each public water system. These assessments provide a powerful link to other watershed assessment activities and should be considered when developing the watershed plan. The source water assessment programs created by states differ, because each program is tailored to a state's water resources and drinking water priorities, but they all seek to characterize and protect sources of drinking water such as lakes, rivers, and other sources (e.g., groundwater aquifers). For more information, go to **http://cfpub.epa.gov/safewater/sourcewater/index.cfm**.

Watershed Organizations

Across the country there are thousands of watershed organizations, which have varying levels of expertise and involvement. These organizations will be a valuable resource in your watershed planning efforts if you can harness their members for problem identification, goal setting, and implementation of the watershed plan. If you're not sure about the organizations in your community, start by looking at EPA's database of watershed organizations at **www.epa.gov/adopt/network.html**.

3.4.2 State and Regional Programs

Most watershed groups draw on local organizations and resources to develop and implement their projects, and some have effectively involved state programs in their efforts. In states that have adopted a statewide watershed management framework, watershed plans should be integrated into the larger watershed or basin plans sponsored under the state framework. Likewise, nonpoint source work plans for local or site-level projects funded under section 319 should be derived from the applicable watershed plan. In cases where there are no larger basin or subbasin plans, the plan under consideration should seek to integrate the full range of stressors, sources, and stakeholders that are likely to emerge as important during or after the planning and implementation process.

The following are some key state and regional programs and resources that can also be tapped to develop and implement watershed plans.

Examples of State Programs

- Statewide watershed or basin planning frameworks
- State water protection initiatives
- Coastal zone management programs
- Source water assessment and protection programs
- State cooperative extension programs
- Wetland conservation plans

Source Water Assessment and Protection (SWAP) Programs

State and local drinking water utilities develop SWAP programs under the 1996 amendments to the Safe Drinking Water Act to protect sources of drinking water, including ground water sources. Many of these waters are affected by nonpoint source pollution. SWAP assessments delineate protection areas for the source waters of public drinking water supplies, identify potential sources of contaminants within the areas, determine the susceptibility of the water supplies to contamination from these potential sources, and make the results of the assessments available to the public. Partnering with state SWAP programs and local drinking water utilities to develop joint watershed assessments provides an excellent opportunity for watershed groups and utilities to pool funds, produce better assessments, and consider surface water and groundwater interactions. ↳ For a list of state source water protection contacts, go to **http://cfpub.epa.gov/safewater/sourcewater/sourcewater.cfm?action=Contacts**.

State and Interstate Water Commissions

Several interstate water commissions, such as the Ohio River Valley Water Sanitation Commission (ORSANCO) and the New England Interstate Water Pollution Control Commission (NEIWPCC), address water quality and water quantity issues. The Association of State and Interstate Water Pollution Control Administrators (ASIWPCA) is a national organization representing the officials responsible for implementing surface water protection programs throughout the United States. ↳ For a listing of state, tribal, and interstate water agencies, go to **www.asiwpca.org** and click on the links.

State Coastal Zone Management Programs

These programs address nonpoint source pollution under section 6217 of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA). These programs can provide a venue for developing or consolidating watershed plans in coastal areas. Under CZARA, states are required to identify and adopt management measures to prevent and control nonpoint source pollution, ensure that enforceable mechanisms exist, enhance cooperation among land and water use agencies, identify land uses that might cause degradation of coastal waters, identify and protect "critical coastal areas," provide technical assistance, provide opportunities for public participation, and establish a monitoring program to determine the extent and success of management measure implementation. Projects within the approved 6217 management area will use the EPA management measures guidance to provide planning objectives for sources covered in the 6217 program. ↳ Coastal zone management measures guidance documents are available at **www.epa.gov/owow/nps/pubs.html**.

State Departments of Transportation

In recent years state DOTs have placed new emphasis on environmental performance related to construction, operation, and maintenance activities. In the past DOTs focused mainly on environmental compliance, but agencies across the country now take a more holistic approach to meeting environmental stewardship goals. Incorporating stewardship priorities into construction and maintenance helps DOTs achieve continuous improvement in environmental performance.

State Fish and Wildlife Programs

Most states have agencies responsible for issuing hunting and fishing permits, maintaining wildlife protection areas, protecting and managing wetlands, and protecting threatened and endangered species. These agencies develop state wildlife action plans and management plans for invasive species control, wildlife management, and habitat protection. They often have very active volunteer programs that you might be able to access to help identify community values and concerns and to help with locating key datasets as part of the characterization process.

State Health Departments

Many state health departments have an environmental health division that manages information on source water protection programs, septic system management programs, well testing and monitoring, and animal feeding operation permits. Some state programs provide online information and maps regarding fish consumption guidelines instituted because of pollutant (often mercury) contamination.

State TMDL Programs

Under section 303(d) of the Clean Water Act, states, territories, and authorized tribes must list waters that are impaired and threatened by pollutants. States, territories, and authorized tribes submit their lists of waters on April 1 in every even-numbered year (except in 2000). The lists are composed of waters that need TMDLs. For more information about TMDLs developed and approved in your state, visit **www.epa.gov/owow/tmdl**.

State Nonpoint Source Programs

State nonpoint source programs help local governments, nonprofit entities, and numerous other state, federal, and local partners to reduce nonpoint source pollution statewide. State nonpoint source programs provide technical assistance, as well as funding sources, to develop watershed management plans for implementing nonpoint source activities. A directory of state nonpoint source coordinators is available at **www.epa.gov/owow/nps/contacts.html**.

State Water Protection Initiatives

Many states have initiated statewide or region-specific watershed management programs or have aligned management and water quality monitoring activities around a watershed framework. You should coordinate with these programs and try to integrate their framework with your goals and objectives; they, in turn, should be aware of your watershed planning issues and concerns. For example, Minnesota's Adopt-a-River program encourages Minnesota volunteers to adopt a section of a lake, river, wetland, or ravine to ensure its long-term health through annual cleanups. To find out whether your state has any of these initiatives, go to the environmental department section of your state's Web site (e.g., Pennsylvania's Department of Environmental Protection).

Integrating Wetlands into Watershed Management

Refer to *A Guide for Local Governments: Wetlands and Watershed Management*, which was developed by the Institute for Wetland Science and Public Policy of the Association of State Wetland Managers. The document provides recommendations for integrating wetlands into broad watershed management efforts and more specific water programs. **www.aswm.org/propub/pubs/aswm/wetlandswatershed.pdf**.

State Wetland Programs

Many states and counties have developed wetland protection programs. These programs offer a variety of services, including developing educational and training materials, working to reduce loss of wetlands, providing landowners with the tools and means to manage wetlands on their property, and coordinating monitoring of wetlands. Some programs propose the use of grants to help share the costs of wetland restoration and help reduce taxes on wetland property and other conservation lands. Some states, such as Wisconsin, require decisions on federal wetland permits to meet state wetland water quality standards.

Regional Geographic Watershed Initiatives

In addition to statewide watershed protection programs, there are several large-scale initiatives that focus on specific regions of the country. These programs collect substantial data that you might use to help characterize your watershed. The programs include the following.

The Columbia River Initiative is a proposed water management program for the Columbia River. In 2004 the former Governor of Washington (Gary Locke) proposed this program to allow the basin's economy to grow and maintain a healthy watershed. The program would offer a plan to secure water for new municipal, industrial, and irrigation uses and to improve stream flows for fish. The proposal also provides for funding. Work on the Columbia River Initiative is on hold until further review by the legislature. For more information on the Columbia River Initiative, visit **www.ecy.wa.gov/programs/wr/cwp/crwmp.html**.

The Chesapeake Bay Program is a unique regional partnership that has directed the restoration of the Chesapeake Bay since 1983. Partners of the program include the states of Maryland, Pennsylvania, and Virginia; the District of Columbia; the Chesapeake Bay Commission, a tristate legislative body; EPA, representing the federal government; and participating citizen advisory groups. An overview of the Chesapeake Bay Program is available at **www.chesapeakebay.net/overview.htm**. For additional information about the program, visit **www.chesapeakebay.net**.

Since 1970 much has been done to restore and protect the Great Lakes. Although there has been significant progress, cleaning up the lakes and preventing further problems has not always been coordinated. As a result, in May 2004 President Bush created a cabinet-level interagency task force and called for a "regional collaboration of national significance." After extensive discussions, the group now known as the Great Lakes Regional Collaboration was convened. The Collaboration includes the EPA-led federal agency task force, the Great Lakes states, local communities, tribes, non-governmental organizations, and other interests in the Great Lakes region. The Collaboration has two components: the conveners (mostly elected local and regional officials) and the issue area strategy teams. The ambitious first goal of the Collaboration is to create within 1 year a workable strategy to restore and protect the Great Lakes. More information about the Regional Collaboration is available at **www.epa.gov/greatlakes/collaboration**.

Another collaborative effort for the Great Lakes is the Great Lakes Initiative, which is a plan agreed upon by EPA and the Great Lake states to restore the health of the Great Lakes. Also called the *Final Water Quality Guidance for the Great Lakes System*, the Great Lakes Initiative started in 1995 to provide criteria for the states' use in setting water quality standards. The plan addresses 29 pollutants and prohibits mixing zones for bioaccumulative chemicals of concern. For more information on the Great Lakes Initiative, visit **www.epa.gov/waterscience/gli**.

3.4.3 Tribal Programs and Organizations

If your watershed planning effort includes, or might affect, tribal lands or waters, or if you are a member of a tribe and are developing a watershed management plan, you should be aware of the various policies and initiatives regarding Indian Country. There are currently 562 federally recognized tribes. The sovereign status of American Indian tribes and special provisions of law set American Indians apart from all other U.S. populations and define a special level of federal agency responsibility. The Bureau of Indian Affairs administers and manages 55.7 million acres of land held in trust by the United States for American Indians and Alaska Natives. For more information go to **www.doi.gov/bureau-indian-affairs**.

In addition, EPA's American Indian Environmental Office (AIEO) coordinates the Agency-wide effort to strengthen public health and environmental protection in Indian Country, with a special emphasis on building the capabilities of tribes so they can administer their own environmental programs. The AIEO provides contact information for all federally recognized tribal governments, maintains a list of tribes that have developed water quality standards, and provides lists of resources. Go to **www.epa.gov/indian** for more information.

EPA's Tribal Nonpoint Source Program provides information on techniques and grant funding for tribes to address nonpoint source pollution. The program's Web site (**www.epa.gov/owow/nps/tribal.html**) includes guidelines for awarding section 319 grants to American Indian tribes, as well as the *Tribal Nonpoint Source Planning Handbook*. EPA also conducts training workshops for tribes interested in becoming involved in tribal nonpoint source programs and obtaining funding.

3.4.4 Federal Programs and Organizations

Various federal programs and agencies are involved in watershed protection activities like data collection, regulation development, technical oversight, and public education. In addition, federal land and resource management agencies sponsor or participate in watershed planning and management processes.

Most federal agencies have regional or state liaisons to help administer their programs. For example, EPA divides the country into 10 regions. Each region is responsible for selected states and tribes and provides assistance for all of its programs. To find the EPA regional office associated with your watershed, go to **www.epa.gov/epahome/locate2.htm** and click on a region.

Abandoned Mines Programs

The Department of the Interior's (DOI) Office of Surface Mining (OSM) works with states and tribes to protect citizens and the environment during mining and reclamation activities. OSM manages the Clean Streams Program, which is a broad-based citizen/industry/government program working to eliminate acid mine drainage from abandoned coal mines. If your watershed includes abandoned mines, contact OSM. For more information on the Clean Streams Program, go to **www.osmre.gov/acsihome.htm**.

Agricultural Conservation Programs

USDA's Natural Resources Conservation Service (NRCS) is an important partner for many water resource projects. It provides valuable support for funding the implementation of agricultural management practices, wetland restoration, land retirement, and other projects associated with watershed plans. NRCS has local offices established through partnerships with local conservation districts. Go to **www.nrcs.usda.gov/about/organization/regions.html#regions** to find state and local contact information.

As part of its watershed protection effort, NRCS administers the USDA Watershed Program (under Public Law 83-566). The purpose of the program is to assist federal, state, and local agencies; local government sponsors; tribal governments; and other program participants in protecting watersheds from damage caused by erosion, floodwater, and sediment; restoring damaged watersheds; conserving and developing water and land resources; and solving natural resource and related economic problems on a watershed basis. The program provides technical and financial assistance to local people or project sponsors, builds partnerships, and requires local and state funding contributions. For more information on this program, go to **www.nrcs.usda.gov/programs/watershed**.

Agricultural Support Programs

USDA's Farm Services Agency (FSA) has several programs that support watershed protection and restoration efforts. Under the Conservation Reserve Program (CRP), farmers receive annual rental payments, cost sharing, and technical assistance to plant vegetation for land they put into reserve for 10 to 15 years. The Conservation Reserve Enhancement Program (CREP) targets state and federal funds to achieve shared environmental goals of national and state significance. The program uses financial incentives to encourage farmers and ranchers to voluntarily protect soil, water, and wildlife resources. The Grassland Reserve Program (GRP) uses 30-year easements and rental agreements to improve management of, restore, or conserve up to 2 million acres of private grasslands. The Conservation Security Program (CSP) is a voluntary program that provides financial and technical assistance to promote the conservation and improvement of soil, water, air, energy, plant and animal life, and other conservation purposes on tribal and private working lands. For more information about FSA, go to **www.fsa.usda.gov/pas/default.asp**. For more information on other conservation programs, go to **www.nrcs.usda.gov/programs**.

Coastal Programs

The National Estuary Program (NEP) was established in 1987 by amendments to the Clean Water Act that seek to identify, restore, and protect nationally significant estuaries of the United States. There are currently 28 active NEPs along the nation's coasts. NEP programs have identified a number of nonpoint source stressors as sources of estuary degradation, and they can provide valuable assistance in working with local governments and other partners to develop and implement watershed plans. To find out if your watershed is in an NEP-designated area, go to **www.epa.gov/owow/estuaries**.

Federal Transportation Programs

Two offices in the Federal Highway Administration, a part of the U.S. Department of Transportation, focus on environmental protection and enhancement. One, the Office of Natural and Human Environment, focuses on environmental programs associated with air quality, noise, and water quality, and on programs associated with the built environment, including transportation enhancements, bicycle and pedestrian facilities, and scenic byways. The other, the Office of Project Development and Environmental Review, focuses on the National Environmental Policy Act (NEPA) project development process as a balanced and streamlined approach to transportation decisionmaking that takes into account both the potential impacts on human and natural resources and the public's need for safe and efficient transportation improvements. **www.fhwa.dot.gov**.

An additional resource for projects dealing with the impacts of infrastructure on watershed resources is *Eco-Logical: An Ecosystem Approach to Developing Infrastructure Projects.* This approach, which was developed by a federal interagency steering team including the Federal Highway Administration, puts forth the conceptual groundwork for integrating plans across agency boundaries and endorses ecosystem-based mitigation. The document describes ways to make the governmental processes needed to advance infrastructure projects more efficient and effective, while maintaining safety, environmental health, and effective public involvement. It also describes a general ecosystem protection approach useful for watershed planning. To read more about Eco-Logical, go to **www.environment.fhwa.dot.gov/ecological/eco_index.asp**.

Natural Resources

USGS maintains vast resources of information on physical processes and features such as soil and mineral resources, surface and ground water resources, topographic maps, and water quality monitoring programs. Regardless of whether you include representatives from USGS in your stakeholder group, USGS will most likely be a valuable resource in the characterization phase. ↳ Go to **www.usgs.gov** to find state contacts.

Public Lands Management

The Forest Service, an agency within USDA, manages the 195 million acres of public lands in national forests and grasslands. Each national forest and grassland in the United States has its own management plan. The plans establish the desired future condition for the land and resources and set broad, general direction for management. Most plans for the national forests were approved in the 1980s, and, by law, national forests revise their plans every 15 years or sooner. ↳ You can reach your local Forest Service managers and their resource staff through the Forest Service Web site at **www.fs.fed.us**. DOI's Bureau of Land Management manages 261 million surface acres of America's public lands, primarily in 12 western states. ↳ For more information go to **www.blm.gov**.

Threatened and Endangered Species Protection Programs

The U.S. Fish and Wildlife Service (USFWS) and National Oceanic and Atmospheric Administration jointly administer the federal Endangered Species Act. USFWS has a program called Endangered Species Program Partners, which features formal or informal partnerships for protecting endangered and threatened species and helping them to recover. These partnerships include federal partners, as well as states, tribes, local governments, nonprofit organizations, and individual landowners. ↳ Go to **http://endangered.fws.gov/partners.html**.

The USFWS's Coastal Program provides incentives for voluntary protection of threatened, endangered, and other species on private and public lands alike. The program's protection and restoration successes to date give hope that, through the cooperative efforts of many public and private partners, adequate coastal habitat for fish and wildlife will exist for future generations.

Water Quantity Issues

The Bureau of Reclamation (BOR) is a water management agency within DOI that works with western states, American Indian tribes, and others to meet new water needs and balance the multitude of competing uses of water in the West. If your watershed planning effort is in one of these states and water quantity is likely to be a key issue, consider involving BOR. ↳ For more information go to **www.usbr.gov**.

Wetland Protection Programs

Section 404 of the Clean Water Act regulates the discharge of dredged or fill material into waters of the U.S., which include many types of wetlands. This program is jointly implemented by EPA and the U.S. Army Corps of Engineers. In addition, USFWS, the National Marine Fisheries Service, and state resource agencies have important advisory roles. If your watershed includes wetlands, you might want to contact representatives from one of these agencies to identify what management programs exist or what data are available. ↳ Go to **www.epa.gov/owow/wetlands** for links to laws, regulations, guidance, and scientific documents addressing wetlands; state, tribal, and local initiatives; landowner assistance and stewardship; water quality standards and section 401 certification for wetlands; monitoring and assessment; wetlands and watershed planning; restoration; education; and information about wetland programs across the country.

Laws Affecting Watershed Management

Dozens of federal statutes and hundreds of regulations affect how watersheds are managed. Most of the key legal programs are outlined above. ↳ For a more complete list of these laws and regulations, go to **www.epa.gov/epahome/laws.htm** (administered by EPA) and **www.fws.gov/laws/lawsdigest.htm**.

Advance Identification (ADID) and Special Area Management Plans (SAMPs) are two types of wetland/watershed planning efforts that EPA and other stakeholders use to enhance wetland protection activities. ADID is a process that involves collecting and distributing information on the values and functions of wetland areas so that communities can better understand and protect the wetlands in their areas. EPA conducts the process in cooperation with the U.S. Army Corps of Engineers and in consultation with states or tribes. Because ADID efforts are usually based on watershed planning, they are extremely compatible with geographic and ecosystem initiatives like the watershed approach.

SAMPs are developed to analyze potential impacts at the watershed scale, to identify priority areas for preservation and potential restoration areas, and to determine the least environmentally damaging locations for proposed projects. SAMPs are designed to be conducted in geographic areas of special sensitivity under intense development pressure. These efforts involve the participation of multiple local, state, and federal agencies. The Corps of Engineers initiated the development of SAMPs and works with EPA. ↳ To find out if a SAMP has been conducted in your watershed, go to **www.spl.usace.army.mil/samp/samp.htm**.

Wildlife Protection Programs

USFWS manages the Partners for Fish and Wildlife Program. Under the program, USFWS staff provides technical and financial assistance to private landowners and tribes who are willing to work with USFWS and other partners to voluntarily plan, implement, and monitor habitat restoration and protection projects. ↳ Go to **www.fws.gov/partners**.

4. Define Scope of Watershed Planning Effort

Chapter Highlights

- Identifying issues of concern
- Using conceptual models
- Setting preliminary goals
- Developing quantitative indicators

Read this chapter if...

- You want to engage stakeholders in identifying issues of concern
- You want to take stakeholders out into the watershed
- You want to develop a conceptual model that links sources of pollution to impairments
- You're unsure of the extent of the watershed boundaries for your project
- You want to develop preliminary goals for the watershed plan
- You want to select indicators that will be used to assess current environmental conditions in the watershed

4.1 Why Define the Scope of Your Watershed Planning Effort?

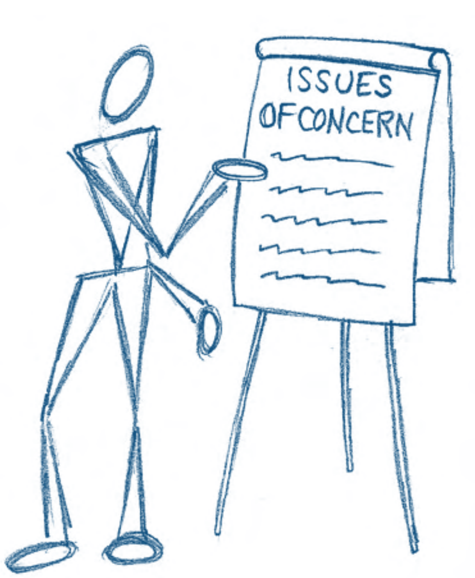
To ensure that your watershed planning effort remains focused, effective, and efficient, defining the *scope* of the effort is critical. The term *scope* is used to describe the boundaries of a program or project, which can be defined in terms of space (the area included in the watershed plan) or other parameters. This handbook defines the scope of your watershed planning effort as not only the geographic area to be addressed but also the number of issues of concern and the types (and breadth) of the goals you want to attain. If your scope is too broad, it will be difficult to "keep it all together" and make the best use of your financial and human resources as you develop and implement the watershed plan. It might also hamper your ability to conduct detailed analyses or minimize the probability of involvement by key stakeholders and, ultimately, successful plan implementation. A scope that is too narrow, however, might preclude the opportunity to address watershed stressors in a rational, efficient, and economical manner. If you define your scope and set preliminary goals early in the planning process, you'll find it easier to work through the later steps in the process.

The issues in your watershed and the geographic scope will also affect the *temporal* scope of the implementation of the watershed plan. Although there are no hard and fast rules, watershed plans are typically written for a time span of 5 to 10 years. Even if you do not achieve your watershed goals in 10 years, much of the information might become out-of-date, and you'll probably want to update the watershed plan.

The stakeholders will provide critical input into the watershed planning process that will help identify issues of concern, develop goals, and propose management strategies for implementation. Information from the stakeholders will help shape the scope of your watershed planning effort.

4.2 Ask Stakeholders for Background Information

The stakeholders will likely be a source of vast historical knowledge of activities that have taken place in the watershed. Ask them for any information they might have on the watershed, including personal knowledge of waste sites, unmapped mine works, eroding banks, and so on. They might have information on historical dump sites, contaminated areas, places experiencing excessive erosion, and even localized water quality sampling data. Stakeholders might be aware of existing plans, such as wellhead or source water protection plans. Collecting this background information will help focus your efforts to identify the issues of concern and solutions. Use Worksheet 4-1 to work with your stakeholders to determine what information is already available. A blank copy of the worksheet is provided in appendix B.



4.3 Identify Issues of Concern

One of the first activities in developing a watershed management plan is to talk with stakeholders in the watershed to identify their issues of concern. These issues will help to shape the goals and to determine what types of data

Worksheet 4-1 *What Do We Already Know?*

[Hand out to stakeholders at the beginning of a meeting, or use as a guide to work through each question as a group]

1. What are the known or perceived impairments and problems in the watershed?
2. Do we already know the causes and sources of any water quality impairments in the watershed? If so, what are they?
3. What information is already available, and what analyses have been performed to support development of a TMDL, watershed plan, or other document?
4. Have the relative contributions from major types of sources of the pollutant or stressor causing impairment been estimated?
5. Are there any historical or ongoing management efforts aimed at controlling the problem pollutants or stressors?
6. Are there any threats to future conditions, such as accelerated development patterns?
7. Have any additional concerns or goals been identified by the stakeholders?

are needed. As a project manager, you might think you already know the problems, such as not meeting designated uses for swimming and fishing. The issues of concern are different in that they are the issues that are important to the community. For example, stakeholders frequently list trash in the streams as an issue even though it doesn't necessarily affect water quality.

Set up a meeting with the stakeholders to gather their input as to what they believe are the major concerns in the watershed, and begin to identify possible causes and sources of these concerns. The stakeholders might provide anecdotal evidence, such as "There aren't any fish in the stream anymore (impact) because the temperature is too warm (stressor) and there is too much dirt going into the stream (stressor) since they removed all the trees along the streambank (source)." This information provides an important reality check for watershed plan sponsors, who might have very different notions regarding problems, and it is the starting point for the characterization step described in chapter 5.

Remember that you should also identify any issues related to conserving, protecting, or restoring aquatic ecosystems. Proactive conservation and protection of such systems can help to ensure that water quality standards will be met. Concepts such as in-stream flow, hydrologic connectivity, and critical habitats (e.g., refugia or stress shelters such as springs and seeps used by species in times of drought) should be considered when identifying issues of concern. Worksheet 4-2 can help you identify the ecosystem-related issues that need to be addressed in your watershed planning effort.

At this stage you can even start to link problems seen in the watershed with their possible causes or sources. For example, stakeholders might say they are concerned about beach closures, which could lead to a discussion of sources of bacteria that led to the closures. As you move through the process and gather more data, these links will become more discernible. Understanding the links between the pollutants or stressors and the impacts in the watershed is key to successful watershed management. In the initial stages of watershed planning, many of the links might not be thoroughly understood; they will more likely be educated guesses that generate further analyses to determine validity.

Worksheet 4-2 *What Ecosystem Issues Need to Be Considered?*

1. What are the sensitive habitats and their buffers, both terrestrial and aquatic?
2. Where are these habitats located in the watershed? Are there any fragmented corridors?
3. What condition are these habitats in?
4. Are these habitats facing any of the following problems?
   a. Invasive species
   b. Changes associated with climate warming
   c. Stream fragmentation and/or in-stream flow alterations
   d. Changes in protection status
5. On what scale are these habitats considered? (e.g., regional, watershed, subwatershed, or site-specific) Are these scales appropriate for the biological resources of concern?
6. Does the variability, timing, and rate of water flow hydrologically support indigenous biological communities?

4.3.1 Draw a Picture

It is often useful to diagram these links as you move through the watershed planning process and present them as a picture, or a conceptual model (figure 4-1). These diagrams provide a graphic representation that you can present to stakeholders, helping to guide the subsequent planning process. In many cases, there will be more than one pathway of cause and effect. You can also present this concept to stakeholders verbally, as if-then links. For example, "*If* the area of impervious surface is increased, *then* flows to streams will increase. *If* flows to streams increase, *then* the channels will become more unstable." Figure 4-2 shows a simple conceptual model based on the construction of logging roads.

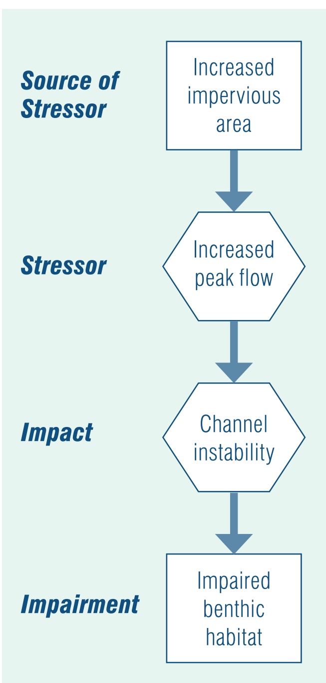


Figure 4-1. Simplified Conceptual Model

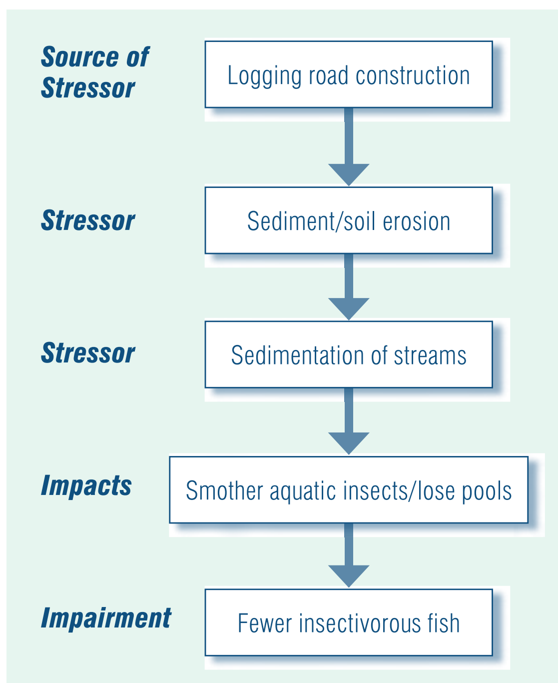


Figure 4-2. Simple Conceptual Model Involving Logging Road Construction Effects on Stream Aquatic Life (adapted from USEPA 1998)

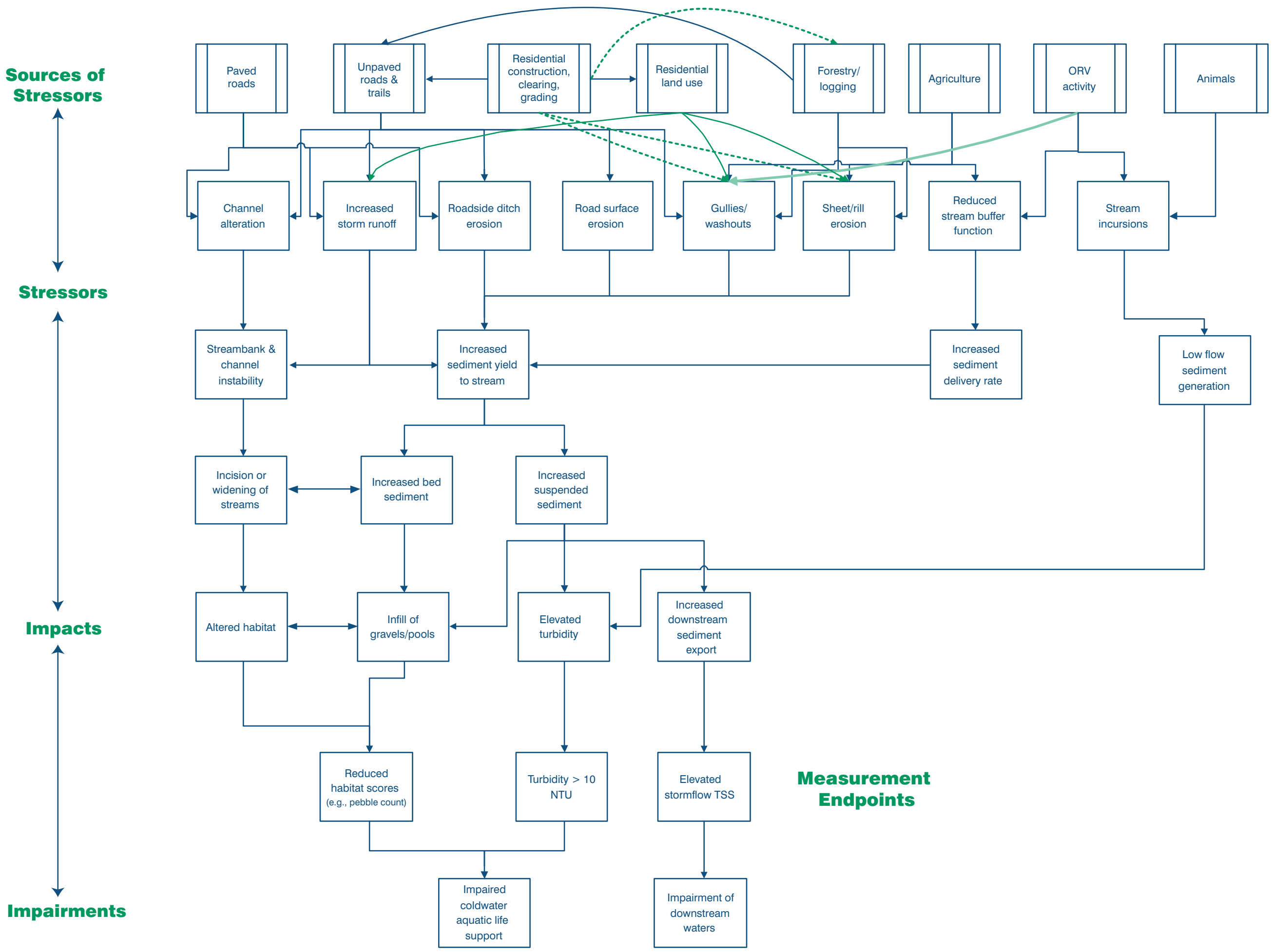


Figure 4-3. Draft Conceptual Model for Greens Creek, North Carolina

The conceptual model can be used to start identifying relationships between the possible causes and sources of impacts seen in the watershed. You don't have to wait until you have collected additional information. In fact, the conceptual model can help to identify what types of data you need to collect as part of the characterization process. Figure 4-3 illustrates a conceptual model that was developed for a watershed planning effort in Greens Creek, North Carolina. The Greens Creek watershed covers approximately 10 square miles in the southwestern part of the state. Greens Creek is classified as a C-trout habitat stream, typical of most of the mountain streams in the region. The watershed is subject to considerable development pressure from vacation homes and has highly erodible soils and steep slopes. Locals have observed significant problems related to road construction and maintenance.

To facilitate identifying the problems and their probable causes, an initial conceptual model of impairment in the Greens Creek watershed was developed. The conceptual model was presented to stakeholders for discussion at a meeting, at which they identified upland loading of sediment and subsequent impacts on water clarity (turbidity) as the key risk pathway for Greens Creek. ↳ For more information on the development of conceptual models as part of the watershed planning process, refer to EPA's *Guidelines for*

Ecological Risk Assessment, which can be downloaded at **http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=12460&partner=ORD_NCEA**.

Build your own conceptual model using Worksheet 4-3, provided in appendix B.

4.3.2 Take Stakeholders Out into the Watershed

Conducting visual watershed assessments with the stakeholders, such as stream walks, "windshield surveys," or flyovers, can provide them with a unique perspective about what's going on in the watershed. They'll be able to make visual connections between sources, impacts, and possible management approaches. Visual assessments show stakeholders the watershed boundaries, stream conditions, and potential sources contributing to waterbody impairment.

Stream surveys can be used at several points in the watershed planning process. Visual assessments might be conducted initially to help stakeholders develop a common vision of what needs to be done in a watershed. Later, they might be used to help identify areas where additional data collection is needed, identify critical areas, or select management measures.

Stream surveys can provide an important means of collecting data for identifying stressors and conducting a loading analysis. For example, streambank erosion can be a considerable source of sediment input to a stream, and illegal pipe outfalls can discharge a variety of pollutants. Both sources might be identifiable only through a visual inspection of the stream or through infrared photography.

In addition to visual assessments, photographic surveys can be used to document features like the courses of streams, the topography of the land, the extent of forest cover and other land uses, and other natural and human-made features of the watershed. Photographs provide valuable pre- and post-implementation documentation. You can make arrangements to take photos, or you might be able to obtain aerial photographs (current and historical) from the U.S. Geological Survey (USGS), the U.S. Department of Agriculture (USDA), or other sources.

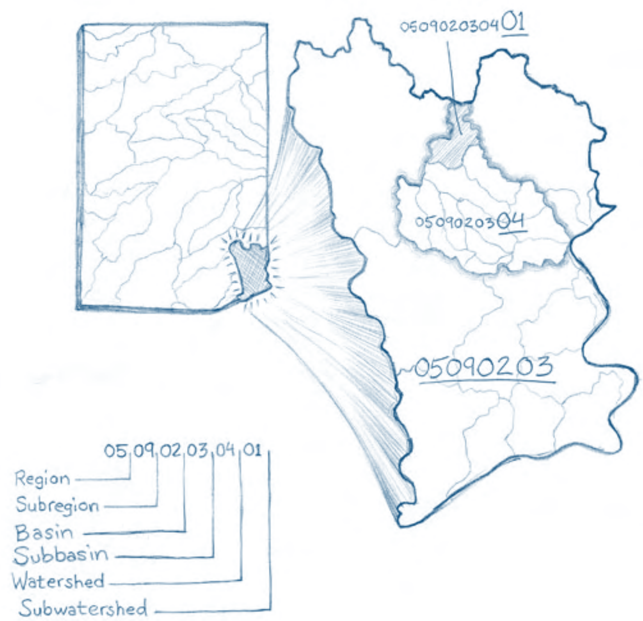
Several protocols for conducting visual assessments are discussed further in section 6.5.1 and are listed in appendix A.

4.4 Define the Geographic Extent of the Watershed

As the stakeholders identify concerns in the watershed, their findings will help to define the geographic extent of the watershed that the plan will address. The plan might address a small urban watershed with wide-ranging stressors and sources or a large river basin with only a few problem parameters. If your plan addresses a small drainage system within a watershed covered by a separate plan, make sure your planned activities are integrated with those broader-scale efforts.

One way to identify the geographic extent of your watershed planning effort is to consult the USGS map of hydrologic units. A hydrologic unit is part of a watershed mapping classification system showing various areas of land that can contribute surface water runoff to designated outlet points, such as lakes or stream segments. USGS designates drainage areas as subwatersheds (including smaller drainages) numbered with 12-digit hydrologic unit codes (HUCs), nested within watersheds (10-digit HUCs). These are combined into larger drainage areas called subbasins (8 digits), basins (6 digits), and subregions (4 digits), which make up the large regional drainage basins (2 digits).

Another way to identify watershed boundaries more precisely is to use a topographic map. These maps are available at USGS map centers and outdoor supply stores and at **http://topomaps.usgs.gov**. When working in very small watersheds of just a few square miles, it's better to obtain more detailed topographic information from city or county planning departments. From these maps, lines can be drawn following the highest ground between the waterways to identify the watershed boundaries, or ridge lines. In areas with storm sewers, maps that show how this "plumbing" might have changed watershed boundaries are often available from local or municipal government offices.



Most watershed planning efforts to implement water pollution control practices occur at the 10- or 12-digit HUC level, although smaller drainage areas within subwatersheds might be used if they represent important water resources and have a significant variety of stressors and sources. It is still helpful to factor in large-scale basin planning initiatives for strategic planning efforts that address interjurisdictional planning and solutions to widespread water quality problems. The key to selecting the geographic scope of your planning effort is to ensure that the area is small enough to manage but large enough to address water quality impairments and the concerns of stakeholders. More information on delineating watershed boundaries is provided in section 5.4.1.

What Happened to 11- and 14-Digit HUCs?

If you're confused by the new numbering, don't worry. The Federal Geographic Data Committee (FGDC) released the *Federal Standards for Delineation of Hydrologic Unit Boundaries* in October 2004 to delineate hydrologic unit boundaries consistently, modify existing hydrologic units, and establish a national Watershed Boundary Dataset (WBD). The guidelines establish a new hierarchy for hydrologic units that includes six levels and supersedes previous numbering schemes. Go to **www.ncgc.nrcs.usda.gov/products/datasets/watershed** for more information.

Breaking Down the Watershed

Watershed Boundary Definition	Example
A region, the largest drainage basin, contains the drainage area of a major river or the combined drainage areas of several rivers.	Mid-Atlantic (02)
Subregions divide regions and include the area drained by a river system.	Chesapeake Bay watershed (0207)
Basins divide or may be equivalent to subregions.	Potomac River watershed (020700)
Subbasins divide basins and represent part or all of a surface-drainage basin, a combination of drainage basins, or a distinct hydrologic feature.	Monocacy watershed (0207009)
Watersheds divide subbasins and usually range in size from 40,000 to 250,000 acres. Subwatersheds divide or may be equivalent to watersheds and usually range in size from 10,000 to 40,000 acres.	Monocacy River watershed (0207000905)
Subwatersheds divide or may be equivalent to watersheds and usually range in size from 10,000 to 40,000 acres.	Double Pipe Creek subwatershed (020700090502)

4.5 Develop Preliminary Goals

After stakeholders provide information on issues of concern, they will begin to identify the vision or goals for the watershed that they would like to see addressed in the watershed plan. Getting this input is critical to ensuring that you address the issues important to them and keep them involved in the planning and implementation effort. In some cases you'll also incorporate goals from other watershed planning activities. For example, if a TMDL has already been developed in your watershed, you can include the goals outlined in the TMDL, such as the required loading targets to be achieved. These goals are very specific.

Often stakeholders will recommend very broad goals such as "Restore lake water quality," "Protect wetlands," or "Manage growth to protect our water resources." These goals might start out broad, but they'll be refined as you move through the watershed characterization process (chapters 5, 6, 7, and 8). For each goal identified, specific management objectives should be developed (chapter 9). The objectives should include measurable targets needed to achieve the goals and specific indicators that will be used to measure progress toward meeting the objectives.

Example Preliminary Goals

- Meet water quality standards for dissolved oxygen.
- Restore aquatic habitat to meet designated uses for fishing.
- Protect drinking water reservoir from excessive eutrophication.
- Manage future growth.
- Restore wetlands to maintain a healthy wildlife community.
- Protect open space.

The more specific you can make your goals at this stage, the easier it will be to develop concrete objectives to achieve the goals. You should also set goals and objectives to guide the process of engaging and informing those who contribute to water quality degradation and motivating them to adopt more appropriate behaviors. For example, a goal for a river might be to restore recreational uses (fishing and swimming). This goal might be further defined as improving cold-water fisheries by reducing sediment in runoff, increasing dissolved oxygen concentrations, and reinstating swimming by lowering bacteria counts during the summer. A wide range of specific objectives should be developed and implemented to support each aspect of the goal. Make sure that the goals link back to the issues of concern.

As you move through the watershed planning process, you should build onto your goals, developing indicators to measure progress toward achieving your goals, developing specific management objectives to show *how* you will achieve your goal, and finally, developing measurable targets to determine *when* you have achieved your goals (figure 4-4).

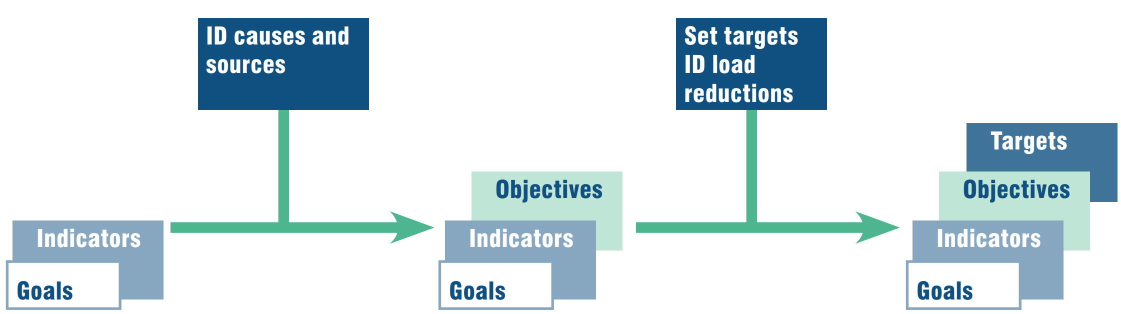


Figure 4-4. Evolution of Goals Throughout the Watershed Planning Process

4.6 Select Indicators to Measure Environmental Conditions

The stakeholders will help to select indicators that will be used to measure the current health of the watershed and to provide a way to measure progress toward meeting the watershed goals. Indicators are direct or indirect measurements of some valued component or quality in a system. Indicators are also extremely useful for assessing and communicating the status and trends of the health of a watershed. Indicators, however, do not tell you the cause of the problem. For example, you might use a thermometer to measure stream temperature. An elevated temperature might indicate a problem, but it does not specifically tell you what the problem is, where it is, or what caused it. Your stakeholder group will begin by identifying the indicators that will be used to quantify existing conditions in the watershed.

Indicators are selected, refined, added to, and modified throughout the watershed planning and implementation process. As you complete the characterization phase and develop goals and management objectives, you'll shift your indicators from those which assess current conditions to those which quantitatively measure progress toward meeting your goals. For example, in the Coal Creek watershed, the goal is to reduce sediment loadings to meet water quality standards and support all beneficial uses. Table 4-1 shows the indicators used and the target values for measuring progress toward reducing the sediment load. ↳ You'll learn how to develop these target values in chapter 9.

Table 4-1. Coal Creek Sediment Loading Indicators and Target Values

Sediment Loading Indicator	Target Value
5-year mean McNeil core percent subsurface fines < 6.35 mm	35 percent
5-year mean substrate score	≥ 10
Percent surface fines < 2 mm	< 20 percent
Clinger richness	≤ 14

Be aware that you might have to refer back to this section as you develop your watershed plan to develop additional indicators to measure performance and the effectiveness of plan implementation. Table 4-2 illustrates where indicators are used to develop and implement your watershed plan.

Table 4-2. Use of Indicators Throughout the Watershed Planning and Implementation Process

Planning Step	How Indicators Are Used
Assess Current Conditions	Indicators are used to measure current environmental conditions, e.g., water quality, habitat, aquatic resources, land use patterns
Develop Goals	Indicators are used to determine when the goal will be achieved, e.g., reducing nutrient loads to meet water quality standards
Develop Pollution Load Reduction Targets	Indicators are used to measure the targets for load reductions, e.g., phosphorus concentration
Select Management Strategies	Indicators are used to track the implementation of the management measures, e.g., number of management practices installed
Develop Monitoring Program	The monitoring program measures the indicators that have been developed as part of the management strategies and information/education program
Implement Watershed Plan	Indicators are used to measure the implementation of the watershed plan, tracking dollars spent, resources expended, management practices implemented, and improvements in water quality

4.6.1 Select Quantitative Indicators

In developing the watershed plan, you'll conduct watershed assessments and analyses to quantify source loads, characterize impacts, and estimate the load reductions needed to meet your goals and objectives. Sometimes the source loads and load reductions will be expressed in slightly different terms, such as the number of miles of eroded banks and the miles of vegetated buffers needed to address the problem. Regardless of the approach, the important point to remember is that *quantification is the key to remediation*. If you can't somehow measure the problems you're facing, it will be almost impossible to know whether you're making any headway in addressing them.

Factors to Consider When Selecting Indicators

Validity

- Is the indicator related to your goals and objectives?
- Is the indicator appropriate in terms of geographic and temporal scales?

Clarity

- Is the indicator simple and direct?
- Do the stakeholders agree on what will be measured?
- Are the methodologies consistent over time?

Practicality

- Are adequate data available for immediate use?
- Are there any constraints on data collection?

Clear Direction

- Does the indicator have clear action implications depending on whether the change is good or bad?

For watershed planning purposes, indicators should be quantitative so that the effectiveness of management measures can be predicted. For example, if one of the goals identified by stakeholders is "restore aquatic habitat to meet designated uses," and you believe the habitat has been degraded because of elevated levels of nutrients entering the waterbody, what indicators will you use to measure progress toward achieving that goal? A specific value should be set as a target for the indicator, representing desired levels. For example, phosphorus can be used as an indicator to directly measure the reduction in loadings. Table 4-3 provides examples of environmental indicators and possible target values, or endpoints. Targets can be based on water quality standards or, where numeric water quality standards do not exist, on data analysis, literature values, or expert examination of water quality conditions to identify values representative of conditions supportive of designated uses. Chapter 9 goes into more detail on how to develop targets for your goals and objectives.

If a TMDL exists, important indicators have already been defined and you can incorporate them when selecting appropriate management actions to implement the load reductions cited in the TMDL. If no TMDL exists, select indicators that are linked to your water quality restoration or protection goals, such as pollutant concentrations or other parameters of concern (e.g., channel instability, eroding banks, channel flow, flow cycles). The indicators selected should consider the impacts, impairments, or parameters of concern in the waterbody and the types and pathways of watershed stressor sources that contribute to those impacts.

Regardless of the approach, the important point to remember is that quantification is the key to remediation. If you can't somehow measure the problems you're facing, it will be almost impossible to know if you're making any headway in addressing them.

4.6.2 Select a Combination of Indicators

You'll use different types of indicators to reflect where you are in the watershed management process and the audience with which you are communicating. You'll first select environmental indicators to measure the current conditions in the watershed and help to identify the stressors and the sources of the pollutants. As you develop your management objectives and actually assemble your watershed plan (chapter 12), you'll add performance indicators,

Table 4-3. Example Environmental Indicators Used to Identify Relationships Between Pollutant Sources and Environmental Conditions

Issue	Indicator	Example Target Value	Why You Would Use It
Sediment	Pebble counts (% surface fines < 2 mm)	< 20%	Pebble counts provide an indication of the type and distribution of bed material in a stream. Too many fines can interfere with spawning and degrade the habitat for aquatic invertebrates.
	Stream channel stability	No significant risk of bank erosion	Channel stability uses a qualitative measurement with associated mathematical values to reflect stream conditions.
	Total suspended solids (TSS)	Monthly avg. concentration < 40 mg/L	Solids can adversely affect stream ecosystems by filling pools, clogging gills, and limiting the light penetration and transparency critical to aquatic flora.
	Turbidity	< 25 NTU	Turbidity measures the clarity of water and can also be used as an indirect indicator of the concentration of suspended matter.
Eutrophication	Chlorophyll *a* (benthic)	Maximum < 100 mg/m^2	In flowing streams, most algae grow attached to the substrate. Too much benthic algae can degrade habitat; alter the cycling of oxygen, nutrients, and metals; and result in unaesthetic conditions.
	Chlorophyll *a* (water column)	Geometric mean < 5 μg/L	Chlorophyll *a* is an indirect measure of algal density. Excess levels might result in harmful swings in dissolved oxygen (DO) concentrations, decrease water clarity, and alter the natural food chain of a system.
	Nitrate + nitrite	Monthly average < 1.5 mg/L	Elevated levels of nitrate + nitrite are good indicators of runoff from irrigation, residential lawn care fertilizers, and effluent waste streams. These parameters can indicate leaching from septic systems and erosion of natural deposits. Nitrogen is a limiting nutrient to algal production in many estuarine and arid freshwater systems.
	Orthophosphate	Monthly average < 0.05 mg/L	Orthophosphate measures the form of phosphorus that is readily available to aquatic systems. Too much phosphorus can often cause excessive aquatic vegetation growth in freshwater systems.
	Total nitrogen	Monthly average < 5 mg/L	Total nitrogen (often measured as the sum of nitrate + nitrite and total Kjeldahl nitrogen) measures the total ability of the waterbody to supply nitrogen to support algal growth after microbial processing.
	Ammonia	< 15 mg/L	Excess ammonia can cause toxicity in fish. The toxicity of ammonia is dependent on pH and temperature.
	Total phosphorus	Monthly average < 0.10 mg/L	Total phosphorus includes phosphorus that is bound to sediment particles or in organic compounds, some of which can become available in the water column. It is often the limiting nutrient for growth of aquatic vegetation in freshwater systems.
Pathogens	Fecal coliform bacteria	30-day geometric mean of < 200/100 mL	This bacterial indicator is often used to monitor for the presence of human/animal waste in a waterbody, which might lead to sickness in human populations. It also indicates compromised sanitary discharge and septic systems.
	E. coli bacteria	30-day geometric mean of < 125/100 mL	This bacterial indicator is often used to monitor for the presence of human/animal waste in a waterbody, which might lead to sickness in human populations. It also indicates compromised sanitary discharge and septic systems.
Metals	Copper	< 7.3 μg/L	Many metals are toxic to various forms of aquatic life, and water quality criteria have been developed. Criteria for most metals vary with the hardness of the water.
	Lead	< 82 μg/L	
	Zinc	< 67 μg/L	

Table 4-3. Example Environmental Indicators Used to Identify Relationships Between Pollutant Sources and Environmental Conditions (continued)

Issue	Indicator	Example Target Value	Why You Would Use It
Habitat	Temperature	Instantaneous < 33 ºC, daily avg. < 29 ºC	Many aquatic organisms are adapted to survive and prosper within specific temperature ranges.
	Physical habitat quality	Rapid Bioassessment Protocol (RBP) value	The assessment of physical habitat quality can be used to determine the potential of waterbodies to sustain healthy aquatic systems.
General Water Quality	Total dissolved solids (TDS)	700 mg/L	TDS is a direct measurement of the dissolved mineral content in stream ecosystems. High TDS can be harmful to aquatic organisms and can restrict the beneficial use of water (e.g., for irrigation).
	Conductivity	< 1,000 μS/cm	Conductivity is a good indicator of the dissolved mineral content in stream ecosystems. Also, it is a good measure of the salinity of the water.
	Dissolved Oxygen (DO)	> 5.0 mg/L	DO is an important measure of the quality of the habitat and overall health of the ecosystem. Oxygen depletion can indicate a number of undesirable physical, chemical, and biological activities in the watershed.
	pH	6 < pH < 9	pH is a measure of the acidity (hydrogen/hydroxide ion concentration). Most aquatic organisms have a preferred pH range, usually pH 6 to 9. Beyond that range aquatic organisms begin to suffer from stress, which can lead to death. High pH levels also force dissolved ammonia into its toxic, un-ionized form, which can further stress fish and other organisms.
	Oil and grease	Minimize	Oil and grease indicate impacts from general vehicular impervious surfaces and illicit disposal activity.
Flow	Dry weather flows	95% of daily flows > 5 cfs	As impervious surface area increases, often stream base flow decreases, resulting in decreased aquatic habitat and exacerbating problems with high temperature and low dissolved oxygen.
	Frequency of overbank flood events	< 1 in 2 years	The frequency and magnitude of flood events is influenced by increased urbanization and can affect channel stability. This indicator is also easily understood by the public.
	Peak flow	Achieve pre-development conditions for response to 2-year storm	Urbanization often leads to increased storm flow peaks, which in turn set off instability in the stream channel.
Biology	Biological indexes	Varies by index, assemblage, stream size, ecoregion	Several indexes under various acronyms (IBI, ICI, SCI, RIVPACS) have been developed to directly measure the health of fish, macroinvertebrate, and periphyton assemblages. See Barbour et al. (1999) for an introduction to the use of these indexes.
	EPT richness	Varies by stream type and ecoregion	This metric is the richness of the sample in taxa that are mayflies (Ephemeroptera), stoneflies (Plecoptera), or caddisflies (Trichoptera). Invertebrates that are members of these groups are generally understood to be sensitive to stressors in streams, whether the stressors are physical, chemical, or biological. Consequently, these taxa are less common in degraded streams. Component of most macroinvertebrate biological indexes.
	DELT anomalies	< 0.1%	The percentage of fish in a sample with external **d**eformities, fin **e**rosion, **l**esions, or **t**umors. These anomalies increase with both conventional organic pollution and toxic pollution. Component of some fish biological indexes.

Table 4-3. Example Environmental Indicators Used to Identify Relationships Between Pollutant Sources and Environmental Conditions (continued)

Issue	Indicator	Example Target Value	Why You Would Use It
Biology (continued)	Beck's Biotic Index	> 11.0	A weighted sum of the number of pollution-sensitive macroinvertebrate species in a standardized sample. Highly sensitive taxa receive 2 points; sensitive taxa receive 1 point. Similar to EPT richness, but more appropriate in low-gradient streams. Component of some macroinvertebrate biological indexes.
	Hilsenhoff Biotic Index (HBI)	< 3.8	The abundance-weighted average tolerance of all taxa in a macroinvertebrate sample. The HBI score increases with pollution and degradation as tolerant taxa replace intolerant (sensitive) taxa. See Barbour et al. (1999). Component metric of many macroinvertebrate biological indexes.
	Observed taxa/ expected taxa (O/E)	> 0.8	This is the measurement endpoint of what are termed RIVPACS, or predictive model indexes. This indicator measures the macroinvertebrate taxa actually observed at a site in relationship to those expected to occur under undisturbed conditions, adjusted for site-specific features (e.g., stream size, elevation). See Wright et al. (2000).

such as social and programmatic indicators, to help measure progress toward meeting your goals. Table 4-4 provides examples of indicators used throughout the watershed plan development and implementation effort.

The Audience

Keep in mind that indicators provide a powerful means of communicating to various audiences about the status of the watershed, as well as demonstrating the progress being made toward meeting goals. Select indicators that will help to communicate these concepts to nontechnical audiences. For example, using a 30-day geometric mean for *E. coli* bacteria to demonstrate reduction in pathogens to the waterbody won't mean much to most people. But using the number of shellfish beds that have been reopened because of the reduction of pathogen inputs is easier to understand. Or being able to count the number of failing septic systems that have been located and repaired shows people how the sources of pathogens are being reduced.

Environmental Indicators

Environmental indicators are a direct measure of the environmental conditions that plan implementation seeks to achieve. The indicators should be directly related to the indicators selected for your management objectives. By definition, the indicators are measurable quantities used to evaluate the relationship between pollutant sources and environmental conditions. Target goals are defined by the values of the selected indicators. Frequently these targets reflect water quality standards for designated uses. In other cases, qualitative standards for water quality and habitat protection need to be interpreted to establish the criteria. For example, if the indicator was phosphorus, the target could be a reduction of the instream concentration value or a total allowable load that is expected to protect the resource.

Programmatic Indicators

Programmatic indicators are indirect measures of resource protection or restoration (e.g., the number of management practices or the number of point source permits issued). These don't necessarily indicate that you're meeting your load reductions, but they do indicate actions intended to achieve a goal. When you develop the implementation plan (chapter 12), look

Table 4-4. Example Indicators Used throughout Watershed Plan Development and Implementation

Concern: No fish in stream due to heavy sedimentation
Goal: Reduce sedimentation into stream to meet designated uses
Objective: Install management practices streamside to reduce sedimentation by 15 percent

Type of Indicator	Example Indicators	Methods
Environmental (baseline conditions)	Turbidity, flow, total suspended solids (TSS), channel stability	Direct water quality measurements, photographs, watershed surveys
Programmatic	Number of brochures mailed for management practice workshop	Mailing lists
Programmatic	Number of participants at management practice workshop	Attendance lists
Social	Number of follow-up phone calls requesting information	Phone records
Social	Increased awareness of watershed issues	Pre- and post-project surveys, focus groups
Social	Number of landowners requesting assistance to install management practices	Phone records
Social	Number of landowners aware of technical and financial assistance available for management practice installation	Pre- and post-project surveys, interviews
Programmatic	Number of management practices installed	Tracking database
Environmental (measure implementation progress)	Turbidity, flow, TSS, channel stability	Direct water quality measurements, photographs, watershed surveys

for important programmatic actions that can be tracked over time. Programmatic indicators include measures such as recording the number of people attending workshops, the number of projects approved, the number of monitoring samples taken, and dollars spent.

Social Indicators

Social indicators measure changes in social or cultural practices, such as increased awareness of watershed issues, and behavior changes that lead to implementation of management measures and subsequent water quality improvements. Indicators may include the percentage of landowners along the stream corridor that know what a watershed is or the number of homeowners that sign a pledge to reduce fertilizer use. Consider the methods you'll use to collect this information, such as pre- and post- surveys, focus groups, and one-on-one interviews. Table 4-5 provides several examples of indicators that can be used to measure progress or performance.

Regardless of the types of indicators and targets you develop, you should establish some means for storing data (e.g., database) and for tracking and reporting progress against these values. ↳ Section 12.10 describes various tracking systems that can be used to manage this information.

Table 4-5. Examples of Performance Indicators That Can Be Used to Develop Targets to Measure Progress in Meeting Watershed Goals

Environmental	Programmatic	Social
• Number (or percentage) of river/stream miles, lake acres, and estuarine and coastal square miles that fully meet all water quality standards • Number (or percentage) of river/stream miles, lake acres, and estuarine and coastal square miles that come into compliance with one or more designated uses • Number (or percentage) of river/stream miles, lake acres, and estuarine and coastal square miles that meet one or more numeric water quality standards • Demonstrated improvement in water quality parameters (e.g., DO, pH, TSS) • Demonstrated improvement in biological parameters (e.g., increase in numbers or diversity of macroinvertebrates) • Demonstrated improvement in physical parameters (e.g., increased riparian habitat) • Reduction in the number of fish consumption advisories, beach closures, or shellfish bed closures • Number of river/stream miles, lake acres, and estuarine and coastal square miles removed from the "threatened" list • Reduction in pollutant loadings from nonpoint sources • Reductions in frequencies of peak flows in developing areas • Increase in the number of acres of wetlands protected or restored • Reduction in the amount of trash collected in stormwater drains	• Number of management measures implemented in a watershed (e.g., number of stream miles fenced, number of riparian buffers created) • Number of approved or certified plans (e.g., sediment and erosion control plans, stormwater plans, nutrient management plans) • Number of ordinances developed • Number of hits on watershed Web site • Number of residents requesting to have their septic systems serviced • Number of illicit connections identified and corrected • Number of permits reissued • Elapsed time from permit violation reports to compliance • Number of public water systems with source water protection plans • Reduction in the amount of impervious surface area directly connected to buildings	• Rates of participation in education programs specifically directed to solving particular nonpoint source pollution problems • Increase in awareness, knowledge, and actions designed to change behavior patterns • Rates of participation in various nonpoint source activities, such as citizen monitoring and watershed restoration activities • Increase in participation at watershed stakeholder meetings • Increase in the number of residents signing watershed stewardship pledge • Number of homeowners requesting an inspection of their septic systems

4.7 Link Concerns with Goals and Indicators

It's important to help stakeholders to link their concerns with goals. It's also important to develop indicators that measure the current conditions in the watershed, as well as to identify possible indicators to measure progress once the watershed plan is implemented. Work with the stakeholders to fill out Worksheet 4-4 to link the concerns with the goals they have identified. For each of the concerns they identify, ask them to write down the potential causes of the problem. Ask them how they would measure the current conditions in the watershed. Then for each goal selected, they should develop the indicators they want to use to measure progress in meeting those goals. The more specific you can be at this stage, the more focused your data-gathering efforts will be in the next phase. A blank copy of the worksheet is provided in appendix B.

Worksheet 4-4 Identifying Concerns, Causes, Goals, and Indicators

What are the problems/ concerns in the watershed?	What do you think caused the problems?	How can we assess current conditions? (Indicators)	What would you like to see for your watershed? (Goals)	How will we measure progress toward meeting those goals? (Indicators)
No more fish in the stream	Sedimentation from eroding streambanks	Visual assessment of eroding banks, turbidity	Meet designated uses for fishing	Turbidity, TSS, fish assemblages
E. coli contamination	Failing septic systems	Fecal coliform concentrations	Meet water quality standards for pathogens	30-day geometric mean concentration of fecal coliforms, number of failing septic systems repaired
Trash in the stream	Stormwater runoff, people littering	Photographs of trash	Reduce trash found in stream	Pounds of trash removed, comparison of photographs taken before and after implementation

Handbook Road Map

5. Gather Existing Data and Create an Inventory

Chapter Highlights

- Determining data needs
- Identifying available data
- Locating the information
- Gathering and organizing necessary data
- Creating a data inventory

Read this chapter if...

- You're not sure where to look for data on your watershed
- You want to learn about the types of data you need to develop the watershed plan
- You want to know where to obtain maps of your watershed
- You want to know how to use GIS and remote sensing to help characterize your watershed
- You want to know how to create a data inventory

5.1 How Do I Characterize My Watershed?

Once you've formed partnerships, you'll begin to characterize the watershed to develop an understanding of the impacts seen in the watershed, identify possible causes and sources of the impacts, and subsequently quantify the pollutant loads. Characterizing the watershed, its problems, and pollutant sources provides the basis for developing effective management strategies to meet watershed goals.

Because it's rare for any watershed planning effort to require starting from scratch, the challenge is to understand and build on existing information. The characterization and analysis process is designed to help you focus the planning efforts strategically to address the most pressing needs and target your data collection and analyses to your specific watershed.

The next four chapters focus on the characterization process:

- Gather existing information and create a data inventory (chapter 5)
- Identify data gaps, and collect new data, if needed (chapter 6)
- Analyze data (chapter 7)
- Estimate pollutant loads (chapter 8)

Although these phases are presented sequentially, several iterations of gathering data, identifying gaps, and analyzing data might be needed within each phase. This chapter focuses on gathering existing information to create a data inventory.

Gathering and organizing data is a major part of developing a successful watershed plan. You'll gather data and conduct data analyses to characterize the condition of your watershed and its waterbodies, identify pollutant sources, and support quantification of the pollutant loads. Estimates of source loads are often a component missing from past and current planning efforts, and filling this gap is critical to successfully controlling sources, restoring watershed health, and meeting watershed and water quality goals. Without an understanding of where pollutants are coming from, it's almost impossible to understand their impact on watershed resources and to target your control efforts effectively. This section provides information on how to target your data-gathering efforts and explains what types of data and information are useful in developing a watershed plan.

> **Before You Start...**
>
> Before you start searching for and gathering data, revisit the conceptual model developed during the scoping process (chapter 4). The watershed problems, potential sources, and goals illustrated in the conceptual model will focus your data gathering, as well as the subsequent analyses.

5.2 Focus Your Data Gathering Efforts

Although the data-gathering and analysis phases of the watershed planning process are very important in estimating source loads, they can also be very challenging. The types and amount of data available vary by watershed, and there is often a variety of data, making it difficult to decide which data (and analyses) are necessary. You should decide which types of data and how much data you need to complete your watershed plan. To make these decisions easier, your data-gathering efforts should be guided by your earlier scoping efforts, during which you developed a conceptual model, identified preliminary watershed goals, and listed stakeholder concerns (chapter 4).

5.2.1 Build on Earlier Scoping Efforts

The conceptual model, discussed in section 4.3, is a graphic representation of the watershed processes and problems. The conceptual model allows you to visualize the pollutants causing impairment, their potential sources and pathways, and interactions between pollutants, related stressors, and impairments.

The information and links depicted in the conceptual model will help you to determine what information to collect for analysis and also prioritize the information. Data compilation can be an almost endless process; there's always something more to find out about your watershed. You should decide what you need and tailor your data-gathering efforts accordingly. It is often time-consuming to gather data and to analyze and make sense of them. You'll want to be careful not to spend your budget on compiling data and information that you don't need—data that will not help you understand the watershed problems and meet your goals. For example, if the primary concern in your watershed is elevated levels of bacteria posing human health risks and prohibiting recreational opportunities, you'll need to focus data collection and analysis on likely sources of bacteria loads to the streams, such as livestock operations, wildlife populations and their distribution, and septic systems. In addition, because bacteria are not typically related to other water quality parameters, you might not need to gather extra monitoring data. Alternatively, some water quality impairments are related to several parameters and affected by many factors, requiring more data and analyses to understand the dynamics of the problem. For example, excess nutrients can increase algal growth (chlorophyll a) and lead to processes that deplete dissolved oxygen, lower pH, and produce ammonia at potentially toxic levels. These parameters are interrelated: when evaluating one, you must often evaluate all of them. Therefore, identifying these types of relationships and interactions in your conceptual model is crucial to efficiently gathering data and conducting useful analyses.

5.2.2 Consider Stakeholder Goals and Concerns

Another factor that will focus your data gathering is the goals and concerns identified by the stakeholders during the initial phases of the watershed planning process. The conceptual model relates to the watershed goals identified with the stakeholders by identifying potential watershed sources causing the problems and, therefore, the sources that must be controlled to meet the goals. For example, if a perceived problem in the watershed is the degradation of fisheries, the conceptual model will identify possible causes of that problem (e.g., low dissolved oxygen) and the associated pollutant sources (e.g., increased nutrient inputs from fertilizer application and subsequent runoff). Similarly, if the stakeholders identified development pressures as a concern, you'll want to collect information on land use patterns, building permits, and current zoning practices. If they identified the protection of wetlands as a goal, you should identify the wetlands in the watershed and any current protection strategies in place.

Seek Out Local Data

Remember to check first for the availability of local data and ground-truth other datasets if possible. State and federal data can provide a broad set of information but might be coarse or out-of-date. Check for recent changes, especially changes in land use and land management that might not be reflected in available datasets. Consider the date when the data were originally generated and processed and compare the data with what you and the stakeholders know about the watershed.

5.3 Who Has the Data and What Types of Data Do You Need?

Building from the information provided by the stakeholders, you'll identify existing reports, plans, studies, and datasets from various sources that can be used to help characterize the watershed. These sources include various local, state, tribal, and federal programs and organizations.

Many of the data types discussed in this section might already be summarized or available through existing programs, reports, and plans. For example, Total Maximum Daily Loads (TMDLs) completed for the watershed might include information on water quality, land use, and sources in the watershed. It's helpful to identify environmental studies that have already been conducted in your watershed because they might provide information on several different data types and guide you toward important stakeholders or sources of additional data. This section provides a variety of information that might help you identify existing plans and studies in your watershed. Another way to find them is an Internet search on your watershed or waterbodies—a broad search through a general browser or more specific searches through relevant state or federal environmental agencies' Web sites.

First, See What's Already Been Done

Much of the data you need for characterizing your watershed might have been partially compiled and summarized in existing reports, including

- TMDL reports
- Watershed Restoration Action Strategies
- Source Water Assessments
- CWA section 208 plans
- Clean Lake Plans (Clean Water Act section 314)

Although some of these plans might be outdated and represent historical conditions, they can provide a valuable starting point for gathering data and characterizing historical and current conditions in your watershed.

Before you begin to identify the types of data you need, it's helpful to understand the different data sources. The following descriptions are meant to familiarize you with these various sources and provide context for the discussions of specific data types in the subsequent sections.

5.3.1 Local Sources of Information

Identifying existing information at the local level is critical to supporting the development of a watershed plan that is based on local current or future planning efforts (e.g., information on zoning, development guidelines and restrictions, master planning, wastewater plans, transportation plans, future land use plans). This information not only will support the characterization of the watershed but also will identify any major changes expected to occur in the watershed (e.g., new development, addition of point sources, change from septic systems to city sewer). The sources for local information will depend on the kinds of land uses in your community (urban or rural).

To know what is available and how to get county-level information, it is necessary to become familiar with state-, county-, and city-level agencies. It's important to understand the authority and jurisdictions of the agencies in the watershed. This understanding facilitates the search for information and also provides valuable insight into the activities most likely to be implemented in the watershed. For example, it's important that the watershed plan identify control actions or management practices that people or agencies in the watershed have the authority and jurisdiction to implement. This will help you select the management strategies that you know can be adopted at the local level with existing

Navigating through Local Governments

Because local governments are organized differently, sometimes it's difficult to find the information you need. The best approach is to start with the local planning or environmental department and ask them to steer you in the right direction for other types of information. Local governments typically provide the following services:

- *County and city planning offices*: master plans, zoning ordinances
- *Environmental departments*: recycling policies, water quality monitoring program
- *Soil and water conservation districts*: agricultural land use information, topographic maps, soil surveys, erosion control information
- *Departments of economic development*: census data, tax records, demographic data
- *Water and sanitation department*: stormwater plans, maps of water intakes and sewer lines
- *Public health department*: septic system inventories, records of outbreaks of illness or ailments from poor water quality
- *Transportation department*: transportation master plans, permits, road and bridge construction information

authorities. Go to section 3.4.1 for a description of various local and regional programs and organizations.

Other "local" sources of watershed data include universities and environmental non-governmental organizations (NGOs). Although a university or NGO might not be located in or near your watershed, it might be active in the watershed and hold relevant local data.

Contact Your Local Stormwater Program

Be sure to check with your local stormwater management office, usually found in your city or county department of public works or planning office. They might already have developed a watershed plan for your area.

Universities can be important sources for demographic, climate, or spatial data. Many state climatology offices are associated with universities. In addition, university faculty or students regularly conduct environmental research related to their fields of study or expertise, sometimes providing data and information relevant to local watershed planning efforts (e.g., water quality, soils, land use changes). However, it might be difficult to identify any relevant studies and data without already knowing the specific project or contact. Universities have a variety of schools and departments, and no two are likely to be organized in the same way. Hopefully, if a university has conducted research in your watershed, one or more of the key stakeholders will be aware of it and can lead you in the right direction.

NGOs (e.g., Trout Unlimited, Izaak Walton League) often have information on stream conditions, habitat, and long-term changes in watershed characteristics (e.g., habitat, water quality). As with university information, it's difficult to identify NGOs active in your watershed and relevant data without already knowing they exist. Typically, if an NGO has an active interest in your watershed or has collected data, you or one of the involved stakeholders will know about it.

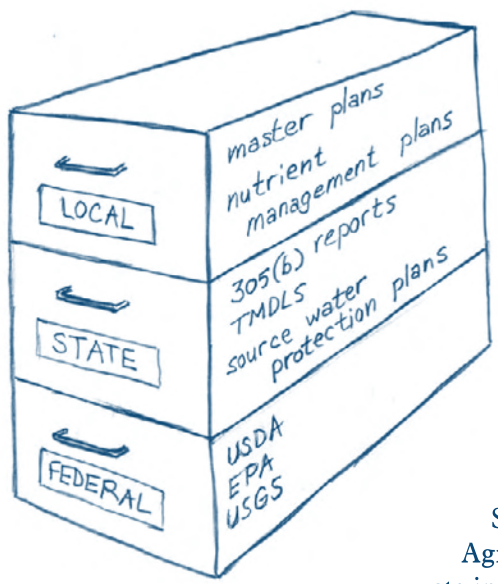
5.3.2 State Sources of Information

State environmental agencies routinely collect biological, hydrological, and water quality information for the waters in the state. State environmental agencies include several divisions and offices, many of which might be useful in characterizing your watershed and some of which might be irrelevant. Environmental agencies typically have a division or office dedicated to watershed or water quality issues. A variety of other offices deal with environmental issues (e.g., wastewater, mining, air quality) and will likely have information relevant to your watershed. It's useful to go to your state environmental agency's Web site to learn what types of offices work in your state and identify potential sources of relevant information.

In addition to state environmental agencies, several other state agencies might be useful in characterizing your watershed and potential sources. For example, the Division of Natural Resources or Department of Fish and Game can provide information on wildlife habitats and populations, and the Department of Agriculture can provide agricultural statistics for counties in your state. Go to section 3.4.2 for a description of various state programs and organizations.

Does Your State Have Its Own Watershed Guidance?

Before you start gathering data, check to see if your state has developed guidance or support materials for watershed planning. Whether comprehensive technical manuals or introductory brochures, these documents can provide information on available data sources, state and local government organizations, and various state-specific issues (e.g., laws, unique environmental conditions). For example, the *California Watershed Assessment Manual* (**http://cwam.ucdavis.edu**) was developed to help watershed groups, local agencies, and private landowners evaluate the condition of their watershed. The manual discusses the watershed assessment process and includes discussions of California-specific agencies, data types and sources, and environmental concerns. Check with your state environmental agency to see whether it has programmatic or technical documents on watershed planning.



5.3.3 Tribal Sources of Information

In watersheds that include tribal lands, tribal sources of watershed information can be important. Often, data and information for lands and waterbodies within reservation boundaries are limited at the state level and you must rely on tribal contacts for monitoring or anecdotal information.

Watershed characterization for tribal lands can be obtained from a variety of sources. First, search the Web to see if the specific tribe has a Web site with historical data or background information or reports. Go to section 3.4.3 for a description of various tribal programs and organizations.

5.3.4 Federal Sources of Information

Several federal agencies, including EPA, the U.S. Department of Agriculture (USDA), and the U.S. Geological Survey (USGS), generate information that will be useful in characterizing your watershed. With the various offices, divisions, and agencies in the federal government, there are likely several federal sources of every type of data used in watershed characterization. Go to section 3.4.4 for a description of various federal programs and organizations. The remainder of this chapter identifies these data types and their corresponding sources.

Types of Data Useful for Watershed Characterization

Physical and Natural Features
- Watershed boundaries
- Hydrology
- Topography
- Soils
- Climate
- Habitat
- Wildlife

Land Use and Population Characteristics
- Land use and land cover
- Existing management practices
- Demographics

Waterbody Conditions
- Water quality standards
- 305(b) report
- 303(d) list
- TMDL reports
- Source Water Assessments

Pollutant Sources
- Point sources
- Nonpoint sources

5.3.5 Data Types

In general, five broad categories of data are used to adequately characterize the watershed:

- Physical and natural features
- Land use and population characteristics
- Waterbody conditions
- Pollutant sources
- Waterbody monitoring data

Within these categories are dozens of reports and datasets that you can access to populate your data inventory. Table 5-1 identifies the types of data typically needed for watershed characterization and describes how the data might be used. Each data type is discussed in the following sections. Be careful not to collect existing information just because it's available. The data should help to link the impacts seen in the watershed to their sources and causes.

The data discussed in this section come in a variety of forms, including tabular data and databases, documents and reports, maps and aerial photographs, and geographic information system (GIS) data. Tabular data include water quality and flow monitoring data consisting of a series of numeric observations. Documents and reports include TMDLs or previous watershed studies that provide background information and summaries of watershed characteristics and conditions. They might address specific topics like fisheries habitats or particular pollutants, or they might cover a range of watershed

Table 5-1. Data Typically Used for Watershed Characterization

Data Type	Typical Uses of Data
Physical and Natural Features	
Watershed boundaries	• Provide geographic boundaries for evaluation and source control • Delineate drainage areas at desired scale
Hydrology	• Identify the locations of waterbodies • Identify the spatial relationship of waterbodies, including what segments are connected and how water flows through the watershed (e.g., delineate drainage areas contributing to wetlands)
Topography	• Derive slopes of stream segments and watershed areas (e.g., to identify unstable areas, to characterize segments and subwatersheds in watershed modeling) • Evaluate altitude changes (necessary when extrapolating precipitation from one area to another)
Soils	• Identify potential areas with higher erosion rates, poor drainage, or steep slopes • Use to delineate subwatersheds and develop input data for models
Climate	• Provide information about loading conditions when evaluated with instream data (e.g., elevated concentrations during storm events and high flow) • Drive simulation of rainfall-runoff processes in watershed models
Habitat	• Describe area's ability to support aquatic life, and identify areas at risk of impairment • Support defining stressors that could be contributing to impairment • Identify shading or lack of riparian cover • Support identification of potential conservation, protection, or restoration areas • Identify any in-stream flow alterations or stream fragmentation
Wildlife	• Identify special wildlife species to be protected • Identify potential sources of bacteria and nutrients
Land Use and Population Characteristics	
Land use and land cover	• Identify potential pollutant sources (e.g., land uses, pervious vs. impervious surfaces) • Provide basis for evaluation of sources, loading, and controls • Provide unit for simulation in watershed models
Existing land management practices	• Identify current control practices and potential targets for future management • Identify potential watershed pollutant sources
Waterbody and Watershed Conditions	
Water quality standards	• Identify protected uses of the waterbody and associated water quality standards
305(b) report	• Identify the status of designated use support in watershed waterbodies • Identify potential causes and sources of impairment
303(d) list	• Identify known pollutant impairments in the watershed • Identify geographic extent of impaired waterbody segments • Identify potential causes and sources of impairment
Existing TMDL reports	• Provide information on watershed characteristics, waterbody conditions, sources, and pollutant loads (for specific waterbodies and pollutants)
Source Water Assessments	• Identify water supply areas to be protected • Identify potential sources of contamination to the water supply

Table 5-1. Data Typically Used for Watershed Characterization (continued)

Data Type	Typical Uses of Data
Pollutant Sources	
Point sources	• Characterize potential point sources for quantifying loads
Nonpoint sources	• Characterize potential nonpoint sources for quantifying loads
Waterbody Monitoring Data	
Water quality and flow	• Characterize water quality and flow conditions throughout the watershed • Provide information on critical conditions, temporal trends, spatial variations, impairment magnitude, etc.
Biology	• Provide information on general health of the watershed, considering long-term effects
Geomorphology	• Describe river/stream pattern, profile, and dimension • Characterize drainage basin, channel/bank morphology • Classify river/stream type, based on morphology • Assess changes to morphology over time

topics. GIS data are available for a wide range of watershed characteristics, such as land use, locations of monitoring stations or flow gauges, vegetation, and population distribution.

Many of the data discussed below can be gathered, organized, and viewed using various tools. The two most popular tools, GIS and remote sensing, are specifically discussed in section 5.9 to provide guidance on how to use these tools, highlight their limitations, and identify the most common datasets.

Many of the datasets discussed in the following sections are provided as GIS data. GIS data can be critical in developing your watershed plan, but often they can be misinterpreted by first-time or novice users unfamiliar with the data types and their application. You might need to do some research or attend training to learn how to use GIS effectively before gathering the associated data—data that could be useless or misleading without the knowledge to use them properly. For more information on using GIS and what information to gather when compiling GIS data, go to section 5.9.1.

Web Sites for Downloading Watershed Coverages

- USGS 8-digit watersheds: **http://water.usgs.gov/GIS/huc.html**
- USDA Natural Resources Conservation Service 14-digit watersheds: **www.ncgc.nrcs.usda.gov/products/datasets/watershed**

5.4 Physical and Natural Features

This section discusses information on the physical and natural features of your watershed, including what data are available, why they are important, and where you can find them. Information on the physical and natural characteristics of your watershed will define your watershed boundary and provide a basic understanding of the watershed features that can influence watershed sources and pollutant loading.

5.4.1 Watershed Boundaries

Defining the geographic boundaries of your watershed planning effort is the first step in gathering and evaluating data. Up to this point, the watershed boundary might have been a theoretical boundary. You know for what watershed you are writing a plan, but you might not have documentation of its physical boundary and the waterbodies contained in it. Depending on the size of your watershed, its boundary might already have been delineated by a state or federal agency.

What's My HUC?

Although most watershed planning efforts focus on areas much smaller than an 8-digit hydrologic unit (subbasin), it's useful to know in what cataloging unit your watershed is included. Many databases (e.g., monitoring, GIS) are organized or referenced by HUC. To find your data and navigate through data repositories and search engines, it's necessary to know the HUC for your watershed.

If you don't know your HUC, visit EPA's "Surf Your Watershed" Web site (**http://cfpub.epa.gov/surf/locate/index.cfm**) to find it.

USGS Hydrologic Units

Major watersheds throughout the country were previously classified according to the USGS system into four levels—regions, subregions, accounting units, and cataloging units. The hydrologic units were nested within each other, from the smallest (cataloging units) to the largest (regions). Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification in the hydrologic unit system. Although the nomenclature for hydrologic units has been revised based on an interagency effort (see section 4.4), the delineation of major watersheds and their hydrologic unit codes remain. There are 2,150 cataloging units (now called "subbasins") in the United States. GIS coverages of the cataloging units are available by EPA region in EPA's BASINS modeling system (**www.epa.gov/ost/basins**). The coverages can also be downloaded from USGS at **http://water.usgs.gov/GIS/huc.html**.

Most likely, your watershed is smaller than the USGS-designated cataloging units. (Most of the cataloging units in the nation are larger than 700 square miles.) It's important, however, to know what cataloging unit includes your watershed because many sources of data are organized or referenced by HUC.

NRCS Watershed Boundary Dataset

During the late 1970s the USDA's Natural Resources Conservation Service (NRCS) initiated a national program to further subdivide USGS's 8-digit cataloging units into smaller watersheds for water resources planning (figure 5-1). By the early 1980s this 11-digit hydrologic unit mapping was completed for most of the United States. During the 1980s several NRCS state offices starting mapping watersheds into subwatersheds by adding 2 or 3 digits to the 11-digit units. By the late 1980s and early 1990s, the advent of GIS made the mapping of digital hydrologic unit boundaries feasible. Through an interagency initiative in the early 1990s, NRCS used GIS to start delineating hydrologic units and subdividing them into smaller units for the entire United States.

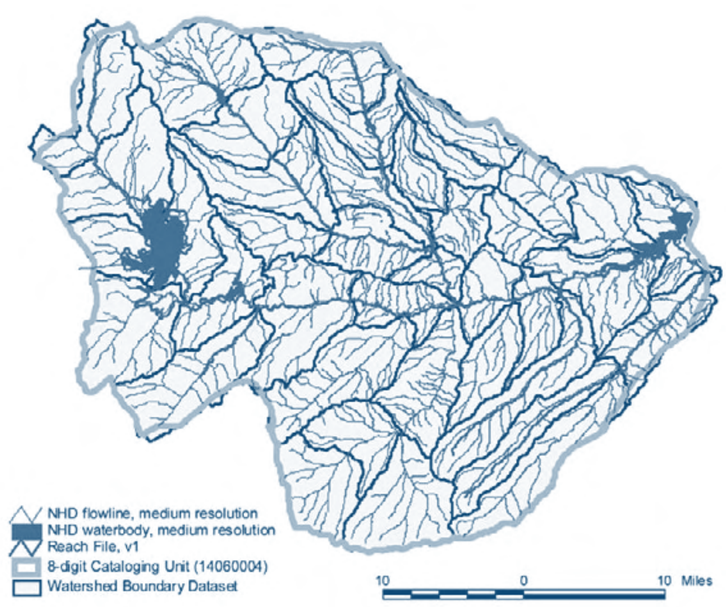


Figure 5-1. Example of NRCS Watershed Delineations Within a USGS 8-digit Cataloging Unit

A goal of this initiative is to provide the Watershed Boundary Dataset (WBD)—a hydrologically correct, seamless, and consistent national GIS database of watersheds at a scale of 1:24,000. The new levels are called watershed (fifth level, 10 digits [formerly 11 digits]) and subwatershed (sixth level, 12 digits [formerly 14 digits]). The size at the watershed level is typically 40,000 to 250,000 acres; at the subwatershed level, it is typically 10,000 to 40,000 acres, with some as small as 3,000 acres. An estimated 22,000 watersheds and 160,000 sub-watersheds will be mapped to the fifth and sixth levels.

GIS coverages of the WBD are publicly available through the Internet (**www.ncgc.nrcs.usda.gov/products/datasets/watershed**); however, because the mapping is ongoing, there is limited availability of the subwatershed coverage. As of January 2005, NRCS had completed the coverages for Alabama, Connecticut, Georgia, Illinois, Maryland, Massachusetts, Montana, Rhode Island, Utah, and Vermont. To check the status of the 12-digit subwatershed coverages and availability for your watershed, go to **www.ncgc.nrcs.usda.gov/products/datasets/watershed/status-maps.html**.

The WBD is also available through USGS's Elevation Derivatives for National Application (EDNA) database and interactive map (**http://edna.usgs.gov**). EDNA uses the USGS's National Elevation Dataset (NED) and National Hydrography Dataset (NHD) to derive and provide nationwide hydrologic data layers at a scale of 1:24,000. EDNA includes the WBD, as well as tools and data to delineate watersheds for any point in the United States.

Regional, State, and Site-specific Watershed Boundaries

In addition to the USGS and NRCS classification, many states have created their own watershed or planning unit delineations that break the USGS cataloging units into smaller watersheds. For example, California has delineated watersheds with a hierarchy of watershed designations that has six levels of increasing specificity. These state watersheds are generally much smaller than the national 8-digit HUCs and are better suited for local watershed planning activities.

An example of a regional dataset or tool for watershed delineation is the Digital Watershed Mapper (**www.iwr.msu.edu/dw**) from the Institute of Water Research at Michigan State University. The Digital Watershed Mapper delineates a watershed based on an address or a selected point on a map. It also provides land use, soils, and curve number coverages for the delineated watershed.

What If My Watershed Has Not Been Delineated?

If your state does not have watershed boundaries available or your watershed is not specified in the state coverages, you might have to create your own watershed boundary based on coverages of the stream network and elevation or topography, discussed in section 5.4.3. There are also tools available to delineate watersheds automatically. For example, BASINS includes an Automatic Watershed Delineation tool that segments watersheds into several hydrologically connected subwatersheds. (BASINS software is free from EPA and available for download at **www.epa.gov/ost/basins**.) The Automatic Watershed Delineation is used in ArcView and requires that the Spatial Analyst (version 1.1 or later) and Dialog Designer (version 3.1 or later) ArcView extensions be installed on your computer. The delineation process also requires a Digital Elevation Model (DEM) in ArcInfo grid format and optionally a stream network coverage (e.g., RF3 or NHD) in ArcView shape format. In addition, the National Hydrography Dataset (NHD) Web site provides several applications for using NHD data, including NHD Watershed, an ArcView (3.x) extension that enables users to delineate a watershed from any point on any NHD reach. The ArcView 3.x Spatial Analyst extension (version 2.0) is required to delineate watersheds from any point. Without Spatial Analyst, watershed delineation can be performed only upstream from an NHD reach confluence. Delineating watersheds using this tool also requires National Elevation Dataset (NED) data in the 8-digit HUC of interest. (NED data can be downloaded from USGS's Seamless Data Distribution System at **http://seamless.usgs.gov**.) In addition, 10-meter DEMs can be used in place of NED data, where they are available. (You can check the availability of 10-meter DEMs at **http://geography.usgs.gov/www/products/status.html**.)

5.4.2 Hydrology

Information on the hydrology of your watershed is necessary to visualize and document the waterbody network, including the locations of all the waterbodies and how they are connected to one another. When water flows through the stream network, it carries pollutant loads, and therefore the conditions of upstream segments can significantly affect the conditions of downstream segments. When evaluating source impacts on watershed conditions, it is crucial to understand the hydrologic network of the watershed. Not only is this information important for characterizing your watershed and evaluating sources and waterbody conditions, but it is also necessary input when modeling the watershed.

> **Web Sites for Downloading Waterbody Coverages**
>
> - USGS's NHD: **http://nhd.usgs.gov**
> - EPA BASINS RF1 and RF3 by HUC: **www.horizon-systems.com/nhdplus**

Reach File

The EPA Reach Files are a series of national hydrologic databases that uniquely identify and interconnect the stream segments or "reaches" that compose the country's surface water drainage system. The three versions of the Reach File currently available are known as RF1, RF2, and RF3-Alpha, and they were created from increasingly detailed sets of digital hydrography data produced by USGS. RF1, at a scale of 1:500,000, contains only major waterbody features in the country, providing too broad a scale to be useful at the watershed planning level. RF2 and RF3 are at a scale of 1:100,000, a scale useful for watershed planning. However, RF3 has been superseded by USGS's National Hydrography Dataset (NHD), which provides more waterbody features (e.g., ponds, springs).

References documenting the content, production, and history of the Reach Files are available at **www.epa.gov/waters/doc/refs.html**. The GIS coverages of the Reach Files are available free for download through EPA's BASINS modeling system at **www.epa.gov/waterscience/basins/b3webdwn.htm**.

National Hydrography Dataset

The NHD is a comprehensive set of digital spatial data for the entire United States that contains information about surface water features such as lakes, ponds, streams, rivers, springs, and wells. In the NHD, surface water features are combined to form reaches, which provide the framework for linking water-related data to the NHD surface water drainage network. The NHD is based on USGS's Digital Line Graph (DLG) hydrography data, integrated with reach-related information from EPA's RF3. The NHD supersedes DLG and RF3 by incorporating them, not by replacing them.

> **Level of Detail in Maps**
>
> A map's scale is expressed as a ratio between a distance on the map and a distance on Earth. For example, a scale of 1:100,000 means that 1 unit of measure on the map represents 100,000 of the same units on Earth.

The full national coverage of the NHD is currently based on 1:100,000 scale data, but the NHD is designed so that it can incorporate higher-resolution data. It is also designed so that improvements and corrections to the dataset by individual users can be incorporated into the national dataset. A 1:24,000-scale NHD is being developed for many parts of the country. The 1:100,000-scale NHD is referred to as the "medium-resolution NHD"; finer scales, such as 1:24,000, are referred to as "high-resolution NHD" (figure 5-2). The attribute information for each waterbody feature is the same in medium- and high-resolution NHD; however, because of the finer scale, high-resolution NHD contains more waterbodies, including smaller-order streams and additional springs. To check the status of the 1:24,000 NHD and download coverages for

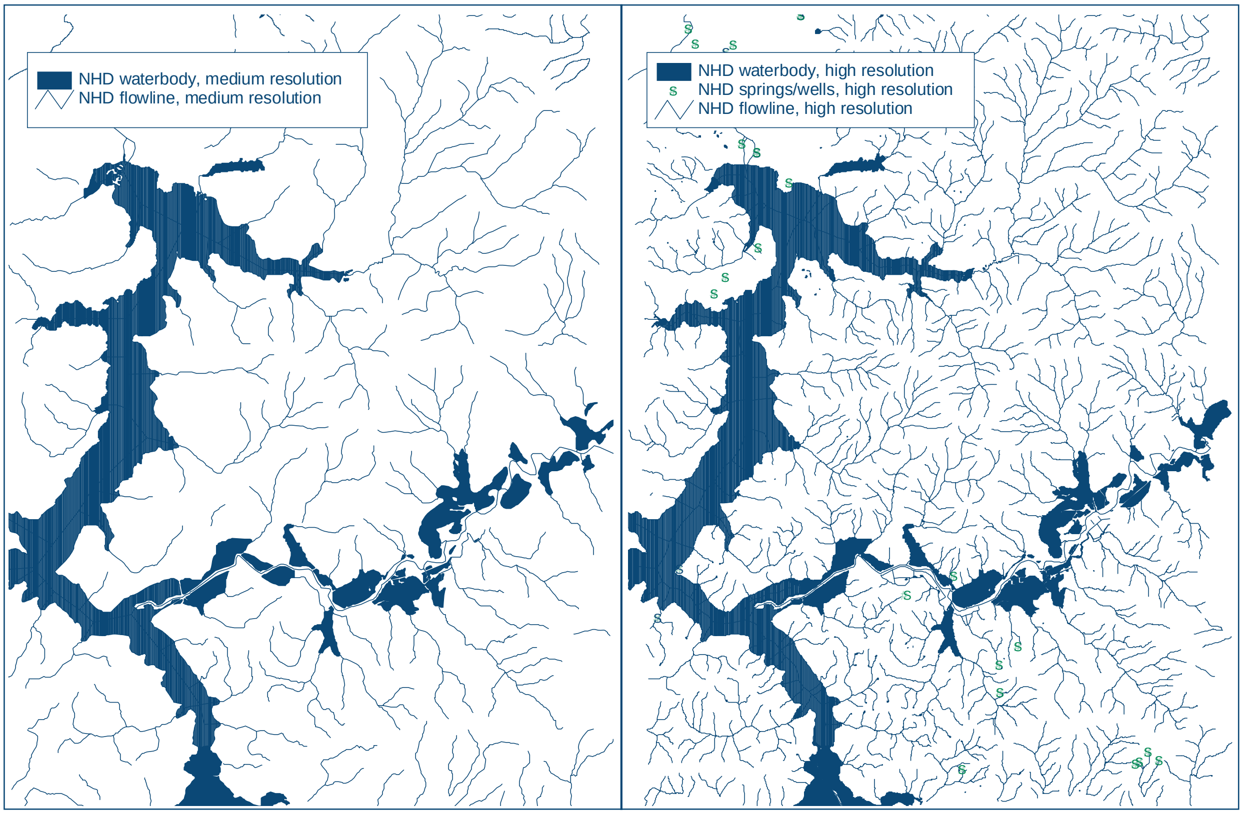


Figure 5-2. Examples of Medium-Resolution and High-Resolution NHD

your watershed at no cost, go to **http://nhd.usgs.gov**. This Web site also includes more information on the NHD, its contents, and related tools. Specifically, the Concepts and Contents technical reference (**http://nhd.usgs.gov/techref.html**) identifies and describes the contents and features of the NHD.

Sources of Digital Elevation Data

- USGS's EROS Data Center: **http://edc.usgs.gov/geodata**
- GIS Data Depot: **http://data.geocomm.com**

In addition, many state environmental agencies might have created state-specific hydrography coverage, whether based on NHD, aerial photos, or other sources. For example, the Utah Division of Water Quality has a coverage of waterbodies for the state that includes irrigation diversions and canals—features that might not be captured in the national datasets. Check your state environmental department's Web site to see if your watershed has already-created GIS coverages.

Floodplain Maps

To address flooding and control water quality, the Federal Emergency Management Agency (FEMA) requires municipalities to perform floodplain mapping and develop management plans to receive federal flood insurance. This information is also relevant to water quality protection and restoration activities because floodplains, when inundated, serve many functions and provide important habitats for a variety of fish and wildlife. Floodplains are important for spawning and rearing areas. Floodplain wetlands act as nutrient and sediment sinks, which can improve water quality in streams. They also provide storage that can decrease the magnitude of floods downstream, which can benefit fish and landowners in riparian areas.

In addition, streams that are actively connected to their floodplains are less prone to severe downcutting and erosion. Therefore, it's important to incorporate protection of these benefits of floodplain areas into your watershed management planning. Check with your local government planning office to see if floodplain maps are available, or search the FEMA map store at **www.store.msc.fema.gov**.

5.4.3 Topography

Characterizing the topography or natural features of the watershed can help to determine possible sources of pollution. For example, steep slopes might contribute more sediment loads to the waterbody than flat landscapes. Topographical information is also needed in many watershed models to route movement of runoff and loading across the land and to the waterbody. Digital elevation models (DEMs) are grid-based GIS coverages that represent elevation. They can be displayed in a GIS and are used for delineating watersheds and displaying topography. One DEM typically consists of thousands of grid cells that represent the topography of an area. DEMs are available with 10-meter, 30-meter, and 90-meter cell sizes. The smaller cell sizes represent smaller areas and provide more detailed and accurate topographic data. However, GIS coverages with small grid cell sizes often have large file sizes and can be difficult to work with over large areas. The 30-meter and 10-meter DEMs are appropriate for smaller watersheds, such as a single 8-digit cataloging unit or smaller.

Where to Get Topographic Maps

USGS has been the primary civilian mapping agency of the United States since 1879. The best-known USGS maps are the 1:24,000-scale topographic maps, also known as 7.5-minute quadrangles. More than 55,000 7.5-minute maps were made to cover the 48 conterminous states. This is the only uniform map series that covers the entire area of the United States in considerable detail. The 7.5-minute map series was completed in 1992. To order hard-copy USGS topographic maps, go to **http://topomaps.usgs.gov/ordering_maps.html**. USGS primary series topographic maps (1:24,000, 1:25,000, 1:63,360 scales) cost $6.00 per sheet, with a $5.00 handling fee for each order. They are also available through a variety of other sources, such as TopoZone (**www.topozone.com**). Electronic versions of topographic maps, called Digital Raster Graphics (DRGs), are also available (**http://topomaps.usgs.gov/drg**). USGS distributes DRGs on CDs, and there is a base charge of $45.00 per order, plus $5.00 shipping and $1.00 for each DRG quadrangle purchased.

5.4.4 Soils

Soils can be an important factor in determining the amount of erosion and stormwater runoff that occurs in your watershed. Soils have inherent characteristics that control how much water they retain, how stable they are, or how water is transmitted through them. Understanding the types of soils in your watershed and their characteristics helps to identify areas that are prone to erosion or are more likely to experience runoff.

Find Your Loca Soil and Water Conservation District

Local conservation districts can provide information on soils in your watershed and how they affect sources and pollutant delivery.

To see if your conservation district is online, visit **www.nrcs.usda.gov/partners/districts.html** or the National Association of Conservation Districts, **www.nacdnet.org/about/districts/websites**.

Historically, USDA and the local soil and water conservation districts have been instrumental in carefully mapping and classifying soils at the county level. Soils are also grouped into hydrologic soil groups according to their runoff potential. These datasets are essential to the development of input data for models that predict runoff and erosion and for the evaluation of land management techniques and alternatives.

NRCS is the principal source of soil data across the nation. You can access that information through the Soil Data Mart at **http://soildatamart.nrcs.usda.gov**. NRCS's Soil Data Mart includes more than 2,000 soil surveys with spatial and tabular information and another

800 soil surveys with tabular (soil attribute) data only. The spatial data on the Soil Data Mart are available for download at no charge and include the following:

- **State Soil Geographic (STATSGO) Database.** Soil maps for the STATSGO database are produced by generalizing the detailed soil survey data. The mapping scale for STATSGO is 1:250,000 (with the exception of Alaska, which is 1:1,000,000). The level of mapping is designed to be used for broad planning and management uses covering state, regional, and multistate areas.
  ↳ Go to **www.ncgc.nrcs.usda.gov/products/datasets/statsgo**.
- **Soil Survey Geographic (SSURGO) Database.** Mapping scales for SSURGO generally range from 1:12,000 to 1:63,360, making the soil maps the most detailed done by NRCS. SSURGO digitizing duplicates the original soil survey maps. This level of mapping is designed for use by landowners, township personnel, and county natural resource planners and managers. ↳ Go to **www.ncgc.nrcs.usda.gov/products/datasets/ssurgo**.

5.4.5 Climate

Local climatological data are often needed in a watershed characterization to help understand the local water budget for the region and also for modeling purposes. Current and historical climate data can be obtained from the National Climatic Data Center (NCDC), maintained by the National Oceanic and Atmospheric Administration (NOAA). ↳ The NCDC data are available online at **www.ncdc.noaa.gov/oa/ncdc.html** and include information such as precipitation, wind speed, temperature, and snow and ice cover at multiple stations throughout the United States. Stations within or near a watershed can be found in the NCDC database by using a variety of search tools, and data are provided (for a fee) in a raw format that can be read by a word processing or spreadsheet program. County-level stormwater management offices might also collect rain gage data.

Hourly or daily precipitation data, as well as temperature, evaporation, and wind speed, are necessary for simulating rainfall-runoff processes in watershed models. However, if weather data are being used only to generally characterize weather patterns in the watershed, daily or monthly averages are sufficient. Daily and monthly temperature and precipitation data are available online at no cost. The data are available by station through the regional climate centers and often through state climate offices. ↳ The Western Regional Climate Center provides a map of regional climate centers with links to their Web sites: **www.wrcc.dri.edu/rcc.html**. City or county stormwater management divisions might also collect rain gauge data.

Climatological data can be organized relatively easily to provide insight into wet and dry seasons, which can be important considerations in characterizing watershed problems and sources. Elevation can have an important impact on precipitation; therefore, in watersheds with significant differences in topography, it is recommended that data be presented from at least two locations (upper and lower).

5.4.6 Habitat

When characterizing your watershed, it's important to gather data not only to identify potential pollutant sources but also to identify areas for conservation, protection, and restoration. Maintaining high-quality wildlife and aquatic habitat is an important goal when developing watershed plans. High-quality, contiguous habitats and their buffers, as well as small pockets of critical habitat, help prevent water quality impairments and provide protection for both terrestrial and aquatic organisms. This section discusses information and programs available to help you identify and characterize critical habitats—terrestrial and aquatic—in your watershed.

National Wetlands Inventory

The National Wetlands Inventory (NWI), operated by the U.S. Fish and Wildlife Service (USFWS), provides information on the characteristics, extent, and status of the nation's wetlands and deepwater habitats and other wildlife habitats. The NWI has a new feature, *Wetlands Mapper*, that allows you to map wetland habitat data. Go to **www.nwi.fws.gov**. Identifying wetlands is crucial to protecting natural habitats in your watershed.

Wetland Assessments

Many programs use a wetland assessment or survey to serve as a baseline for future management activities. The survey might include global positioning system (GPS) coordinates of sample plots, a general plot description and condition assessment (land use impacts), canopy information or measurements, and digital pictures of sampling areas. In addition, the survey might document flora and fauna diversity observations. These datasets can be used to help characterize the watershed and identify wetland areas. In addition, State Wetland Conservation Plans are strategies for states to achieve no net loss and other wetland management goals by integrating regulatory and nonregulatory approaches to protecting wetlands. For more information on state wetland conservation planning activities, go to **www.epa.gov/owow/wetlands/facts/fact27.html**.

EPA's Web site for state, tribal, and local wetland initiatives (**www.epa.gov/owow/wetlands/initiative**) provides links to a variety of wetland information, including state/tribal regulatory programs; state/tribal watershed planning; local initiatives; and state, tribal, and local partners. The Web site also provides a link to the Association of State Wetland Managers' Web site, which provides links to state and local wetland programs. EPA also provides a link to wetland efforts throughout the EPA regions at **www.epa.gov/owow/wetlands/regions.html**.

National Wetlands Status and Trends Report

The Emergency Wetlands Resources Act of 1986 requires the USFWS to conduct status and trend studies of the nation's wetlands and report the results to Congress each decade. The report provides the most recent and comprehensive estimates of the current status and trends of wetlands on public and private lands in the United States. To download a copy of the most recent report, go to **http://wetlands.fws.gov**.

Natural Heritage Program

The NHP is a nonprofit program operated in every state under cooperative agreements with many state and federal agencies, such as the National Park Service, Forest Service, U.S. Department of Defense, and USFWS, to monitor the status of the state's rare, threatened, and endangered plants. State NHPs are part of a network established by The Nature Conservancy and currently coordinated by NatureServe, an international nonprofit organization. All NHP programs use a standard methodology for collecting, characterizing, and managing data, making it possible to combine data at various scales to address local, state, regional, and national issues. State NHP programs provide a variety of information, including statewide lists of tracked species and communities, plant atlases and maps, rare plant field guides, lists of rare plants (including rarity status, counties of occurrence, and flowering and fruiting times), synonyms for the scientific names of rare plants, and descriptions of how rare plants are treated under federal and state laws. Go to **www.natureserve.org/visitLocal/usa.jsp** to find local programs and datasets for your area.

Habitat Conservation Plans

Private landowners, corporations, state or local governments, and other non-federal landowners that wish to conduct activities on their land that might incidentally harm (or "take") wildlife listed as endangered or threatened must first obtain an incidental take permit from the USFWS. To obtain this permit, the applicant must develop a Habitat Conservation Plan (HCP), designed to offset any harmful effects the proposed activity might have on the species. HCPs describe the impacts expected from the proposed operations or activities (e.g., timber harvesting) and detail the measures to mitigate the impacts. HCPs can provide valuable information on critical habitat in your watershed and also identify stakeholders and current management measures to be integrated into the watershed planning process. Go to **http://endangered.fws.gov/hcp** for more information on the HCP program.

The Nature Conservancy

The Nature Conservancy (TNC) is a conservation organization working to protect ecologically important lands and waters for nature and people. TNC has numerous resources that you might find helpful when gathering habitat data. For example, TNC's Aquatic Ecosystem Classification Framework is an approach for establishing freshwater priorities across large geographic areas that uses all available data on species distributions as well as physical and geographic features. The approach allows consideration of higher levels of biological information—communities, ecosystems, and landscapes—in addition to rare and imperiled species. For more information, go to **www.nature.org/initiatives/freshwater/resources/art17010.html**. In addition, through the Sustainable Waters Program, TNC is demonstrating how water flows can be managed to meet human needs while sustaining ecosystem health. TNC works with local stakeholders to help bring their ecosystem-dependent needs and values to the decision tables, craft scientific approaches and tools to define the water needs of ecosystems, work with water managers to protect and restore natural patterns of water flow, and help to build alliances to push for new water policies that embrace environmental sustainability. For more information and resources on habitat conservation, go to **www.nature.org**.

5.4.7 Fish and Wildlife

Identifying the types of wildlife and their habitat requirements in your watershed can help to identify areas for protection and conservation in your watershed plan. Previous watershed reports might provide information on wildlife in your watershed. In addition, local and state fish and wildlife offices can provide you with information on wildlife species and distribution in their jurisdictions. Go to **http://offices.fws.gov/statelinks.html** for a list of and links to state and territorial fish and wildlife offices. The Nature Conservancy also has ecoregional plans and other reports that provide this kind of information. *Rivers of Life: Critical Watersheds for Protecting Freshwater Biodiversity* provides information on freshwater species (**www.natureserve.org/publications/riversOflife.jsp**). It's especially important to consider wildlife habitat in your watershed plan when endangered or threatened species occur in your watershed. To find out more about endangered species, go to **http://endangered.fws.gov**. That page also includes links to endangered species contacts in your area (**http://endangered.fws.gov/contacts.html**).

Understanding the types of wildlife in your watershed can not only identify critical habitat areas to protect but sometimes also identify pollutant sources affecting water quality. For example, waterfowl can be a significant source of bacteria and nutrients to reservoirs and lakes. Although wildlife are an important component of the watershed ecology and should be protected, it's important to understand their impact on waterbody conditions when developing a watershed plan.

State Comprehensive Wildlife Conservation Strategies

State comprehensive wildlife conservation strategies (also known as wildlife action plans) assess the condition of each state's wildlife and habitats, identify the problems they face, and outline the actions that are needed to be conserve them over the long term before they become more rare and more costly to protect. State fish and wildlife agencies have developed these plans by working with a broad array of partners, including scientists, sportsmen, conservationists, and members of the community. There is a plan for each state and U.S. territory. Plans contain data on the distribution and abundance of wildlife; locations and relative conditions of habitats essential to species in need of conservation; and problems that might adversely affect species or their habitats and priority research and survey efforts. ➥ For more information on state wildlife action plans, go to **www.wildlifeactionplans.org**.

USGS GAP and Aquatic GAP

Gap analysis is a scientific method for identifying the degree to which native animal species and natural communities are represented in our present-day mix of conservation lands. The purpose of the Gap Analysis Program (GAP) is to provide broad geographic information on the status of ordinary species (those not threatened with extinction or naturally rare) and their habitats to provide land managers, planners, scientists, and policy makers with the information they need to make better-informed decisions. GAP is coordinated by the Biological Resources Division of the U.S. Geological Survey (➥ **http://gapanalysis.nbii.gov**). Aquatic GAP promotes conservation of biodiversity through information by providing conservation assessments of natural communities and native species.

The Aquatic GAP examines how well all aquatic species and their habitats are represented within places and managed for their long-term persistence, which species and habitat types are under-represented in aquatic biodiversity management areas or activities, and which species and habitat types are at risk. GIS models are used to predict aquatic biodiversity at the community and species levels. Examples of data and information collected include habitat cover and quality, fish species and macroinvertebrates associated with habitat types, water quality, and stream gradient. Aquatic GAP projects are completed or on-going in several states (NY at the watershed scale) and regions (e.g., Upper Tennessee River). For more information, go to ➥ **www.glsc.usgs.gov/main.php**.

5.4.8 Ecosystems

Ecosystem management requires that all aspects of a watershed (e.g., land, water, air, plants, and animals) be managed as a whole, not as separate and unrelated parts. Ecosystem management plans protect the viable populations of native species and the natural rhythms of the natural range of variability of the ecosystem. They allow public use of resources at levels that do not result in the degradation of the ecosystem. Successful, effective ecosystem management requires partnerships and interdisciplinary teamwork within the watershed.

There are a number of good resources for developing an ecosystem management plan. The following article provides relevant background information to help you protect ecosystems in your watershed:

- *Endangered Ecosystems of the United States: A Preliminary Assessment of Loss and Degradation* R.F. Noss, E.T. LaRoe III, and J.M. Scott. U.S. Department of the Interior, National Biological Service (now called BRD). 1995. (➥ **http://biology.usgs.gov/pubs/ecosys.htm**)

  This article provides estimates of declines of natural ecosystems in the United States, a rationale for ecosystem-level conservation, discusses decline and threat as criteria for conservation, and relates ecosystem losses to endangerment at species and population levels. Ecosystems are defined generally and at various spatial scales and include vegetation types, plant associations, natural communities, and habitats defined by ecologically relevant factors. Appendix B of the article includes a comprehensive list of at-risk ecosystems of the United States.

Another valuable resource is The Wildlands Project (**www.twp.org**). The Wildlands Project works toward restoring networks of wild landscapes with area-specific, native species. Its mission is to strengthen existing wilderness areas and create more sustainable ecosystems by creating a series of wilderness corridors that link larger areas. Development and human activity in these corridors are limited to lessen their impact on local wildlife. The project has done notable partnership work in Minnesota, where the Minnesota Ecosystems Recovery Project (MERP) is working toward the design and establishment of a comprehensive nature reserve system that includes core reserve areas; buffer zones with limited, sustainable human activities; and corridors that will allow migration of plant and animal species between core areas.

5.5 Land Use and Population Characteristics

This section discusses data and information for determining the distribution of land use and population in your watershed. Land uses are an important factor influencing the physical conditions of the watershed, as well as an indicator of the types of sources active in the watershed. Together with land use characteristics, population can help you to understand the potential growth of the area and possible changes in land uses and sources.

National Sources for Land Use and Land Cover Data

GIS coverages

MRLC/NLCD data: **www.mrlc.gov/index.asp**

USGS's LULC data: **http://edc.usgs.gov/geodata**

Survey-based land use data

U.S. Census of Agriculture: **www.agcensus.usda.gov**

National Resources Inventory: **www.nrcs.usda.gov/technical/NRI**

5.5.1 Land Use and Land Cover Data

Evaluating the land uses of a watershed is an important step in understanding the watershed conditions and source dynamics. Land use types (together with other physical features such as soils and topography) influence the hydrologic and physical nature of the watershed. In addition, land use distribution is often related to the activities in the watershed and, therefore, pollutant stressors and sources. Sources are often specific to certain land uses, providing a logical basis for identifying or evaluating sources. For example, sources of nutrients such as grazing livestock and fertilizer application associated with agricultural land uses would likely not contribute to loading from other land uses such as urban or forest land uses. Likewise, urban land uses typically have specific pollutants of concern (e.g., metals, oil and grease) different from those associated with rural land uses. Evaluating land use distribution and associated sources also facilitates identifying future implementation efforts because some management practices are most effective when applied to a certain land use.

This section discusses some of the most common sources of land use data. Typically, land use and land cover data are obtained from aerial photographs, satellite images, and ground surveys. Because in some areas land uses continually change, it's important to keep in mind the type and date of available land use data when reviewing the sources of land use data for use in developing your watershed plan.

What Is the MRLC?

Many of the land use datasets discussed in this section are products of the Multi-Resolution Land Characteristics (MRLC) consortium. Because of the escalating costs of acquiring satellite images, in 1992 several federal agencies agreed to operate as a consortium to acquire satellite-based remotely sensed data for their environmental monitoring programs. The original members of the MRLC consortium were USGS, EPA, NOAA, and the Forest Service. The National Aeronautics and Space Administration (NASA) and the Bureau of Land Management (BLM) joined the consortium later.

During the 1990s the MRLC created several mapping programs, including (1) the Coastal Change Analysis Project (C-CAP) administered by NOAA; (2) the Gap Analysis Project (GAP) directed by the Biological Resources Division of USGS; and (3) the National Land Cover Data (NLCD) project directed by USGS and EPA. The data developed by these projects are available publicly through download or by contacting the agencies involved.

For more information on the MRLC and its data products, go to **www.epa.gov/mrlc**.

National Land Cover Data

Satellite data from the early 1990s are available for the entire United States as part of the National Land Cover Data (NLCD) program, made available by the Multi-Resolution Land Characteristics Consortium (MRLC). The NLCD data are classified using a standard land use classification system and are available as 30-meter grid cell GIS coverages that can be displayed and queried in a GIS. The NLCD includes 21 land use classifications within the following broad categories:

- Water
- Developed
- Barren
- Natural Forested Upland (non-wet)
- Natural Shrubland
- Non-natural Woody
- Herbaceous Upland Natural/Semi-Natural Vegetation
- Herbaceous Planted/Cultivated
- Wetlands

Definitions of the land use classifications are included at **http://landcover.usgs.gov/classes.php**.

The NLCD data can be downloaded from the NLCD Web site at **www.epa.gov/mrlc/nlcd.html** or through USGS's Seamless Data Distribution Center (**http://seamless.usgs.gov**). The entire United States is being mapped using imagery acquired circa 2000 as part of the MRLC 2001 land use project. To check the status of NLCD 2001 and whether it is available for your watershed, go to **www.mrlc.gov/mrlc2k_nlcd_map.asp**.

Land Use and Land Cover Data

USGS's Land Use and Land Cover (LULC) data consist of historical land use and land cover classification data based primarily on the manual interpretation of 1970s and 1980s aerial photography. Secondary sources include land use maps and surveys. Along with the LULC files, associated

NLCD 1992 vs. NLCD 2001

NLCD 1992 was derived from the early to mid-1990s Landsat Thematic Mapper (TM) satellite data purchased under MRLC 92. The entire United States is being mapped through NLCD 2001 using imagery acquired circa 2000 from Landsat-7's enhanced TM (ETM). This project entails re-mapping the lower 48 states, as well as covering Hawaii and Alaska for the first time. Classification schemes for the two rounds of classification are similar but not identical. For a list and definitions of the classifications, go to **www.epa.gov/mrlc/classification.html**.

NLCD 2001 is a Landsat-based land cover database that has several independent data layers, thereby allowing users a wide variety of potential applications. Primary components in the database include

- Normalized imagery for three time periods
- Ancillary data, including a 30-m DEM, slope, aspect, and a positional index
- Per-pixel estimates of percentage of imperviousness and percentage of tree canopy
- 21 classes of land-cover data derived from the imagery, ancillary data, and derivatives using a decision tree
- Classification rules, confidence estimates, and metadata from the land cover classification

To check the status of NLCD 2001 and determine whether it is available for your watershed, go to **www.mrlc.gov/mrlc2k_nlcd_map.asp**.

maps that provide additional information on political units, hydrologic units, census county subdivisions, and federal and state land ownership are included. LULC includes 21 possible categories of cover type within the following Anderson Level I codes:

- Urban or Built-up
- Agricultural
- Rangeland
- Forest
- Water
- Wetland
- Barren
- Tundra
- Perennial Snow or Ice

LULC data are available for the conterminous United States and Hawaii, but coverage is not complete for all areas. The data are based on 1:100,000- and 1:250,000-scale USGS topographic quadrangles. The spatial resolution for all LULC files depends on the format and feature type—GIRAS (Geographic Information Retrieval and Analysis System) or CTG (Composite Theme Grid). Files in GIRAS format have a minimum polygon area of 10 acres with a minimum width of 660 feet (200 meters) for man-made features. Non-urban or natural features have a minimum polygon area of 40 acres (16 hectares) with a minimum width of 1,320 feet (400 meters). Files in CTG format have a resolution of 30 meters.

All LULC data are available for free by download at **http://edc.usgs.gov/geodata**.

State and County Land Use Databases

In addition to national coverages, several states and counties have statewide or local land use and land cover information available. Specialized local land use or land cover sets might include land parcel or land ownership, impervious surfaces, wetland or forest coverage, sewer areas, land use zoning, or future land use projections. For example, King County, Washington's GIS Center (**www.metrokc.gov/gis**) has an online database of available GIS data for the area, including 2001 Landsat land cover. Regional examples of land use datasets include land use data for southern California counties available from the San Diego Association of Governments (**www.sandag.cog.ca.us**) and Southern California Association of Governments (**www.scag.ca.gov/index.htm**). The Internet is an excellent tool for locating land use data available from local and regional agencies.

Many GIS Web sites, including Geography Network (**www.geographynetwork.com**), have links to local, state, and federal GIS sources and provide query engines to identify available GIS data by geographic location or content. In addition, states often have GIS groups as part of their environmental agencies and provide access to the data on the Internet. Examples of state GIS Web pages are included in section 5.9.

Survey-Based Data

In addition to GIS coverages and databases of land use distribution, there are several survey-based inventories of land use information. Two examples are the USDA's National Resources Inventory (NRI) and the USDA's Census of Agriculture. Be careful when using NRI and Census of Agriculture data to evaluate land use in your watershed because these inventories are built on a more gross scale than is typically needed for watershed planning. The NRI is based on data collected at thousands of sites across the country to evaluate state, regional, and national trends in resources. The Census of Agriculture includes county-level data on agriculture characteristics that might or might not reflect the characteristics of your watershed. If these data are evaluated for your watershed, they should be used to gain a general sense of the sources and conditions, not as hard facts on the watershed.

USDA National Resources Inventory

Survey-based land use data are available from the USDA's NRI (**www.nrcs.usda.gov/technical/NRI**). The NRI is a statistical survey of information on natural resources on non-federal land in the United States that captures data on land cover and land use, soil erosion, prime farmland soils, wetlands, habitat diversity, selected conservation practices, and related resource attributes. The NRI includes inventories such as highly erodible lands, land capabilities, and land uses.

With data collected during each survey from the same 800,000 sample sites in all 50 states, Puerto Rico, the U.S. Virgin Islands, and some Pacific Basin locations, the NRI is designed to assess conditions and long-term trends of soil, water, and related resources. Previously, data were collected every 5 years, with information available at each sampling point for 1982, 1987, 1992, and 1997. Since 2001 the NRI has been updated continually with annual releases of NRI data. The NRI provides information for addressing agricultural and environmental issues at the national, regional, and state levels.

NRI data are provided on a county or cataloging unit level. Therefore, at the smaller watershed level, they are likely useful mainly for providing "big picture" information on trends in land use over the years. However, NRI data are useful at the watershed level when evaluating the erodibility of agricultural land in your watershed. When developing watershed models, for example, the NRI can be an important source of information on site-specific soil characteristics for agricultural lands (e.g., cropland, pastureland) in your area. It's also important to note that the NRI data are provided as inventories and are not in GIS format.

USDA Census of Agriculture

Additional survey-based land use data are available from USDA's Census of Agriculture (**www.agcensus.usda.gov**). Prepared by the USDA's National Agricultural Statistics Service, the census includes comprehensive data on agricultural production and operator characteristics for each U.S. state and county, including area of farmland, cropland, and irrigated land; livestock and poultry numbers; and acres and types of crops harvested.

Unfortunately, Census of Agriculture information is provided at the county level—often a more gross scale than is useful for watershed planning. Moreover, the Census of Agriculture information is provided as inventories, not in GIS format, preventing you from isolating data for only your watershed. You must be careful about using county-level information to evaluate your watershed because farming practices can vary widely across a county.

Specialized Land Use Datasets

In addition to the national datasets discussed previously in this section, there are several specialized datasets on land use focusing on specific regions (e.g., coastal areas, forested areas) or on specific types of land uses (e.g., mineral areas).

The following are examples of these types of data. You can find more examples at the following MRLC Web site: **www.epa.gov/mrlc/data.html**.

The NOAA Coastal Services Center is developing a nationally standardized database of land cover within the coastal regions of the United States as part of the Coastal Change Analysis Program (C-CAP). C-CAP includes land cover and change data for the nation's coastal zone, designed to assist coastal resource managers in their decisionmaking processes. These land cover products inventory coastal intertidal habitats, wetlands, and adjacent uplands with the goal of monitoring changes in these habitats on a 1- to 5-year cycle. For more information on the C-CAP and related data, go to **www.csc.noaa.gov/crs/lca**.

Another type of specialized land use dataset is the BLM's Land and Mineral Use Records. The Land and Mineral Use Records Web site allows users to search, locate, and map the BLM's land and mineral use authorizations and mining claims on public lands throughout the United States. Land and mineral use authorizations include such things as oil and gas leases, right-of-ways, and mineral leases. To search the Land and Mineral Use Records, go to **www.geocommunicator.gov/GeoComm/landmin/home/index.shtm**.

5.5.2 Land Management Practices

Information on how the land is managed in a watershed is helpful to identify both current control practices and potential targets for future management. This information not only will support the characterization of the watershed but also will be important in identifying current watershed sources, future management efforts, and areas for additional management efforts.

Local Conservation Districts

Conservation districts are local units of government responsible for the soil and water conservation work within their boundaries. A district's role is to increase voluntary conservation practices among farmers, ranchers, and other land users. Depending on the location of the districts, their programs and available information vary. For example, districts in agricultural areas can provide assistance with erosion control, agriculture-related water quality projects, and nutrient and pesticide management plans. Districts in suburban or urban areas might focus on protection of streams from impacts of urban activities and erosion control for construction activities.

Local conservation districts can be a good source of information on potential watershed sources, as well as restoration activities in your watershed. To see if your conservation district is online, visit **www.nrcs.usda.gov/partners/districts.html** or the National Association of Conservation Districts, **www.nacdnet.org/about/districts/websites**.

Nonpoint Source Projects

Under Clean Water Act section 319, states, territories, and tribes receive grant money to support a wide variety of activities, including implementation of best management practices (BMPs) to improve water quality. To find out if there are any current nonpoint source projects in your watershed, contact your state environmental department. EPA's Web site for nonpoint source pollution (**www.epa.gov/nps**) provides a variety of links, including section 319 information, publication and information resources, background on the state-EPA nonpoint source partnership, and outreach information. A list of state nonpoint source coordinators is available at **www.epa.gov/owow/nps/319hfunds.html**.

Local Ordinances

Local ordinances that establish construction-phase erosion and sediment control requirements, river corridors and wetland buffers, and other watershed protection provisions are often included as part of a watershed plan implementation strategy. Check to see what current ordinances are in place for your community through the planning or environmental department. For example, your locality might have a local wetland protection ordinance that protects wetlands by restricting or requiring a special permit for certain activities, such as dredging, filling, clearing, and paving, within wetland boundaries or buffers. CWP provides model ordinance language for wetland protection in *Adapting Watershed Tools to Protect Wetlands: Wetlands & Watersheds Article #3* (**www.cwp.org/wetlands/articles/WetlandsArticle3.pdf**). Also go to CWP's Stormwater Manager's Resource Center, which provides examples of real-world and model ordinances (**www.stormwatercenter.net/intro_ordinances.htm**) that can be used to guide future growth while safeguarding local natural resources. The intent is to provide language and ideas that communities and stormwater managers can incorporate when writing an ordinance for their local area. The Web site includes a sampling of ordinances from across the nation and can help watershed managers understand what ordinances might exist in their watershed. ↳ Other references for model ordinances are provided in appendix A.

Land and Water Conservation Measures

There are several ways that land can be conserved for water quality protection, habitat conservation, or water supply protection. For example, Purchase of Development Rights (PDR) is a voluntary land protection tool that pays landowners to protect their land from development. Through PDR a government agency, or private nonprofit organization, buys development rights (also known as a conservation easement) from landowners in exchange for limiting development on the land in the future. Transfer of Development Rights (TDRs) is a land use management technique that can support local comprehensive planning goals and facilitate watershed-based zoning proposals by transferring development potential from sensitive subwatersheds to subwatersheds designated for growth. The principle of TDRs puts to creative use the premise that ownership of land entails certain property rights and therefore individual rights can be bought and sold to accomplish various community planning objectives. TDRs allow developers to purchase the rights to an undeveloped piece of property in exchange for the right to increase the number of dwelling units on another site. The practice is often used to concentrate development density in certain land areas.

Under the USDA NRCS's Conservation Reserve Program, farmers convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as native grasses, wildlife plantings, trees, filter strips, or riparian buffers. Farmers receive an annual rental payment for the term of the multi-year contract. In addition, designation of conservation preserves and hydrologic reserves, as well as conservation tax credits (income tax deduction for conservation easements) are other tools that can be used to protect sensitive lands. Hydrologic reserves are undeveloped areas that are maintained to protect natural hydrology and provide habitat during drought periods.

Master Plans

Economic development plans for counties or multi-county regions often have significant impacts on water resources. The designation of future development areas, greenways, sewer service districts, and drinking water sources should address how water resources will be protected through watershed planning/management, antidegradation policy implementation, and other measures. Integrating watershed planning with economic development master planning builds efficiencies and effectiveness in both processes and ensures compatibility among activities that might have competing objectives. In addition, master planning studies might provide information on future land uses and growth projections. Contact your local government planning department to find out if your community has a master plan.

Stormwater Pollution Prevention Plans

Federal regulations require many industrial facilities and most construction sites disturbing more than 1 acre of land to obtain a stormwater permit. Each covered industrial facility or construction site is required to develop and implement a stormwater pollution prevention plan (SWPPP) that describes the activities that will be conducted to prevent stormwater pollution. If you're interested in how a certain industrial facility or construction site plans to control stormwater pollution, you can often obtain a copy of the SWPPP from your state environmental agency, EPA regional office, or local municipality. Additional information is available at **www.epa.gov/npdes/stormwater**.

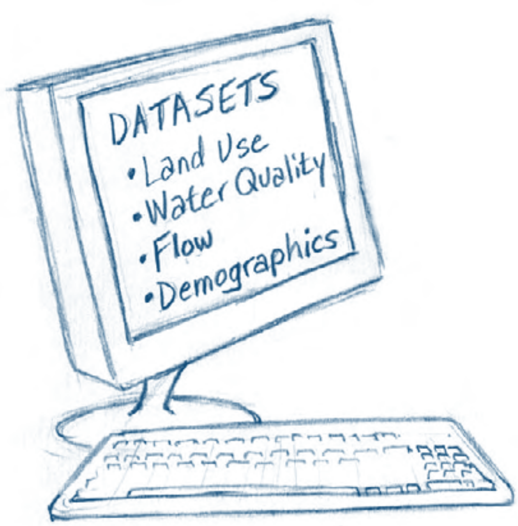
BLM Resource Management Plans

The BLM administers 262 million surface acres of America's public lands, primarily in 12 western states, and 700 million acres of mineral estate. The BLM's 162 resource management plans (RMPs) form the basis for every action and approved use on public lands throughout the country. The RMPs typically establish guidance, objectives, policies, and management actions for public lands administered by the BLM and might address a combination of the following issues:

- Air quality
- Cultural resources
- Grazing and rangeland
- Wildlife habitat
- Mineral and mining resources
- Recreation and off-highway vehicle use
- Special management designations
- Hazardous materials
- Soil and water resources
- Vegetation
- Lands and realty management
- Fisheries management
- Oil and gas resources
- Visual resource management
- Soil and water resources

An RMP in your watershed could provide information on potential sources, as well as general background information on watershed activities and conditions.

The BLM's national planning Web site (Planning, Assessment, and Community Support Group) allows you to search for BLM management plans by state. Go to **www.blm.gov/planning/plans.html**.



5.5.3 Demographics

Demographic data include information on the people in the watershed, such as the number of persons or families, commuting patterns, household structure, age, gender, race, economic conditions, employment, and educational information. This information can be used to help design public outreach strategies, identify specific subpopulations to target during the implementation phase, or help determine future trends and needs of the populations.

Local governments usually collect demographic information on their communities through the planning or economic departments. The primary database for demographic, social, and economic data is the U.S. Census Bureau (**www.census.gov/popest**). Within the database you can search county population estimates.

Population Statistics

Population can provide insight into the distribution of pollutant sources in a watershed and into future growth patterns. In developing areas, it's important to consider future growth when evaluating sources of impairment and identifying potential management options. GIS data for mapping human population are provided by the U.S. Census Bureau through the TIGER (Topologically Integrated Geographic Encoding and Referencing) program. Go to **www.esri.com/data/download/census2000_tigerline/index.html**. TIGER data consist of man-made features (such as roads and railroads) and political boundaries. Population data from the 2000 Census can be linked to the TIGER data to map population numbers and density for small areas (census blocks) and large areas like counties and states. Information from the 1990 Census includes data on household wastewater disposal methods (e.g., sewer, septic systems, other), but similar information was not collected as part of the 2000 Census. Cultural data are also available through many of the states' GIS Web sites.

Land Ownership

Many watersheds contain land owned by a variety of parties, including private citizens and federal, state, and county government agencies. Although information on land ownership in a watershed might not help to characterize the physical nature of the area, it can provide insight into sources of information for characterizing the watershed or identifying pollutant sources. It can also be very useful in identifying implementation opportunities. For example, federal parks can cover large expanses of land, comprising large portions of the watershed, and the managing agency (e.g., National Park Service, USDA Forest Service) can be a valuable source of information on watershed and waterbody characteristics and potential sources (e.g., wildlife populations). State and federal agencies owning and managing land in the watershed should also be contacted to identify any previous studies conducted in the watershed that might support watershed or instream characterization. Keep in mind that local county or city agencies often maintain parcel maps as GIS coverages.

GIS coverages of managed lands in the country are available through EPA's BASINS modeling system. To download data for your cataloging unit, go to **www.epa.gov/waterscience/basins/b3webdwn.htm**. Many states and counties also have coverages of land ownership by parcel or census block.

5.6 Waterbody and Watershed Conditions

Several sources can provide helpful information on the current condition of the waterbodies in your watershed, including whether they meet water quality standards and support designated uses. This section discusses where to find water quality standards for your waterbody, how to identify impaired waters and use support in your watershed, and how to find any TMDLs that have already been completed in your watershed. This information provides a general overview of the health of the waterbodies in your watershed and what uses should be supported.

5.6.1 Water Quality Standards

You'll need to obtain the current water quality standards for the waterbodies in your watershed to understand for what uses the waterbodies should be protected and to compare instream monitoring data with standards to evaluate impairment. You should also document the designated uses for the waterbodies and any relevant criteria for evaluating waterbody conditions. This information can be obtained from EPA's Web site at **www.epa.gov/wqsdatabase**. Tribal water quality standards can be found at **http://epa.gov/waterscience/tribes**.

5.6.2 Water Quality Reports

State water quality reports produced to meet federal requirements provide data on the status of waterbodies, designated uses, known impairments, and potential sources of the stressors. Local municipalities or counties may also produce individual reports on the status of water quality in their jurisdictions.

Biannual 305(b) State Water Quality Report

Under section 305(b) of the Clean Water Act, states are required to prepare a report describing the status of their water quality every 2 years. EPA compiles the data from the state reports, summarizes them, and transmits the summaries to Congress along with an analysis of the nationwide status of water quality. The 305(b) reports evaluate whether U.S. waters meet water quality standards, what progress has been made in maintaining and restoring water quality, and the extent of remaining problems. Check your state's report to see if your watershed has been monitored or assessed. If so, you should find information like the following:

- Status of use support with descriptions of significant water quality impairments
- Identification of problem parameters for impaired waters, along with potential sources of the stressors
- Priority for TMDL development

↳ Go to **www.epa.gov/OWOW/305b** for information on your state's 305(b) report.

303(d) List of Impaired Waters

Under section 303(d) of the 1972 Clean Water Act, states, territories, and authorized tribes are required to develop lists of impaired waters. Impaired waters are those which do not meet water quality standards, 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 for waters on the lists and develop TMDLs for these waters.

Reviewing your state's 303(d) lists will help you identify any impaired waterbodies in your watershed. If there are impairments that have not been addressed through TMDLs, you might want to consider coordinating with your state's TMDL program to develop TMDLs concurrently with your watershed plan. The 303(d) list may identify the schedule for TMDL development, highlighting TMDLs already done, currently under way, or scheduled for coming years. The list may identify potential sources of the impairment and include notes on why the waterbody was listed—information that can guide your source assessment and search for information.

Integrating 303(d) and 305(b) Reports

Beginning with the 2002 305(b) and 303(d) reporting cycle, EPA had encouraged states to prepare a single integrated report that satisfies the reporting requirements of Sections 303(d) and 305(b). As part of EPA's guidance to states for preparing integrated reports, EPA recommends that states use the following five reporting categories to report on the water quality status of all waters in their states:

Category 1: All designated uses are supported, no use is threatened;

Category 2: Available data and/or information indicate that some, but not all of the designated uses are supported;

Category 3: There is insufficient available data and/or information to make a designated use support determination;

Category 4: Available data and/or information indicate that at least one designated use is not being supported or is threatened, but a TMDL is not needed;

Category 5: Available data and/or information indicate that at least one designated use is not being supported or is threatened, and a TMDL is needed.

In classifying the status of their waters, states may report each waterbody in one or more category (the latter, where there is more than one impairment in a waterbody). Waters assigned to categories 4 and 5 are impaired or threatened; however, waters assigned to Category 5 represent waters on a state's Section 303(d) list. A state's Section 303(d) list is comprised of waters impaired or threatened by a pollutant, and needing a TMDL. Similar to Category 5, waters in Category 4 are also impaired or threatened; however, other conditions exist that no longer require them to be included on a state's Section 303(d) list. These conditions, which are referred to as subcategories of Category 4 in EPA's Integrated Reporting Guidance, are described below:

Category 4a: TMDL has been completed;

Category 4b: TMDL is not needed because other required controls are expected to result in the attainment of an applicable WQS in a reasonable period of time (see Section 5.6.3 for additional details);

Category 4c: The non-attainment of any applicable WQS for the waterbody is the result of pollution and is not caused by a pollutant. Examples of circumstances where an impaired segment may be placed in Category 4c include waterbodies impaired solely due to lack of adequate flow or to stream channelization.

For additional information on EPA's five recommended reporting categories, go to EPA's *Integrated Reporting Guidance* at **www.epa.gov/owow/tmdl**.

5.6.3 Watershed-Related Reports

In addition to state or local water quality reports, there might be existing watershed-related studies produced for all or a portion of your watershed under various state, local, or federal programs. These studies might have a narrower focus than your watershed plan (e.g., source water, specific pollutant) or be out-of-date, but they can provide information on available data, potential pollutant sources, and historical water quality and watershed conditions. This section provides a few examples of current or recent programs that might provide relevant watershed information. This is not a comprehensive list of the programs or reports that could be available for a watershed, but it does highlight commonly used plans that can provide information relevant to watershed planning.

Existing TMDL Reports

If a TMDL has been developed for all or part of your watershed, the supporting documents can often provide much of the information needed to support watershed plan development, such as

- Descriptions of the stressors causing water quality impairment
- The extent (length of stream, area of watershed) and magnitude of the impairment
- Sources of impairment and relative contributions for parameters causing impairment

TMDLs Are a Starting Point

Do not limit your watershed planning effort strictly to the information provided in the TMDL. You'll need to review the TMDL and determine the following:

Pollutants and Sources. TMDLs are developed specifically to address the pollutants included on the state's 303(d) list. The watershed planning effort should consider all pollutants causing problems in the watershed.

Availability of Information. Since the TMDL was completed, has more information that would change or refine the source assessment become available?

Scale/Resolution. What was the scale of the TMDL source assessment? Does it fit the needs of the watershed plan? Generally, the resolution of your watershed plan will need to provide more detail for developing and implementing specific control strategies.

Resources Available. Was the TMDL completed with limited resources? Are there sufficient resources to refine the original source assessment?

- Loading targets for watershed and water quality protection
- Overall load allocations for point and nonpoint sources

To find a link to your state's TMDL program Web site, go to **www.epa.gov/owow/tmdl/links.html**.

In addition, the National TMDL Tracking System (NTTS) houses the 303(d) lists and tracks TMDL approvals. The NTTS stores information necessary to track the performance of state and regional TMDL programs and to ensure that TMDLs are being calculated at an adequate pace for waters currently listed as impaired. The database includes numerous Web-based reports. The NTTS is mapped to the NHD through the EPA WATERS (Watershed Assessment, Tracking & Environmental Result) system. Data files and GIS shapefiles with information on segments listed for one or more pollutants and listed waters for which TMDL loading reduction targets have been established are available for download at **www.epa.gov/waters/data/prog.html**.

Category 4b Rationales

Similar to a TMDL, a state's rationale for assigning an impaired water to Category 4b of the integrated report can also provide much of the information needed to support watershed management plans. Specifically, EPA's *Integrated Reporting Guidance* recommends that states include the following information in their rationales for assigning an impaired water to Category 4b:

- Identification of segment and statement of problem causing the impairment;
- Description of pollution controls and how they will achieve WQS;
- An estimate or projection of the time when WQS will be met;
- Schedule for implementing pollution controls;
- Monitoring plan to track effectiveness of pollution controls; and
- Commitment to revise pollution controls, as necessary.

In return, watershed-based management plans may also provide much of the information needed to support assigning an impaired waterbody to Category 4b.

For additional information on Category 4b, go to EPA's Integrated Reporting guidance for the 2006 and 2008 reporting cycles at **www.epa.gov/owow/tmdl**.

Source Water Assessments

The Safe Drinking Water Act (SDWA) Amendments of 1996 require states to develop and implement Source Water Assessment Programs (SWAPs) to analyze existing and potential threats to the quality of the public drinking water throughout the state. Every state is moving forward to implement assessments of its public water systems through the SWAPs. Assessments were required to be completed by 2003 for every public water system—from major metropolitan areas to the smallest towns, including schools, restaurants, and other public facilities that have wells or surface water supplies. (Assessments are not conducted for drinking water systems that have fewer than 15 service connections or that regularly serve fewer than 25 people because these are not considered public water systems.)

The SWAPs created by states differ because they are tailored to each state's water resources and drinking water priorities. However, each assessment must include four major elements:

- Delineating (or mapping) the source water assessment area
- Conducting an inventory of potential sources of contamination in the delineated area
- Determining the susceptibility of the water supply to those contamination sources
- Releasing the results of the determinations to the public

The assessments are available through the local utility in its annual consumer confidence reports. Many local water utilities provide this information online, and it can be found by searching the Internet. Go to EPA's Local Drinking Water Information Web page, **www.epa.gov/safewater/dwinfo/index.html**, to find links to many online water quality reports and specific information about local drinking water supplies, including information about the state's drinking water program and source water protection program. Go to **www.epa.gov/safewater/dwinfo/index.html** to find links to regional and state contacts for source water protection. Additional information about SWAPs is available at **http://cfpub.epa.gov/safewater/sourcewater/sourcewater.cfm?action=Assessments**.

Watershed Restoration Action Strategies

In 1998 EPA and USDA released the Clean Water Action Plan (USEPA and USDA 1998) as a means toward fulfilling the original goal of the Clean Water Act—fishable and swimmable waters for all Americans. A key component of the plan was the development of Watershed Restoration Action Strategies (WRASs) to comprehensively address watershed restoration, including a balance between discharge control for specific chemicals and prevention of broader, water-related problems such as wetland loss and habitat degradation. The plan proposed that states and tribes develop WRASs for those watersheds identified as having the greatest need for restoration.

The development and implementation of WRASs were a focus of EPA guidelines for awarding section 319 funds in Fiscal Years 1999 through 2001. Consequently, many states developed WRASs for priority watersheds, and some might continue to do so. If a WRAS has been completed for your watershed, it can be an important source of information about water quality conditions, available data, land uses and activities, threats to water quality, restoration priorities, key stakeholders, and sources of funding. Browse your state environmental agency's Web site to see if a WRAS is available for your watershed.

5.7 Pollutant Sources

Pollutants can be delivered to waterbodies from various point and nonpoint sources. Identifying and characterizing sources are critical to the successful development and implementation of a watershed plan and the control of pollutant loading to a stream. Characterizing and quantifying watershed pollutant sources can provide information on the relative magnitude and influence of each source and its impact on instream water quality conditions. Watershed-specific sources are typically identified and characterized through a combination of generation, collection, and evaluation of GIS data, instream data, and local information. However, some common types of pollutant sources might be contributing to watershed problems, and this section discusses information available to characterize them.

Who Is Subject to NPDES?

To find out more about NPDES and what discharges are subject to NPDES permitting requirements, go to EPA's NPDES Web page at **http://cfpub.epa.gov/npdes/index.cfm**.

5.7.1 Point Sources

The discharge of pollutants from point sources, such as pipes, outfalls, and conveyance channels is generally regulated through National Pollutant Discharge Elimination System (NPDES) permits. Check with state agencies for the most recent and accurate point source discharge information. Be sure to verify actual monitored discharges and future discharge projections or capacity because often not all of the water quality parameters that you might be interested in are monitored.

Permits

Existing dischargers that discharge into waterbodies from specific point sources should be identified. These include wastewater treatment plants, industrial facilities, and concentrated animal feeding operations. Generally point sources that discharge pollutants into waterbodies are required to have a permit under the NPDES program. Information on major facilities is stored in EPA's Permit Compliance System (PCS). PCS is an online database of information regarding permitted point sources throughout the United States (**www.epa.gov/enviro/html/pcs/index.html**). Data from major NPDES permits is included in PCS; PCS also includes information from certain minor NPDES permits as well. Included in the database is information about facility location, type of facility, receiving stream, design flow, and effluent pollutant limits. PCS also contains Discharge Monitoring Report data on effluent monitoring and recorded violations. Data are continuously added to the database so that the most recent point sources can be tracked. Geographic information is included with each point source so that data can be plotted and analyzed in a GIS.

Wastewater Permits

Many communities have a wastewater treatment plant that uses a series of processes to remove pollutants from water that has been used in homes, small businesses, industries, and other facilities before discharging it to a receiving waterbody. Generally facilities that discharge wastewater into waterbodies are required to have a permit under the NPDES program. Information about wastewater treatment facilities is available in EPA's "Envirofacts" data system for water (**http://oaspub.epa.gov/enviro/ef_home2.water**). Search for facilities in your area by entering your ZIP Code, city, or county. Envirofacts will display a list of permitted facilities in your area, including each facility's name, permit number, location, and discharge information.

Stormwater Permits

Federal regulations require certain municipalities, generally those in urban areas with separate stormwater sewer systems, to obtain municipal stormwater permits. These permits require each municipality to develop a stormwater management plan that describes how the municipality will prevent stormwater pollution. Copies of the permits are available from your state environmental agency or EPA regional office. The stormwater management plans written to comply with the requirements in the permit typically include activities to educate the public about stormwater impacts, control stormwater runoff from new developments and construction sites, control stormwater runoff from municipal operations, and identify and eliminate illicit discharges. Contact your local municipality's environmental agency or public works department to find out whether it addresses stormwater runoff. You should also be able to obtain a copy of the municipality's current stormwater management plan to see what activities are planned. Additional information is available at **www.epa.gov/npdes/stormwater**.

5.7.2 Nonpoint Sources

Nonpoint source pollution, unlike pollution from industrial facilities and treatment plants, typically comes from many diffuse sources, not specific pipes or conveyances. Nonpoint source pollution is caused by rainfall or snowmelt moving over and through the ground, carrying natural and man-made pollutants and finally depositing them into surface waters. Surface water runoff represents a major nonpoint source in both urban and rural areas. Runoff from urban watersheds can deliver a variety of pollutants from roadways and grassed areas, and rural stormwater runoff can transport significant pollutant loads from cropland, pastures, and livestock operations. Natural background sources like wildlife or geology (e.g., soils high in iron) can also contribute loadings and might be particularly important in forested or less-developed areas of the watershed. Additional nonpoint sources include on-site wastewater systems (septic tanks, cesspools) that are poorly installed, faulty, improperly located, or in close proximity to a stream and illicit discharges of residential and industrial wastes. This section discusses some common nonpoint sources characterized in watershed plans.

Local USDA Extension Offices

Extension offices are a valuable source of information on local agricultural practices and can provide information on types and distribution of livestock, crops, and management practices. The national Cooperative Extension System works in six major areas:

- 4-H youth development
- Agriculture
- Leadership development
- Natural resources
- Family and consumer sciences
- Community and economic development

Although the number of local extension offices has declined over the years and some county offices have consolidated into regional extension centers, approximately 2,900 extension offices remain nationwide.

To find your local extension office, go to **www.csrees.usda.gov/Extension/index.html**.

Livestock Sources

In watersheds with extensive agricultural operations, livestock can be a significant source of nutrients and bacteria and can increase erosion. If available, site-specific information on livestock population, distribution, and management should be used to characterize the potential effects from livestock activities. Local USDA officials are typically the best source of livestock information. If local information is not available, you can use the Census of Agriculture to find information about the number and type of animal units per county. The census is conducted every 5 years; the most recent census was conducted in 2002. Data from the census are available online at **www.agcensus.usda.gov**, and data can be analyzed at the county level in a GIS. You should consult local USDA officials to determine whether conditions in the watershed are accurately reflected in the census. You should also obtain local information on additional agricultural sources, such as land application of manure.

Cropland Sources

Depending on crop type and management, croplands are a potentially significant source of nutrients, sediment, and pesticides to watershed streams. Cropland can experience increased erosion, delivering sediment loads and attached pollutants to receiving waterbodies. Fertilizer and pesticide application to crops increases the availability of these pollutants to be delivered to waterbodies through surface runoff, erosion (attached to sediment), and ground water. If cropland is an important source of pollutants in your watershed, it's useful to determine the distribution of cropland as well as the types of crops grown. Land use coverages for your watershed can identify the areas of cropland in your watershed. For more information on the types of crops and their management, contact local extension offices or conservation districts. The USDA Census of Agriculture can also provide information on crop types and fertilizer and chemical applications. However, census data are presented at the county level and might not reflect the cropland characteristics in your watershed. The USDA's Spatial Analysis

Research Section has developed a coverage of the distribution of crop types (e.g., soybeans, corn, potatoes, cotton) called the Cropland Data Layer (**www.nass.usda.gov/research/Cropland/SARS1a.htm**). Currently, the Cropland Data Layer is available for Arkansas, Illinois, Indiana, Iowa, Mississippi, Missouri Boot Heel, Nebraska, North Dakota, and Wisconsin. Some states have data available annually since 1997, and some have only recent (2003–2004) data available. In addition, NRCS offices in agricultural regions often take annual aerial photos to track crop usage.

Literature values for pollutant generation by crop type are often used in modeling and other loading analyses to estimate loads from cropland sources. NRI data also provide information on cropland characteristics by county and cataloging unit.

Urban Sources

Impervious coverage information is typically used to characterize the density of and potential loading from urban areas. Impervious coverages are developed from direct photointerpretation and delineation or estimated by relating imperviousness to land use and land cover. Because urban or developed areas have high percentages of impervious area, they typically experience greater magnitudes of stormwater runoff than do more rural areas. Runoff from developed areas can wash off and transport pollutants, and urban pollutant loads can be a significant source when the watershed is predominantly developed, with little or no agricultural area. In addition to the larger areas of impervious surfaces, urban areas typically have pollutant sources unique to the urban and residential environment (e.g., pet wastes, lawn fertilizers, pollutants from car maintenance) that are often difficult to identify. These sources are usually collectively represented by the term *stormwater runoff*. Literature values of urban accumulation or stormwater loading rates can be used to characterize the urban land uses in source analyses and model applications.

Onsite Wastewater Systems

Individual and clustered wastewater systems provide appropriate treatment if they are designed, installed, operated, and maintained correctly. Malfunctioning systems, however, can contribute significant nutrient and bacteria loads to receiving waterbodies, particularly those in close proximity (less than 500 ft). Local agencies can provide estimates of the total number of septic systems in a specific area or county. For example, the Panhandle Health District in Idaho has an online searchable database of septic system permits, geographically identified by Census block. Also, county-level population, demographic, and housing information, including septic tank use, can be retrieved from the U.S. Census Bureau (↳ **http://quickfacts.census.gov**).

To evaluate septic systems as a source of pollutants, however, you'll want to know the distribution of malfunctioning systems. In some cases, local health departments can provide information on septic systems (e.g., location, frequency, malfunction rates), but in many watersheds the specific incidence and locations of poorly performing systems are unknown. Literature values and local or county statistical information can be used to estimate the number of failing septic systems in a watershed. ↳ For example, the National Small Flows Clearinghouse (NSFC 1993) surveyed approximately 3,500 local and state public health agencies about the status of onsite systems across the country (NSFC 1993) and provides the number of reported failing septic systems in the United States by county.

Local Knowledge Goes a Long Way

Having a local understanding of your watershed and the activities that take place there is critical to accurately identifying and characterizing sources. If you need help identifying sources, the information in this section should guide you in the right direction, but it's also very important to involve local experts that can help you through the process. Without input from local agencies (e.g., conservation districts), you might miss important sources that are unique to your area.

(Go to **www.nesc.wvu.edu/nsfc/nsfc_index.htm**.) Using the county-specific estimates from NSFC (1993), the number of failing septic systems in a county can be extrapolated to the watershed level based on county and watershed land use distribution. The number of malfunctioning systems can also be estimated by applying an appropriate failure rate, from literature or from local sanitation personnel, to the total number of septic systems in a watershed.

Silviculture Sources

Silviculture can be a significant source of sediment and other pollutants to a waterbody. The primary silviculture activities that cause increased pollutant loads are road construction and use, timber harvesting, site preparation, prescribed burning, and chemical applications. Without adequate controls, forestry operations can cause instream sediment concentrations and accumulation to increase because of accelerated erosion. Silviculture activities can also cause elevated nutrient concentrations as the result of prescribed burns and an increase in organic matter on the ground or in the water. Organic and inorganic chemical concentrations can increase because of harvesting and fertilizer and pesticide applications. Harvesting can also lead to instream accumulation of organic debris, which can lead to dissolved oxygen depletion. Other waterbody impacts include increased temperature from the removal of riparian vegetation and increased streamflow due to increased overland flow, reduced evapotranspiration, and runoff channeling.

The BLM administers millions of acres of commercial forests and woodlands in the western United States. For a list of BLM state offices, visit **www.blm.gov/nhp/directory/index.htm**. Local BLM personnel can help you identify areas of silvicultural activity in your watershed.

Wildlife Sources

Although wildlife inputs typically represent natural background sources of pollutants, they can be an important source of bacteria or nutrients in forested or less-developed areas of a watershed. In addition, animals that inhabit area waters (e.g., waterfowl) represent a direct source to receiving waters. Although wildlife sources are often uncontrollable, it's important to consider their potential impact on water quality and their importance relative to other pollutant sources when characterizing your watershed. State or local wildlife agencies (e.g., Department of Fish and Game) or relevant federal agencies (e.g., Forest Service) can be contacted for estimates of wildlife populations in your area. Go to **http://offices.fws.gov/statelinks.html** for links to state and territorial fish and wildlife offices.

> **Airborne Deposition of Pollutants**
>
> Watersheds downwind from sources of air emissions containing nitrogen, phosphorus, ammonia, mercury, or other metals can receive significant loads of these pollutants under certain conditions. Airborne pollution can fall to the ground in raindrops, in dust or simply due to gravity. As the pollution falls, it may end up in streams, lakes, or estuaries and can affect the water quality there. For example, studies show that 21% of the nitrogen pollution entering Chesapeake Bay comes from the air. In addition, much of the mercury linked to fish tissue contamination comes from the combustion of fuels and other material containing mercury compounds, transported downwind and deposited in distant watersheds. Dealing with these sources will require long-term actions to identify source areas/categories and determine appropriate load reduction management strategies. More information on air deposition of pollutants—including isopleth maps showing general areas of high loadings—can be found at **www.epa.gov/owow/airdeposition/** and **http://nadp.sws.uiuc.edu/**.

5.8 Waterbody Monitoring Data

A number of federal, state, local, and private entities monitor waterbodies across the nation. These data might represent specialized data collected to answer a specific question about waterbody conditions, or the data might be collected regularly as part of a fixed network of long-term monitoring to assess trends in water quality. Monitoring data, including chemical, physical, and biological data, are critical to characterizing your watershed. Without such data, it is difficult to evaluate the condition of the waterbodies in your watershed. The waterbody data

Identify the Weakest Link

Just as a chain is only as strong as its weakest link, a watershed characterization is only as good as the data it is based on. It's important to understand the quality and quantity of your instream monitoring data when using the data for watershed planning and associated decisions. Common factors that can affect the usefulness of data include the following:

- **Data quality:** Data quality represents a variety of aspects of the data, including accuracy, precision, and representativeness. For more information on data quality, go to section 6.2.2.
- **Spatial coverage:** The number of locations with relevant data can determine the detail of your watershed analysis. Without instream data collected throughout the watershed, you can't evaluate the spatial differences in water quality conditions or identify areas of greater impairment.
- **Temporal coverage:** Without watershed data covering a long time period or a variety of environmental conditions, it's difficult to understand the typical instream conditions of your waterbody. Because most instream data consist of occasional (e.g., monthly) grab samples, monitoring data often represent only a snapshot of the waterbody at the moment of sampling.

Often, data are limited and you don't have the luxury of daily samples collected over a 10-year period. If the amount of data is insufficient to continue with watershed plan development, it might be necessary to initiate additional monitoring (see chapter 6). Otherwise, having limited data should not stop the watershed planning process; the process can continue with an understanding that the data might not fully represent or characterize waterbody conditions and that future monitoring should be used to update the plan as necessary.

gathered and evaluated for the watershed characterization typically include flow, water quality (e.g., chemical concentrations), toxicity, and biological data. Other specialized datasets might also be available for your waterbodies, such as physical stream assessments or ground water studies, but this section discusses the most common sources of waterbody data available to the public.

Much of the nation's hydrology, water quality, and biological data resides in national datasets accessible on the Internet. Many of the databases include several datasets and analysis tools. The following sections describe the major databases that contain waterbody monitoring data.

5.8.1 Water Quality and Flow Data

This section discusses a variety national databases containing water quality and flow monitoring data.

STORET

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. Currently, there are two versions of the STORET database. Legacy STORET contains historical data from the early 1900s through 1998, and new data are no longer input to the Legacy STORET database. Modernized STORET has data from 1999 to the present. New data are input into the Modernized STORET database as they become available. STORET data can be downloaded online from **www.epa.gov/STORET/index.html**.

STORET includes data for the following topics:

- Station descriptions
- Non-biological physical and chemical results ("regular results")
- Biological results
- Habitat results

Data can be queried through several search options, including geographic location, organization, and station ID. You can also browse STORET data using mapping tools available through STORET's main page.

National Listing of Fish Advisories
The NLFA database includes information describing state-, tribe-, and federally issued fish consumption advisories in the United States for the 50 states, the District of Columbia, and four U.S. territories. The information is provided to EPA by the states, tribes, and territories. The advisories recommend limiting or avoiding consumption of specific fish species or limiting or avoiding consumption of fish from specific waterbodies. The NLFA Web site lists 3,089 advisories in 48 states through the end of 2003. The Web site can generate national, regional, and state maps that summarize advisory information. Also included on the Web site are the name of each state contact, a phone number, a fax number, and an e-mail address. Go to **www.epa.gov/waterscience/fish/advisories**.

NWISWeb
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 are organized by several categories, such as surface water, ground water, real time, and flow. The data can be queried using information such as station name, location (latitude and longitude), or 8-digit HUC. Data can be downloaded online at **http://waterdata.usgs.gov/nwis**.

Beach Environmental Assessment, Communication, and Health Program Data
The BEACH Program appropriates funds to states for developing monitoring and notification programs that will provide a uniform system for protecting the users of marine waters. The BEACH Program can provide information on issues and concerns related to bacteria contamination at recreational beaches, provide monitoring data, and assist with educating the public regarding the risk of illness associated with increased levels of bacteria in recreational waters. If your watershed borders the coast or the Great Lakes, go to **www.epa.gov/beaches** for additional information.

Volunteer Monitoring Program Data
State, tribal, and local volunteer monitoring programs might also be good sources of water quality data. Many volunteer groups upload their data to STORET. Go to **www.epa.gov/owow/monitoring/volunteer** for more information.

WATERS
The WATERS information system uses EPA's standard mapping application to display water quality information about local waters. WATERS combines information about water quality goals from EPA's Water Quality Standards Database with information about impaired waters from EPA's TMDL database. Go to **www.epa.gov/waters**.

National Sediment Inventory
EPA completed the National Sediment Inventory (NSI) in response to the Water Resources Development Act of 1992 (WRDA), which directed EPA, in consultation with NOAA and the U.S. Army Corps of Engineers, to conduct a comprehensive program to assess the quality of aquatic sediments in the United States. EPA also submits to Congress a report on the findings of that program. The report identifies areas in the United States where the sediment might

be contaminated at potentially harmful levels. The report also assesses changes in sediment contamination over time for areas in the United States with sufficient data. The first National Sediment Quality Survey report was released in 1997, and it was updated in 2004. Before releasing the update, EPA released the National Sediment Quality Survey Database, which has compiled information from 1980 to 1999 from more than 4.6 million analytical observations and 50,000 stations throughout the United States. The database contains information on

- Sediment chemistry, a measure of the chemical concentration of sediment-associated contaminants
- Tissue residue, a measure of chemical contaminants in the tissue of organisms
- Toxicity, a measure of the lethal and sublethal effects of contaminants in environmental media on various test organisms

Go to **www.epa.gov/ost/cs/report/2004/index.htm** for more information on the NSI report. Go to **www.epa.gov/waterscience/cs/nsidbase.html** to download the associated sediment quality data.

5.8.2 Biological Data

Aquatic life (e.g., fish, insects, plants) are affected by all the environmental factors to which they are exposed over time and integrate the cumulative effects of pollution. Therefore, biological data provide information on disturbances and impacts that water chemistry measurements or toxicity tests might miss. This makes these data essential for determining not only the biological health but also the *overall* health of a waterbody.

Although there is no single source of biological data, many of the datasets already mentioned under the instream monitoring section include biological datasets. To learn more about the specific biological assessment programs of states and regions, visit EPA's Biological Indicators of Watershed Health Web site at **www.epa.gov/bioindicators/index.html**. This site provides links to state program Web sites, contacts, and relevant documents.

Biological community samples (fish, invertebrates, algae) are collected in the nation's streams and rivers as part of the USGS National Water-Quality Assessment (NAWQA) Program's ecological studies (**http://water.usgs.gov/nawqa**). Data for thousands of fish and invertebrate samples are available for retrieval online, and algal community and instream habitat data will be released in summer 2005. Go to **http://infotrek.er.usgs.gov/traverse/f?p=136:13:0::NO:::**.

5.8.3 Geomorphological Data

Rivers and streams change in direct response to climate and human activities in the watershed. Increasing impervious surfaces like pavement, clearing forests and other vegetation, compacting soils with heavy equipment, and removing bank vegetation typically result in an adjustment in the pattern, profile, or dimensions of a river or stream. Assessments of river and stream geomorphology can help determine (1) the prior or "undisturbed" morphology of the channel; (2) current channel conditions; and (3) how the stream is evolving to accommodate changes in flow volumes/timing/duration, channel alteration, and so forth. This information is also helpful in analyzing the movement of sediment downstream from upland sources and channel banks.

Geomorphological studies focus on characterizing the drainage area, stream patterns (single/multiple channels, sinuosity, meander width), the longitudinal profile (gradient), channel dimensions (e.g., width/depth ratio relative to bankfull stage cross section, entrenchment), bank and channel material, riparian vegetation, channel evolution trends, and other features. Because of the fairly recent development and application of analytical tools to assess and classify rivers and streams and explore the relationships among variables affecting their physical conditions, geomorphological data are not available for many river systems. Guidance on conducting geomorphological assessments is available from the Federal Interagency Stream Corridor Restoration Working Group (**www.nrcs.usda.gov/technical/stream_restoration**), Wildland Hydrology (**www.wildlandhydrology.com**), and some state water resource and fish/wildlife agencies.

5.9 Selected Tools Used to Gather, Organize, and View Assessment Information

Although you can use various tools to help visually organize data, two of the most popular tools are GIS and remote sensing techniques, which help to collect and display land use data.

5.9.1 Geographic Information Systems

A GIS is a tool used to support data analysis by creating watershed maps and displaying a variety of spatial information that is helpful for characterizing a watershed; gaining insight into the local environmental, cultural, and political settings; and identifying potential pollutant sources. For example, application of fertilizer on cropland might be a source of nutrients to watershed streams, and GIS data can help in identifying the locations of cropland throughout the watershed and the proximity of cropland to affected streams. Using water quality data analysis in conjunction with GIS evaluations can provide a basis for evaluating water quality trends throughout the watershed. GIS provides the flexibility of evaluating data in different ways and combinations. Users can display only the data useful to their needs and can easily display a combination of spatial coverages. In addition, users can easily create their own watershed coverages to display specific information (e.g., average pollutant concentrations at different waterbody sites).

Check State and Local GIS Data Sources

This section provides several examples of GIS data sources, primarily national, but additional state, local, or regional sources might exist and should be investigated. Several states maintain online databases of GIS data for the state; for example, California Spatial Information Library (**http://gis.ca.gov**), West Virginia Department of Environmental Protection Internet Mapping (**http://gis.wvdep.org**).

See table 5-2 for more information on locating state and local GIS data.

GIS also allows users to combine and display spatial data from a variety of sources. A wide range of sources for accessing and obtaining GIS data are available. The Internet provides a convenient source for much of the GIS data available from federal, state, and local agencies, as well as GIS organizations and companies. Browsing the Web sites of state and local environmental agencies or contacting the agencies directly can often lead to GIS sites and databases. Table 5-2 provides a selected list of several online GIS data sources.

A GIS is very useful and allows for easy display and evaluation of a variety of watershed characteristics (e.g., soils, land use, streams). However, several aspects of GIS and related data can “trip up” GIS novices. This section discusses several topics that you should keep in mind when using GIS and gathering and evaluating GIS data.

Table 5-2. Sources of GIS Data Available on the Internet

GIS Distribution Source Description and Web Site
Federal Agencies and Consortiums
National Geospatial Data Clearinghouse. Sponsored by the Federal Geographic Data Committee (FGDC), the Clearinghouse offers a collection of more than 250 spatial data servers that can be searched through a single interface based on their descriptions or metadata. **www.fgdc.gov/dataandservices**
EPA's BASINS. BASINS is a multipurpose environmental analysis system that integrates a GIS, national watershed data, and environmental assessment and modeling tools. The BASINS GIS data include more than 35 standard coverages, including physical data (e.g., waterbodies, elevation, land use, soils), administrative and political data (e.g., jurisdictional boundaries), landmarks and features (e.g., roads, dams, cities), and other monitoring or environmental information (e.g., gauge sites, monitoring sites, point source facility locations, mine locations, Superfund sites). **www.epa.gov/OST/BASINS/b3webdwn.htm**
USGS's Earth Resources Observation Systems (EROS) Data Center. EROS Data Center is a data management, systems development, and research field center for the USGS National Mapping Division. The EROS Web site contains aerial, topographic, elevation, satellite, and land cover data and information. **http://edc.usgs.gov**
U.S. Census Bureau Topologically Integrated Geographic Encoding and Referencing (TIGER) System. The Census Bureau developed the TIGER system and digital database to support its mapping needs for the Decennial Census and other Bureau programs. **www.esri.com/data/download/census2000_tigerline/index.html** or **www.census.gov/geo/www/tiger**
Bureau of Land Management Geospatial Data Clearinghouse. BLM established the GeoSpatial Data Clearinghouse as part of the FGDC Geospatial Data Clearinghouse Network. BLM data can be searched through the FGDC Web site or the BLM clearinghouse Web site. The BLM Geospatial Data Clearinghouse contains only geospatial data held by the BLM, and it can be searched by state or by keyword (e.g., geology, minerals, vegetation, fire). **www.blm.gov/nstc/gis/GISsites.html** or **www.or.blm.gov/metaweb**
U.S. Department of the Interior, National Atlas of the United States, Map Layers Warehouse. The Atlas is a largely digital update of a large, bound collection of paper maps that was published in 1970. It provides high-quality, small-scale maps, as well as authoritative national geospatial and geostatistical datasets. Examples of digital geospatial data are soils, county boundaries, volcanoes, and watersheds; examples of geostatistical data are crime patterns, population distribution, and incidence of disease. **http://nationalatlas.gov/atlasftp.html**
Watershed Characterization System. WCS is an ArcView-based program that uses spatial and tabular data collected by EPA, USGS, USDA-NRCS, the Census Bureau, and NOAA. The tool can quickly characterize land use, soils, and climate for watersheds in the EPA Region 4 states. **www.epa.gov/athens/wwqtsc/html/wcs.html**
EnviroMapper for Water. EnviroMapper for Water provides a Web-based mapping connection to a wealth of water data. It can be used to view and map data such as the designated uses assigned to local waters by state agencies, waters that are impaired and do not support their assigned uses, beach closures, and location of dischargers. Water quality data include STORET data, National Estuary Program (NEP) study areas, and locations of nonpoint source projects. **www.epa.gov/waters/enviromapper**
State Sources
State GIS Clearinghouse Directory. The Directory provides a list of state GIS agencies, groups, and clearinghouses. **www.gisuser.com/content/view/2379**
GIS Organizations or Companies
ESRI. ESRI is a software, research and development, and consulting company dedicated to GIS. Its software includes ArcInfo, ArcGIS, and ArcView. **www.esri.com/data/download/index.html**
Geography Network. This global network of GIS users and providers supports the sharing of geographic information among data providers, service providers, and users around the world. www.geographynetwork.com, provided through **www.esri.com**
GIS Data Depot. GIS Data Depot is an online resource for GIS and geospatial data from The GeoCommunity, a GIS online portal and daily publication for GIS, CAD, mapping, and location-based industry professionals, enthusiasts, and students. **http://data.geocomm.com**
University of Arkansas Libraries and the Center for Advanced Spatial Technologies (CAST). Starting the Hunt: Guide to Mostly On-Line and Mostly Free U.S. Geospatial and Attribute Data, written by Stephan Pollard and sponsored by the University of Arkansas Libraries and CAST, provides a compilation of links to online GIS data, categorized into two broad classifications—State and Local Aggregations and National Aggregations. **www.cast.uark.edu** or **http://libinfo.uark.edu/GIS/us.asp** (direct link to data lists)

When You Can't Do It Yourself

Although the advent of GIS has made many aspects of watershed planning much easier, using GIS effectively requires a certain level of knowledge and practical experience. Sometimes it's not feasible for watershed planners to use GIS extensively, perhaps because they don't have the expertise or the required software. If this is the case, you can use a variety of online mapping applications to gain an understanding of the watershed and its characteristics and pollutant sources without doing the GIS work yourself. Many state, local, and university GIS programs or offices have online interactive mapping applications to display or query their GIS data. For example, the California Digital Conservation Atlas (**http://gis.ca.gov/ims.epl**) is an interactive map with coverages for a wide variety of natural resources-related information, including waterbodies, watershed boundaries, environmental hazards, available plans, and land use and cover. Another example is the Pennsylvania Department of Environmental Protection's eMapPA (**www.emappa.dep.state.pa.us/emappa/viewer.htm**), which is a mapping application that displays state permit information along with various statewide data layers. The mapping application displays information on general watershed features (e.g., streams, floodplains, roads) and a variety of permitted facilities (e.g., wastewater treatment plants, landfills, mines). Although you won't be able to customize the GIS data or add your own coverages (e.g., average nitrate concentrations at monitoring stations), these types of interactive maps allow you to view and evaluate general watershed GIS data without having to gather, store, and manipulate them.

Projections

The spatial representation of data in a GIS is tied to a mapping plane, and all data have an associated projection. Map projections are the means of representing a spherical Earth on a flat mapping plane, and the process of data projection transforms three-dimensional space into a two-dimensional map. Different map projections retain or distort shape, area, distance, and direction.

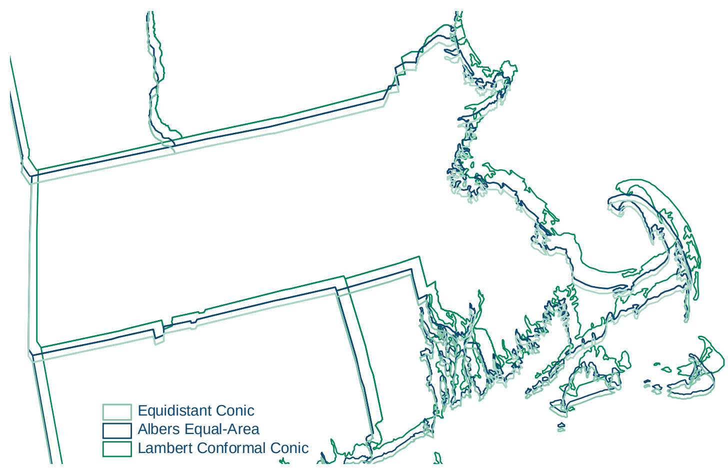


Figure 5-3. Example Map Projections

It is not possible for any one projection to retain more than one of these features over a large area of the earth. Because different projections result in different representations of the shape, area, distance, and direction of mapped objects, GIS data for the same watershed in different projections will not overlap correctly. As an example, figure 5-3 presents a map of Massachusetts in three different projections. Although centered around the same latitude and longitude, these representations obviously do not spatially represent the state in the same way.

Much of the GIS data available through the Internet is provided in decimal degrees—unprojected latitude and longitude. However, GIS data can be projected, and different sources of GIS data use different projections. As an example, EPA's BASINS and U.S. Census Bureau TIGER data are provided in decimal degrees, but many state GIS Web sites provide their GIS data in projections specific to the state (e.g., state plane) or its location in the country (e.g., Universal Transverse Mercator [UTM] zones). When gathering GIS data from a variety of sources, it's important to gather information on the different projections as well so that data can be "re-projected" into a common projection. Projection information is included in the GIS data's metadata (under "Spatial Reference Information").

Don't Forget the Metadata

When gathering GIS data, it's very important to obtain and review the associated metadata. Metadata are "data about data" and include the information needed to use the data properly. Metadata represent a set of characteristics about the data that are normally not contained within the data itself, such as

- Description of the data (e.g., creator, contact, distribution information, citation information)
- Information on how and when the data were created
- Spatial reference information (data projection)
- Definitions of the names and data items

Understanding the content and structure of the data is especially important when compiling and comparing data from various sources or agencies.

Scale

The map scale of GIS data specifies the amount of reduction between the real world and its graphic representation, usually expressed as a ratio of the unit of measure on the map to the same units on the ground (e.g., 1:20,000). Map scale determines how much area is included on paper maps; however, because the capabilities of GIS allow you to zoom in and zoom out to customize your map display, map scale does not determine the extent of the mapped information in a GIS. Scale, however, does affect what is included in the GIS data. The smaller a map's scale (the more ground area it covers on a paper map), the more generalized the map features. A road or stream that is sinuous on the ground might be represented by a fairly straight line in data with a small scale, and some features might not even be included in small-scale data. The scale of your GIS data is an important aspect to keep in mind when combining datasets for evaluating your watershed. The scale of your information influences the spatial detail of your analysis. For example, if you want to evaluate road crossings for streams in your watershed and you use data at a small scale, the data will likely not include many of the small roads and streams. Figure 5-4 presents maps of streams and roads obtained from datasets of different scales. Obviously, the smaller-scale dataset (1:500,000) has much coarser detail, while the larger-scale dataset provides a higher level of detail.

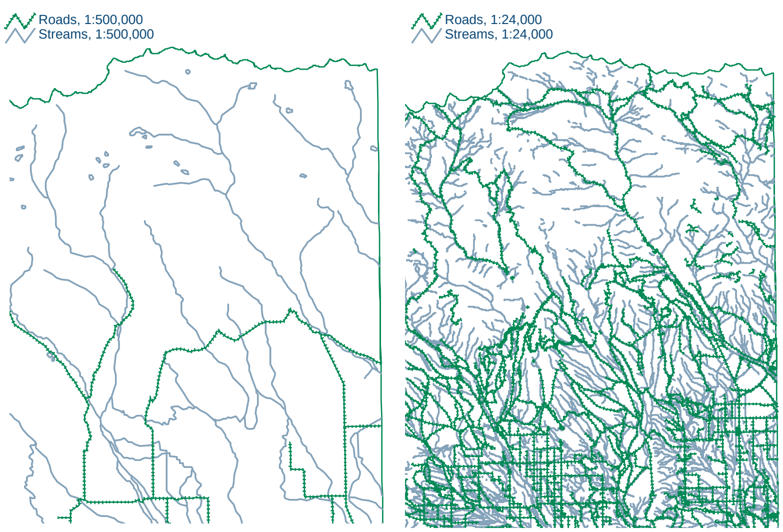


Figure 5-4. Example of GIS Datasets at Different Scales

Time Frame

It's very important to consider the date of the GIS data you are evaluating, especially when combining datasets. Because of the time and effort it takes to create GIS data, often there are not many versions (dates) of the same coverage available and you are limited to what is available. Sometimes, however, there are different sources of the same kinds of data from different periods. For example, USGS has a variety of land use datasets based on satellite images taken during different time frames. The LULC data are based on images taken during the 1970s and 1980s, while the NLCD data are based on images from the early 1990s and 2000. It is important to obtain the data that are most representative of the time period you want to evaluate. If you want to compare land use and water quality data, try to obtain land use data from the time your monitoring was conducted. For example, compare historical data collected in the 1970s with the LULC data and compare more recent monitoring data with the NLCD data from the 1990s.

If GIS data are significantly out-of-date, it might be necessary to ground-truth them to avoid undermining your analysis. For example, if the land use data represent watershed land uses 20 years ago, you might under- or overestimate certain types of sources when evaluating current loading conditions. If you have a small watershed and land ownership has not changed significantly (parcels are still comparable to historical land use divisions or aerial photos), you might be able to drive through your watershed and note any major land use changes.

Another factor to keep in mind is the date of creation versus the date of the original data on which the GIS coverage is based. For example, the NLCD 2001 data are still being developed; therefore, many datasets will be dated 2005 even though they are based on satellite images from 2001. Be sure to review the metadata to determine the dates of all of your GIS coverages.

The Importance of Training

Several nuances are associated with displaying, manipulating, and controlling GIS data. It is recommended that you have some training before you undertake significant GIS evaluations.

The availability and type of GIS training are highly specific to your location and needs. To find out more about GIS training and educational resources, visit **www.gis.com/education/index.html** or conduct an Internet search to research training opportunities in your area.

Organization, Storage, and Manipulation of Files

GIS data can come in a variety of formats and typically have several associated files needed to view and understand their content. For example, a standard shapefile includes the files (the main file [*.shp] and the index file [*.shx]) that control the display of the shapes and the file (dBASE file [*.dbf]) that contains feature attributes (e.g., area, name) for each shape in the file. Grid data require even more files to display. When dealing with data in different projections, it is necessary to "re-project" the data into a common projection, creating even more data files. In addition, GIS data that cover large areas or include highly detailed information (e.g., parcel-based land use) can have very large files. Because of the number and size of files, the organization of GIS files can become cumbersome and require considerable disk space on your computer. It is often helpful to organize data according to watershed topics (e.g., hydrology, land use, soils, stations) or by the source of the data (e.g., TIGER, EPA BASINS).

In addition, GIS data can be manipulated very easily to evaluate certain areas or certain data types, but doing so can lead to a number of extraneous files, as well as unintended changes to your original data files. You can delete or add records to GIS data files, but it's important to remember that when you do this, you are changing the original data files. If you want to isolate areas (e.g., subwatersheds) or records (e.g., certain monitoring stations), it is necessary to clip existing coverages to create new coverages.

Several other issues related to organizing, storing, and using GIS files can aggravate the new user; therefore, it's useful to rely on members of your watershed group that have experience in using GIS or contacts that can provide guidance to beginners.

5.9.2 Remote Sensing Techniques to Collect Land Use/Land Cover Information

Remote sensing refers to the collection of data and information about the physical world by detecting and measuring radiation, particles, and fields associated with objects located beyond the immediate vicinity of the sensor device(s). For example, photographs collected by an aircraft flying over an area of interest (e.g., aerial photography) represent a common form of remote sensing information. Satellites that orbit the earth are often used to collect similar images over larger areas, and these images are another example of remote sensing information. Remote sensing information is collected, transmitted, and processed as digital data that require sophisticated software and analysis tools. An excellent and wide-ranging review of remote sensing can be found at **http://rst.gsfc.nasa.gov/Homepage/Homepage.html**.

Using Land Use Data to Evaluate and Manage Stormwater in Anchorage

The Municipality of Anchorage (MOA), Alaska, created a complete land cover classification to provide the foundation for mapping inland areas according to their common surface hydrologic and gross pollutant generation potential. The "Storm Water Runoff" grid was derived in summer 2000 through analysis of IKONOS satellite imagery and other geographic datasets (especially land use, streets, drainage, coastland, and wetlands data). The GIS-based dataset was built to provide information for stormwater management applications.

The land cover data include five major classes—Impervious, Barren Pervious, Vegetated Pervious, Snow and Ice, and Water. These classes are further subdivided to reflect changes in perviousness due to different land development applications. For example, impervious surfaces are classified as street surface, directly connected impervious, and indirectly connected impervious, and vegetation classes are classified as landscaped or forested. Values for hydraulic connectedness (direct or indirect connection) are attributed to each mapped land parcel independently of the assessment of the pervious quality.

MOA uses the GIS coverage to support development and application of the Stormwater Management Model (SWMM) for stormwater management within the municipality. SWMM, based on MOA's land use coverage, also was modified and applied in the Chester Creek watershed to develop draft TMDLs for bacteria in the creek and two watershed lakes.

Remote sensing data products, especially land cover and elevation, provide fundamental geospatial data for watershed characterization. Remote sensing is a powerful tool for watershed characterization because the data are digital and therefore you can use the information analytically, especially in a GIS system. You can integrate remote sensing data with other types of data, such as digital elevation data, the stream network (e.g., NHD), and so forth. You can then use GIS to classify landscape and ecological attributes at detailed levels within a watershed. An example is identifying steeply forested lands and riparian buffers.

This section includes remote sensing principles and highlights some of the most readily available and useful datasets. The highlighted datasets have undergone extensive quality control, are low-cost or free, and can be used in a basic GIS platform, especially ArcView. Their use in ArcView includes being able to perform basic analytical functions, such as calculating land cover distribution statistics in watersheds, as well as integration with other data such as Census data.

Types of Remote Sensing

Remotely sensed data can be broadly placed into two basic categories: (1) aerial imagery, which includes images and data collected from an aircraft and involves placing a sensor or camera on a fixed-wing or rotary aircraft, and (2) space-based imagery, which includes images and data collected from space-borne satellites that orbit the earth continuously. Although air-based and space-based remote sensing involve the same general principles, there are important technical differences in the acquisition and application of imagery from these sources.

Aerial Imagery

Aerial images are collected using sensors placed onboard the aircraft. For example, a photographic sensor can be placed on the underside of an aircraft and used to collect color photos over an area of interest. In contrast, a much more sophisticated sensor, such as AVIRIS (Airborne Visible/Infrared Imaging Spectrometer), can be placed onboard an aircraft to collect hyperspectral data and thereby acquire much more than simple color photographic images. A simple photographic sensor collects standard color imagery that is composed of the red, blue, and green spectral regions of the visible light spectrum (e.g., what the human eye can detect). In contrast, AVIRIS collects 224 contiguous spectral channels (bands) with wavelengths from 400 to 2,500 nanometers, spanning both the visible and non-visible regions of the light spectra. Go to **http://aviris.jpl.nasa.gov** for more information about AVIRIS.

Most sensors used in remote sensing measure the radiance from the sun that is reflected by the earth's surface. Various land surface features absorb and reflect this radiance to varying degrees, which is what enables the recognition of various features on the ground. However, some sensors used in remote sensing emit a source of energy that is reflected from the surface of the earth or from the object toward which the energy is directed. Such sensors can be laser-based or radar-based (e.g., SAR, which is Synthetic Aperture Radar, detailed here: **www.sandia.gov/RADAR/sar.html**).

Light Detection and Ranging (LIDAR) uses the same principle as radar—using electromagnetic waves in the visible or near-visible spectrum to remotely investigate properties of a medium—and is used in topographic mapping. LIDAR technology is not dependent on atmospheric conditions like cloud cover, so it has several advantages over traditional photogrammetry for topographic mapping. LIDAR technology offers the opportunity to collect terrain data of steep slopes and shadowed areas (such as the Grand Canyon), and inaccessible areas (such as large mud flats and ocean jetties). These LIDAR applications are well suited for making digital elevation models (DEMs), creating topographic maps, and extracting automatic features. Applications are being established for forestry assessment of canopy attributes, and research continues for evaluating crown diameter, canopy closure, and forest biometrics. Go to **www.etl.noaa.gov/et2** for more information.

Hyperspectral vs. Multispectral Remote Sensing Information Products

Spectral sensors record data related to sunlight in the visible, near infrared, and shortwave infrared regions that strikes surfaces on the earth and is reflected back to the sensor. Multispectral sensors capture a few relatively broad spectral bands, whereas hyperspectral sensors capture hundreds of narrow spectral bands. Multispectral sensors are used on satellite systems like LANDSAT, and these systems provide the remote sensing information used to build the National Land Cover Data (NLCD).

Hyperspectral sensors are still at an experimental stage for use in orbiting satellites, so that virtually all the available hyperspectral data come from airborne sensors. Hyperspectral imagery provides data for a broad range of electromagnetic wavelengths with finer spectral resolutions than conventional multispectral systems. Substantial costs are associated with hyperspectral systems for collecting the raw imagery, processing large amounts of data, and ground-truthing the remote sensing information with conventional water quality or land cover data. After specific kinds of hyperspectral information have been regionalized to particular watershed areas, the costs can be substantially reduced. Hyperspectral data can be applied to develop enhanced gridded datasets for land covers. With suitable regional calibration, both hyperspectral and multispectral information can help to provide numeric estimates for such water quality parameters as chlorophyll a (or other measures of algal standing crop), turbidity, and nutrient levels for phosphorus or nitrogen.

Satellite Imagery

Like aircraft-based sensors, satellite sensors have unique operational limitations and characteristics that must be considered before using them as a remote sensing tool. These factors include the incidence of cloud cover, the frequency at which the satellite passes over a given spot, the ground resolution desired, and the amount of post-acquisition data processing required. Several kinds of imagery and data are collected from satellites. For example, commercial satellites like QuickBird, IKONOS, and SPOT typically acquire high-resolution imagery useful for basic mapping of land surfaces. In contrast, satellites like LANDSAT-5, LANDSAT-7 (currently off-line due to an irreparable malfunction), TERRA, AQUA, and Earth Observing-1 (EO-1) contain an array of on-board sensors that collect far more than simple photographic imagery. These spacecraft are designed to collect data for a broad scientific audience interested in a variety of disciplines—climatology, oceanography, geography, and forestry to name a few. Thus, the project objectives must be clearly defined before the acquisition of satellite-based data to ensure that the proper remote sensing data product is chosen. Satellite imagery is available from several different land-mapping satellites, including LANDSAT, IKONOS, and SPOT. However, acquiring new aerial photography and satellite imagery requires extensive knowledge of image processing, and the data can be expensive or cost-prohibitive for many projects.

Remote Sensing Datasets

The raw data from the satellite sensors are voluminous, and specialized knowledge and software are needed to process the data into meaningful information. The digital signals from the multiple sensors need to be combined and processed, for instance, to be converted into meaningful land cover classifications. Furthermore, the digital images need to be registered and projected into a coordinate system, such as a Lambert projection. This makes the use of the raw data expensive and time-consuming. Fortunately, you can access preprocessed "derived" products, such as land cover datasets, that are available for free or at low cost. ↳ The USGS maintains a Web site for "seamless" data products at **http://seamless.usgs.gov**. You can also purchase data for less than $100 per item from USGS's Earth Resources Observation and Science (EROS) data center (↳ **http://edc.usgs.gov**). In addition to the land use datasets mentioned in section 5.7.1, several other datasets might be useful as part of the watershed characterization process:

- Landsat data
- Elevation
- Greenness
- "Nighttime Lights"
- Coastal and Great Lakes Shorelines

Landsat Data

The Landsat Orthorectified data collection consists of a global set of high-quality, relatively cloud-free orthorectified TM and ETM+ imagery from Landsats 4-5 and 7. This dataset was selected and generated through NASA's Commercial Remote Sensing Program as part of a cooperative effort between NASA and the commercial remote sensing community to provide users with access to quality-screened, high-resolution satellite images with global coverage over the earth's land masses. The data collection was compiled through a NASA contract with Earth Satellite Corporation (Rockville, Maryland) in association with NASA's Scientific Data Purchase program.

Specifically, the Landsat Orthorectified data collection consists of approximately 7,461 TM (Landsat 4-5) images and approximately 8,500 ETM+ (Landsat 7) images, which were selected to provide two full sets of global coverage over an approximate 10-year interval (circa 1990 and circa 2000). All selected images were cloud-free or contained minimal cloud cover. In addition, only images with a high-quality ranking with respect to the possible presence of errors such as missing scans or saturated bands were selected.

In addition to the NLCD datasets, the basic Landsat data can be obtained from the USGS EROS Data Center. Unlike the NLCD, the Landsat spectral data need to be processed before they can produce meaningful information such as land cover characteristics. The advantages of using the Landsat data include a wider temporal range, covering the 1990s to essentially current conditions. In addition, trained users can produce customized classification schemes that might be more meaningful at the local scale. For instance, BMP analyses might require cropping types to be broken down into finer classes than the standard NLCD classes. Landsat data combined with local ground-truthing can produce such custom land cover breakouts. The Landsat Orthorectified datasets have been preprocessed so that the images are cloud-free, joined images that are georeferenced.

Extra steps are required for using the Landsat data, including special software and training in interpreting the multispectral images. ↳ A good place for users to start is the Purdue Multispec system, which is available for free at **http://dynamo.ecn.purdue.edu/~biehl/MultiSpec**. This site also contains links to several training and user guides.

Elevation

The USGS National Elevation Dataset (NED), ↳ **http://ned.usgs.gov**, has been developed by merging the highest-resolution, best-quality elevation data available across the United States into a seamless raster format. The NED provides a tool for the precise delineation of small watershed units, which can then be overlain with other vector or gridded GIS data. For instance, custom watershed polygons can be delineated using vector data from the NHD.

In addition to the NED, the Elevation Derivatives for National Applications (EDNA) datasets can be used for watershed analyses. EDNA is a multilayered database that has been derived from a version the NED and hydrologically conditioned for improved hydrologic flow representation.

The seamless EDNA database provides 30-meter-resolution raster and vector data layers, including

- Aspect
- Contours
- Filled DEM
- Flow accumulation
- Flow direction
- Reach catchment seedpoints
- Reach catchments
- Shaded relief
- Sinks
- Slope
- Synthetic streamlines

↳ EDNA data are available at **http://edna.usgs.gov**.

Greenness Maps

Greenness maps show the health and vigor of the vegetation. Generally, healthy vegetation is considered an indicator of favorable climatic and environmental conditions, whereas vegetation in poor condition is indicative of droughts and diminished productivity. You can use USGS greenness maps to evaluate the vegetation condition of a region. The availability of current and past greenness data can be quite useful in, for instance, correlating the health of vegetation in a watershed with ambient monitoring data.

The greenness maps are representations of the Normalized Difference Vegetation Index (NDVI). NDVI is computed daily from two spectral channels. The two channels are reflected sunlight in the red (RED) and near-infrared (NIR) regions of the electromagnetic spectrum. NDVI, which is the difference between near-infrared and red reflectance divided by the sum of near-infrared and red reflectance, is computed for each image pixel as follows:

$$NDVI = (NIR - RED) / (NIR + RED)$$

Greenness maps reflecting current conditions can be obtained for free from the USGS seamless data Web site (**http://seamless.usgs.gov**). In addition, historical greenness data can be purchased from the EROS data center for $55 per scene. Go to **http://edcwww.cr.usgs.gov/greenness**. A scene is quite large, covering about half the country.

"Nighttime Lights"

One problem with the NLCD is difficulties in distinguishing vegetated areas such as suburbs from, for instance, woodlands. *The Nighttime Lights of North America* map layer is an image showing lights from cities, towns, industrial sites, gas flares, and temporary events, such as fires. Most of the detected features are lights from cities and towns. This image can be quite effective in delineating urban-rural boundaries. The data can be accessed at **http://nationalatlas.gov/mld/nitelti.html**.

Remote Sensing Data for Coastal and Great Lakes Shorelines

Coastal area elevation data can be especially challenging because of the low relief. Fortunately, the NOAA Coastal Services Center (CSC) provides additional remote sensing products for coastal and Great Lakes shoreline areas. These data include more detailed elevation data using LIDAR plus specialized hyperspectral-derived imaging datasets. The CSC LIDAR and other datasets can be accessed at **www.csc.noaa.gov/crs**.

Table 5-3 provides a summary of sample costs for purchasing remote sensing products.

Table 5-3. Sample Costs for Purchasing Remote Sensing Products

Remote Sensing Product	Resolution	Cost
NLCD	30 m	Free
NED	30 m	Free
Greenness	1 km	Free; $55/scene for historical data
"Nighttime Lights"		Free
EDNA	30 m	Free
LIDAR	Varies	Free for selected coastal and Great Lakes shorelines
Landsat	14.25 m to 28.5 m	$30/scene to $60/scene
SPOT	Varies; maximum resolution is 2.5 m	$1,000 +
IKONOS	Varies; maximum resolution is 1 m	Varies

5.10 Create a Data Inventory

Once you've gathered current datasets and existing studies, you should document the available relevant data in a data inventory. A comprehensive data inventory provides an ongoing list of available monitoring and watershed data. The data inventory should be updated during the course of the watershed planning effort so that a complete summary is available to stakeholders.

It is often useful to organize the data inventory by data type, allowing you to document the different types with information that might not be relevant to all types. The most likely types of data to be gathered are tabular data (e.g., monitoring data), reports and anecdotal information, and GIS data. For each of the datasets, you should document the important characteristics to identify and summarize the data. It is often useful to create the lists in a spreadsheet, such as Microsoft Excel, or a database, such as Microsoft Access. Spreadsheets are easy to use, but you can't search or query the data as you can in a database. Creating the data inventory in a spreadsheet, or even in a word processing program (e.g., Microsoft Word), is adequate. However, if you have a large amount of data and would like to be able to query the data, for example, by keyword or content type, you should use a database program for the inventory. The following paragraphs identify the types of information that should be used to document and organize the gathered data. These lists provide guidelines to help you create your data inventory, but you can also tailor your data inventory according to your needs and the types of data and information you gather. You should also document data not used in the analysis and justify their exclusion.

Information to Be Summarized in the Data Inventory

- Type of data (e.g., monitored, geographic)
- Source of data (agency)
- Quality of data (QA/QC documentation, QAPP)
- Representativeness of data (number of samples)
- Spatial coverage (location of data collection)
- Temporal coverage (period of record)
- Data gaps

For all the tabular datasets, you should create a list documenting the following information:

- Type (e.g., water quality, flow)
- Source/agency
- Number of stations
- Start date
- End date
- Number of samples/observations
- Parameters
- Frequency
- Known quality assurance issues related to the data
- Special comments (e.g., part of special study, ground water vs. surface water)

Once you begin to analyze your monitoring/tabular data (chapter 7), you'll identify more details about each dataset, including the type and amount of data at each station. For the data inventory, it's appropriate to document the general types and coverage of the datasets to provide an evolving list of the monitoring datasets available, where they came from, and what they include.

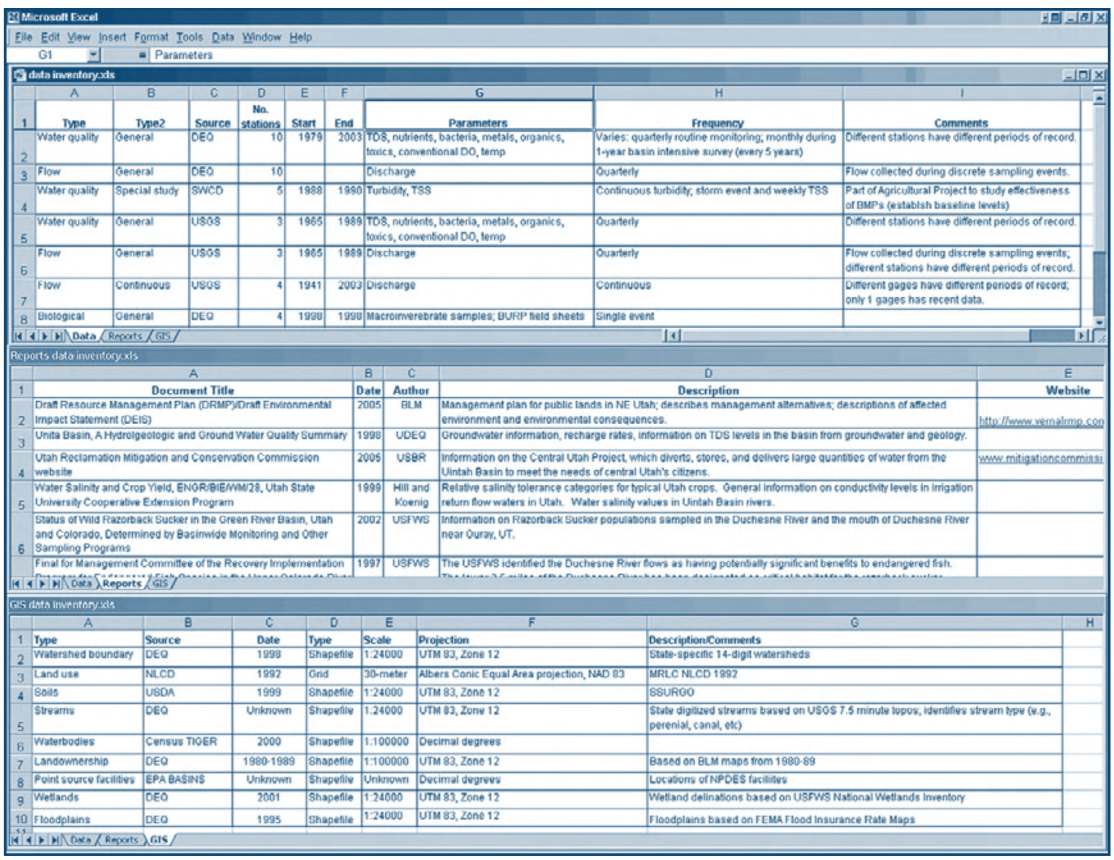
For all the reports and anecdotal information gathered for the watershed, you should include the following information in the data inventory:

- Document title
- Date
- Source/Author
- Description
- Web site (if available)

For the GIS data gathered, you should document the following information:

- Type (e.g., land use, soils, station locations)
- Source/agency
- Date (date or original data on which the coverage is based)
- Scale (e.g., 1:24,000)
- Projection (e.g., UTM, state plane)
- Description

Figure 5-5 provides an example of the fields in a data inventory.



Type	Type2	Source	No. stations	Start	End	Parameters	Frequency	Comments
Water quality	General	DEQ	10	1979	2003	TDS, nutrients, bacteria, metals, organics, toxics, conventional DO, temp	Varies: quarterly routine monitoring; monthly during 1-year basin intensive survey (every 5 years)	Different stations have different periods of record.
Flow	General	DEQ	10			Discharge	Quarterly	Flow collected during discrete sampling events.
Water quality	Special study	SWCD	5	1988	1990	Turbidity, TSS	Continuous turbidity; storm event and weekly TSS	Part of Agricultural Project to study effectiveness of BMPs (establish baseline levels)
Water quality	General	USGS	3	1965	1989	TDS, nutrients, bacteria, metals, organics, toxics, conventional DO, temp	Quarterly	Different stations have different periods of record.
Flow	General	USGS	3	1965	1989	Discharge	Quarterly	Flow collected during discrete sampling events; different stations have different periods of record.
Flow	Continuous	USGS	4	1941	2003	Discharge	Continuous	Different gages have different periods of record; only 1 gages has recent data.
Biological	General	DEQ	4	1998	1998	Macroinverebrate samples; BURP field sheets	Single event	

Document Title	Date	Author	Description	Website
Draft Resource Management Plan (DRMP)/Draft Environmental Impact Statement (DEIS)	2005	BLM	Management plan for public lands in NE Utah; describes management alternatives; descriptions of affected environment and environmental consequences.	http://www.vernalrmp.con
Unita Basin, A Hydrolgeologic and Ground Water Quality Summary	1998	UDEQ	Groundwater information, recharge rates, information on TDS levels in the basin from groundwater and geology.	
Utah Reclamation Mitigation and Conservation Commission website	2005	USBR	Information on the Central Utah Project, which diverts, stores, and delivers large quantities of water from the Uintah Basin to meet the needs of central Utah's citizens.	www.mitigationcommissi
Water Salinity and Crop Yield, ENGR/BIE/WM/28, Utah State University Cooperative Extension Program	1999	Hill and Koenig	Relative salinity tolerance categories for typical Utah crops. General information on conductivity levels in irrigation return flow waters in Utah. Water salinity values in Uintah Basin rivers.	
Status of Wild Razorback Sucker in the Green River Basin, Utah and Colorado, Determined by Basinwide Monitoring and Other Sampling Programs	2002	USFWS	Information on Razorback Sucker populations sampled in the Duchesne River and the mouth of Duchesne River near Ouray, UT.	
Final for Management Committee of the Recovery Implementation	1997	USFWS	The USFWS identified the Duchesne River flows as having potentially significant benefits to endangered fish.	

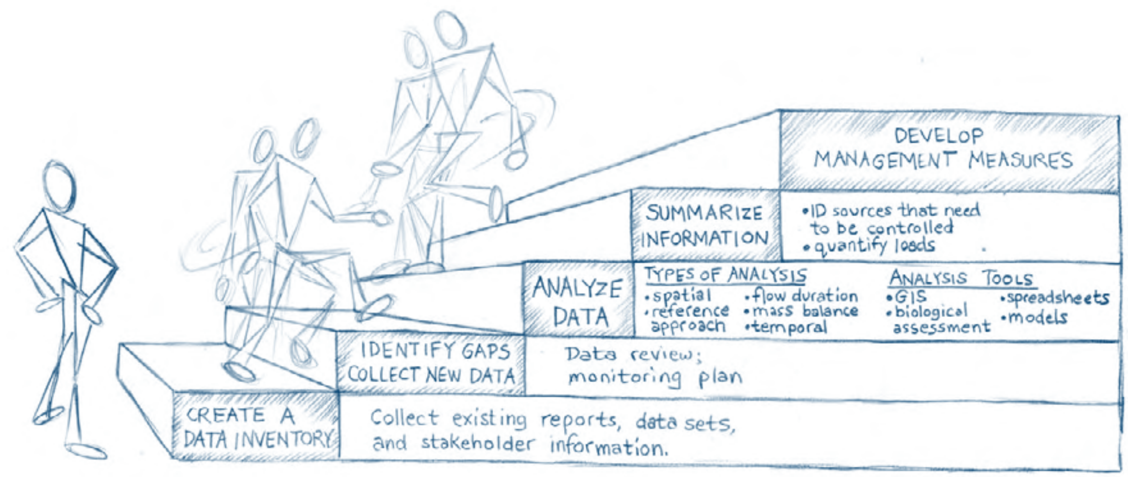
Type	Source	Date	Type	Scale	Projection	Description/Comments
Watershed boundary	DEQ	1998	Shapefile	1:24000	UTM 83, Zone 12	State-specific 14-digit watersheds
Land use	NLCD	1992	Grid	30-meter	Albers Conic Equal Area projection, NAD 83	MRLC NLCD 1992
Soils	USDA	1999	Shapefile	1:24000	UTM 83, Zone 12	SSURGO
Streams	DEQ	Unknown	Shapefile	1:24000	UTM 83, Zone 12	State digitized streams based on USGS 7.5 minute topos; identifies stream type (e.g., perenial, canal, etc)
Waterbodies	Census TIGER	2000	Shapefile	1:100000	Decimal degrees	
Landownership	DEQ	1980-1989	Shapefile	1:100000	UTM 83, Zone 12	Based on BLM maps from 1980-89
Point source facilities	EPA BASINS	Unknown	Shapefile	Unknown	Decimal degrees	Locations of NPDES facilities
Wetlands	DEQ	2001	Shapefile	1:24000	UTM 83, Zone 12	Wetland delinations based on USFWS National Wetlands Inventory
Floodplains	DEQ	1995	Shapefile	1:24000	UTM 83, Zone 12	Floodplains based on FEMA Flood Insurance Rate Maps

Figure 5-5. Example Fields in a Data Inventory

For all the data types, it's also useful to document the physical location of the files. For example, if the dataset is electronic, provide the name of the file and the file path or location on your computer or network. Another option is to provide a numbering system for the filing cabinets or location of the hard copy reports you gather.

The data inventory will also be used to help identify any relevant gaps, especially those that could hinder data analysis. The data inventory can be used to identify obvious, broad gaps, such as a lack of water quality or flow data for the watershed. The identification of data gaps is an iterative process, however, and more specific data needs will be identified during the next phase of the characterization process (chapter 6). For example, a long period of record of water quality monitoring data might indicate sufficient water quality data for analysis of the waterbody. When you begin data analysis, however, it might become apparent that the data are not adequate for evaluating seasonal trends or other relationships and patterns.

The characterization process involves many steps. Once you've created the data inventory, you'll move on to the next phase in characterization: identify gaps and collect new data. As you review the data, however, you might realize that you need to gather additional existing information. You'll have to go back, add additional information to your data inventory, and then proceed forward.



6. Identify Data Gaps and Collect Additional Data If Needed

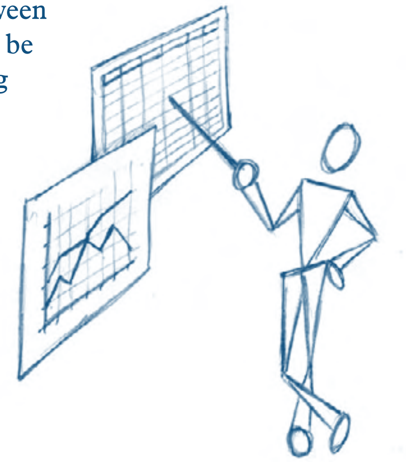
Chapter Highlights

- Conducting a data review
- Identifying data gaps
- Determining acceptability of data
- Designing a sampling plan
- Collecting new data

Read this chapter if...

- You want to determine whether you have enough data to start your analysis
- You'd like to review your data
- You want to determine whether you need to collect new data
- You want to design a sampling plan for collecting additional data
- You need to collect new data

6.1 How Do I Know If I Have Enough Data to Start My Analysis?



One of the most difficult challenges in watershed planning is knowing when you have enough data to identify relationships between impairments and their sources and causes. There will always be more data to collect, but you need to keep the process moving forward and determine whether you can reasonably characterize watershed conditions with the data you have. Once you've gathered all the necessary data related to the watershed goals identified by the stakeholders, you must examine the data to determine whether you can link the impairments seen in the watershed to the causes and sources of pollutants. Although you will develop a monitoring component as part of your watershed implementation plan (↳ chapter 12), it's often necessary to collect additional data during the planning phase to complete the characterization step. The additional data will help you to develop management measures linked to the sources and causes of pollutants.

6.2 Conduct a Data Review

The first step is to review the data you've gathered and ask the following questions:

- Do I have the right types of data to identify causes and sources?
- What is the quality of the data?

The answers to these questions will tell you whether you need to collect additional data before proceeding with data analysis. For example, you might have gathered existing monitoring information that indicates the recreational uses of a lake are impaired by excessive growth of lake weeds due to high phosphorus levels. The permit monitoring data might show that wastewater treatment plants are in compliance with their permit limits, leading to speculation that nonpoint source controls are needed. This kind of information, although adequate to define the broad parameters of a watershed plan, will probably not be sufficient to guide the selection and design of management measures (USEPA 1997a, 1997d) to be implemented to control the as-yet-unidentified nonpoint sources. Therefore, further refinements in problem definition, including more specific identification and characterization of causes and sources, will be needed and can be obtained only by collecting new data.

You'll review the data to identify any major gaps and then determine the quality of the data. ◎ Be careful to first determine whether the data are essential to the understanding of the problem. For example, although it might become obvious during the inventory process that chemical data are lacking, this lack should be considered a gap only if chemical data are essential to identifying the possible sources of the impacts and impairments of concern. If the necessary datasets are available, you should then compare the quality of the information with the data quality indicators and performance characteristics. If the data quality is unknown or unacceptable (that is, it doesn't meet the needs of the stakeholders for watershed assessment), you should not use the existing dataset. Using data of unknown quality will degrade the defensibility of management decisions for the watershed and could, in the long run, increase costs because of the increased likelihood of making incorrect decisions.

Remember that collecting existing and new data, identifying data gaps, and analyzing data are parts of an iterative process. Although obvious data gaps can be identified during the data inventory process, more specific data needs are often discovered only during data analysis and subsequent activities, such as source assessment or modeling.

6.2.1 Identify Data Gaps

Several different types of data gaps might require that you collect additional information. What constitutes a gap is often determined by the information needed to adequately identify and characterize causes and sources of pollutants in the watershed. There are three major types of data gaps—informational, temporal, and spatial.

Informational Data Gaps

First, you need to determine whether your data include the types of information needed. For example, if one of the goals stakeholders identified was to restore the aquatic resources of a waterbody and you have only flow and water quality data, you should conduct biological assessments to get baseline information on the biology of the waterbody and obtain habitat data. Information gaps can also result if there are no data addressing the indicators identified by stakeholders to assess current watershed conditions. For example, stakeholders might want to use the amount of trash observed in a stream as an indicator of stream health. If you don't have any baseline data on trash, you should collect data to assess the amount of trash in the stream (e.g., volume of trash per mile). Without baseline data, you'll have little against which to measure progress. A common data gap is a lack of flow data that specifically correspond to the times and locations of water quality monitoring.

Temporal Data Gaps

Temporal data gaps occur when there are existing data for your area(s) of interest but the data were not collected within, or specific to, the time frame required for your analysis. Available data might have been collected long ago, when watershed conditions were very different, reducing the data's relevance to your current situation. The data might not have been collected in the season or under the hydrologic conditions of interest, such as during spring snowmelt or immediately after crop harvest. In addition, there might be only a few data points available, and they might not be indicative of stream conditions.

Spatial Data Gaps

Spatial data gaps occur when the existing data were collected within the time frames of interest but not at the location or spatial distribution required to conduct your analyses. These types of data gaps can occur at various geographic scales. At the individual stream level, spatial data gaps can affect many types of analyses. Samples collected where a tributary joins the main stem of a river might point to that tributary subwatershed as a source of a pollutant load, but not specifically enough to establish a source. Measuring the effectiveness of restoration efforts can be difficult if data are not available from locations that enable upstream and downstream comparisons of the restoration activities.

Data collected at the watershed scale are often used to describe interactions among landscape characteristics, stream physical conditions (e.g., habitat quality, water chemistry), and biological assemblages. The reliability of these analyses can be affected by several types of spatial data gaps. Poor spatial coverage across a study region can hinder descriptions of simple relationships between environmental variables, and it can eliminate the potential for describing multivariate relationships among abiotic and biotic parameters. In addition,

Example Performance Criteria for Determining Acceptability of Data

Accuracy: The measure of how close a result is to the true value

Precision: The level of agreement among multiple measurements of the same characteristic

Representativeness: The degree to which the data collected accurately represent the population of interest.

Bias: The difference between an observed value and the "true" value (or known concentration) of the parameter being measured

Comparability: The similarity of data from different sources included within individual or multiple datasets; the similarity of analytical methods and data from related projects across areas of concern.

Detection Limit: The lowest concentration of an analyte that an analytical procedure can reliably detect.

Practical quantification limit: The lowest level that can be reliably achieved with specified limits for precision and accuracy during routine sampling of laboratory conditions.

underrepresentation of specific areas within a study region can affect the reliability and robustness of analyses. For instance, in a landscape that is composed of a wide range of land uses and has large variations in topography, preferential sampling in easily accessible areas can bias the dataset and subsequent analyses.

6.2.2 Determine Acceptability of Data

In many cases, the existing data were collected to address questions other than those being asked in the watershed assessment. Also, sufficient data are rarely available from a single source, particularly if the watershed is large. As a result, you might have to rely on data from different sources, collected for different purposes and collected using a variety of sample collection and analysis procedures. Therefore, it's critical that you review existing data to determine their acceptability before you use them in your analyses.

Data acceptability is determined by comparing the types and quality of data with the minimum criteria necessary to address the monitoring questions of interest. For each data source, focus on two areas: *data quality* and *measurement quality*. Data quality pertains to the purpose of the monitoring activity, the types of data collected, and the methods and conditions under which the data were collected. These characteristics determine the applicability of the data to your planning effort and the decisions that can be made on the basis of the data. The main questions to ask are the following:

- **What were the goals of the monitoring activity?** Consider whether the goals of the monitoring activity are consistent with and supportive of your goals. Daily fecal coliform data collected at a swimming beach document compliance with recreational water quality standards but might not help in linking violations of those standards to sources in the watershed. Monthly phosphorus concentration data collected to evaluate long-term trends might or might not help you to relate phosphorus loads from concentrated animal feeding operations (CAFOs) to storm events in your watershed.
- **What types of data were collected?** Determine whether the types of data collected are relevant to your needs. Data on stream macroinvertebrate communities might be useful only if physical habitat data were also collected. Water quality data without associated land use and management data might not be useful in linking impairments to source areas.
- **How were the data collected?** Data collected at random sites to broadly characterize water quality in the watershed might present a very different picture from data deliberately collected from known hot spots or pristine reference sites. Data from a routine, time-based sampling program typically underestimate pollutant loads compared to data collected under a flow-proportional sampling regime (collecting more samples at high flows, fewer at base flow).

Measurement quality describes data characteristics like accuracy, precision, sensitivity, and detection limit. These are critical issues for any monitoring activity, and you'll consider them in detail when you design your own data collection program (↳ section 6.4). For pollutants like metals, toxic substances, or pesticides that are of concern at very low concentrations, the detection, or reporting, limit of the analytical method is one of the most readily distinguished measurement quality parameters in all monitoring programs. Existing data are of little value in evaluating compliance with water quality standards if the method detection limits used were higher than the standard.

There are several levels of measurement quality, and these should be determined for any data source before interpreting the data or making decisions based on the data. State and federal laboratories are usually tested and certified, meet EPA or other applicable performance standards, employ documented analytical methods, and have quality assurance data available to be examined. Analytical results reported from consultants and private laboratories might or might not meet similar standards, so documentation needs to be obtained. Data from citizen groups, lay monitoring programs, school classes, and the like might not meet acceptable measurement quality criteria; in most cases, they should be considered qualitatively if proper documentation can't be obtained.

Ideally, information on the methods used to collect and analyze the samples, as well as the associated measurement quality attributes, should be associated with the data in a database so you can easily determine whether those data are acceptable for your purposes. The Quality Assurance Project Plan (QAPP) associated with a data collection effort is an excellent source of information if available (↳ section 6.4.4). In some cases, sufficient information might be readily available, but you'll have to dig deeply to obtain the best information. For example, even though most published analytical methods have performance characteristics associated with them, the organization conducting the analyses and reporting the data might not have met those performance characteristics. Some laboratories, however, report performance characteristics as part of the method, making it easier for data users to identify the potential quality of data collected using those methods. ↳ An example illustrating the use of a performance-based approach for bioassessment methods is presented in chapter 4 of EPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish,* available at **www.epa.gov/owowwtr1/monitoring/rbp/ch04main.html**.

For some types of parameters, method performance information might be limited, particularly if the data obtained are dependent on the method used. For example, parameters like chemical oxygen demand (COD), oil and grease, and toxicity are defined by the method used. In such cases, you might need to rely on a particular method rather than performance characteristics per se. (↳ See Methods & Data Comparability Board COD Pilot at **http://wi.water.usgs.gov/methods/about/publications/cod_pilot_v.4.4.3.htm** or the National Environmental Methods Index (NEMI) at **www.nemi.gov**.)

Other critical aspects of existing data quality are the age of the data and the format of the database. Old data might be highly valuable in understanding the evolution of water quality problems in your watershed and are likely to be impossible to recreate or re-measure today. However, old data might have been generated by laboratory methods different from those in use today and therefore might not be entirely comparable to current data. Detection limits for organics, metals, and pesticides, for example, are lower today than they were even a decade ago. It might be difficult to adequately document measurement quality in old datasets. In addition, older data might not be in an easily accessible electronic form. If the quality of such data is known, documented, and acceptable, and the data are useful for your purpose, you'll need to consider the effort and expense necessary to convert them into an electronic form.

6.3 Determine Whether New Data Collection Is Essential

At this point, you've collected existing data for your watershed, assessed its quality and relevance, and identified gaps. Compare your available resources against your tasks:

- Can we identify and quantify the water quality problems in the watershed?
- Can we quantify pollutant loads?
- Can we link the water quality impairments to specific sources and source areas in the watershed?
- Have we identified critical habitat including buffers for conservation, protection, and restoration?
- Do we know enough to select and target management measures to reduce pollutant loads and address water quality impairments?

If you were able to answer "yes" to each of these questions, congratulations! You're ready to move on to the next phase and begin to analyze the data. If you answered "no," the next step is to come up with a plan to fill the gaps. Although this might seem like a short-term task, it is critical to consider data collection requirements in the context of your overall watershed plan. The kind of sampling plan you initiate now could well become the foundation of the later effort to monitor the effectiveness of your implementation program, and therefore the plan should be designed with care.

6.4 Design a Sampling Plan for Collecting New Data

If you've determined that additional data must be collected to complete your watershed characterization, you should develop a sampling plan. The sampling plan will focus on immediate data collection needs to help you finish the watershed characterization, but it's very important to consider long-term monitoring needs in this effort. Once data collection and analysis is complete and management strategies have been identified, your implementation efforts should include a monitoring component designed to track progress in meeting your water quality and other goals (chapter 12). Many of the data tools developed to support the sampling plan, including data quality objectives (DQOs), measurement quality objectives (MQOs), and a QAPP, can be modified or expanded on for the monitoring component of the implementation plan. For more information on designing a sampling plan, visit **www.epa.gov/quality/qs-docs/g5s-final.pdf**.

Before collecting any environmental data, you should determine the type, quantity, and quality of data needed to meet the project goals and objectives (e.g., specific parameters to be measured) and to support a decision based on the results of data collection and observation. Failure to do so risks expending too much effort on data collection (more data collected than necessary), not expending enough effort on data collection (not enough data collected), or expending the wrong effort (wrong data collected). You should also consider your available resources. Water quality monitoring and laboratory testing can be very expensive, so you need to determine how best to allocate your resources.

A well-designed sampling plan clearly follows the key steps in the monitoring process, including study design, field

Quality Assurance Project Plans

A QAPP documents the planning, implementation, and assessment procedures for a particular project, as well as any specific quality assurance and quality control activities. It integrates all the technical and quality aspects of the project to provide a blueprint for obtaining the type and quality of environmental data and information needed for a specific decision or use. All work performed or funded by EPA that involves acquiring environmental data must have an approved QAPP. For more information on QAPPs, visit **www.epa.gov/quality/qapps.html**.

sampling, laboratory analysis, and data management. Sampling plans should be carefully designed so that the data produced can be analyzed, interpreted, and ultimately used to meet all project goals. Designing a sampling plan involves developing DQOs and MQOs, a study design, and a QAPP, which includes logistical and training considerations, detailed specifications for standard operating procedures (SOPs), and a data management plan. Because a variety of references on designing and implementing water quality monitoring programs are available, this section provides only a general overview and resources available for further information. ↳ For more information visit EPA's *Quality Management Tools* Web site at **www.epa.gov/quality/qapps.html**.

6.4.1 Select a Monitoring Design

The specific monitoring design you use depends on the kind of information you need. Water quality sampling can serve many purposes:

- Defining water quality problems
- Defining critical areas
- Assessing compliance with standards or permits
- Determining fate and transport of pollutants
- Analyzing trends
- Measuring effectiveness of management practices
- Evaluating program effectiveness
- Making wasteload allocations
- Calibrating or validating models
- Conducting research

Depending on the gaps and needs you've identified, monitoring to define water quality problems, assess compliance with standards, and define critical areas might be most appropriate for your watershed. For example, synoptic or reconnaissance surveys are intensive sampling efforts designed to create a general view of water quality in the study area. A well-designed synoptic survey can yield data that help to define and locate the most severe water quality problems in the watershed, and possibly to support identification of specific major causes and sources of the water quality problem. Data collected in synoptic surveys can also be used to help calibrate and verify models that might be applied to the watershed (USEPA 1986).

There are a variety of approaches to conducting synoptic surveys. Less-expensive grab sampling approaches are the norm for chemical studies. Rapid Bioassessment Protocols and other biological assessment techniques can be used to detect and assess the severity of impairments to aquatic life, but they typically do not provide information about the causes or sources of impairment (USEPA 1997a, 1997d). Walking or canoeing the course of tributaries can also yield valuable, sometimes surprising information regarding causes and sources. It's important to recognize that, because synoptic surveys are short in duration, they can yield results that are inaccurate because of such factors as unusual weather conditions, intermittent discharges that are missed, or temporal degradation of physical or biological features of the waterbody. Follow-up studies, including fate and transport studies, land use and land treatment assessments, and targeted monitoring of specific sources, might be needed to improve the assessment of causes and sources derived from synoptic surveys.

Sampling network design refers to the array, or network, of sampling sites selected for a monitoring program and usually takes one of two forms:

- ***Probabilistic design:*** Network that includes sampling sites selected randomly to provide an unbiased assessment of the condition of the waterbody at a scale above the individual site or stream; can address questions at multiple scales.
- ***Targeted design:*** Network that includes sampling sites selected on the basis of known, existing problems; knowledge of coming events in the watershed or a surrounding area that will adversely affect the waterbody, such as development or deforestation; or installation of management measures or habitat restoration intended to improve waterbody quality. The network provides for assessments of individual sites or reaches.

Compliance monitoring might focus on regular sampling at specific locations, depending on the source, constituent, and relevant standard. Although typically associated with point source discharges, compliance monitoring can be used effectively to characterize and isolate pollutant loads from relatively defined sources such as stormwater outfalls or concentrated runoff from a concentrated animal feeding operation (CAFO). Monitoring to define critical areas can also be focused on specific locations, chosen on the basis of land use patterns or in response to known or suspected problem areas.

Fate and transport monitoring is designed to help define the relationships between the identified water quality problems and the sources and causes of those problems. This type of monitoring typically involves intensive sampling over a relatively short period, with frequent sampling of all possible pollutant pathways within a fairly small geographic area. The limited geographic scope of fate and transport monitoring, coupled with the required sampling intensity, makes it an expensive venture if applied broadly within a watershed. Because of its cost and relatively demanding protocols, fate and transport monitoring is best used in a targeted manner to address the highest-priority concerns in a watershed. For example, the preferential pathways of dissolved pollutants (e.g., nitrate nitrogen) that can be transported via surface or subsurface flow to a receiving waterbody might need to be determined and quantified to help identify the critical area, design effective management measures, and estimate potential pollutant load reductions.

Because nonpoint source contributions are often seasonal and dependent on weather conditions, it's important that all sampling efforts be of sufficient duration to encompass a reasonably broad range of conditions. Highly site-specific monitoring should be done on reasonably representative areas or activities in the watershed so that results can be extrapolated across the entire area.

Station location, selection, and sampling methods will necessarily follow from the study design. Ultimately, the sampling plan should control extraneous sources of variability or error to the extent possible so that data are appropriately representative and fulfill the study objectives.

In the study design phase, it's important to determine how many sites are necessary to meet your objectives. If existing data are available, statistical analysis should be conducted to determine how many samples are required to meet the DQOs, such as a 95 percent confidence level in estimated load or ability to detect a 30 percent change. If there are no applicable data for your watershed, it might be possible to use data from an adjacent watershed or from within the same ecoregion to characterize the spatial and temporal variability of water quality. ↳ For more on statistical analyses, see EPA's "Statistical Primer" on power analysis at **www.epa.gov/bioindicators/statprimer/index.html**.

In addition to sampling size, you should also determine the type of sampling network you'll implement and the location of stations. The type of sampling network design you choose depends on the types of questions you want to answer. Generally, sampling designs fall into two major categories: (1) random or probabilistic and (2) targeted. In a probabilistic design, sites are randomly chosen to represent a large sampling population for the purpose of trying to answer broad-scale (e.g., watershed-wide) questions. This type of network is appropriate for synoptic surveys to characterize water quality in a watershed. In a targeted design, sites are allocated to specific locations of concern (e.g., below discharges, in areas of particular land use, at stream junctions to isolate subwatersheds) with the purpose of trying to answer site-specific questions. A stratified random design is a hybrid sampling approach that deliberately chooses parts of the watershed (e.g., based on land use or geology) to be sampled and then selects specific sampling points within those zones at random.

➥ For more information on sampling designs, see EPA's *Guidance on Choosing a Sampling Design for Environmental Data Collection* at **www.epa.gov/quality/qs-docs/g5s-final.pdf**.

Your monitoring plan should focus not only on water quality, but also on the land-use activities that contribute to nonpoint source loads. You might need to update the general land use/land cover data for your watershed or gather information on specific activities (e.g., agricultural nutrient management practices or the use of erosion and sediment control plans in construction projects). Monitor not only where implementation might occur, but in all areas in the watershed that could contribute to nonpoint source loads. Part of this effort should focus on collecting data on current source activities to link pollutant loads to their source.

Leveraging Resources for Monitoring Efforts

Local watershed groups in Baltimore, Maryland, have long been troubled by the aging, leaky sewage pipes that run through the beds of city streams. They were interested in tracking the raw sewage entering the stream system, especially after storm events, but didn't have the resources for the required equipment. The city's Department of Public Works was also interested in the problem but had the time and resources for only weekly screenings. They decided to partner: the City agreed to provide the groups with ammonia test kits (high levels of ammonia can indicate the presence of sewage) in return for screening of additional stations and a greater sampling frequency. Now both parties have the data they need to better understand the problem.

In addition, you should generate baseline data on existing land-use and management activities so that you can better predict future impairments. One tool that can be used to predict where impairments might occur, allowing you to target monitoring efforts, is U.S. EPA's Analytical Tools Interface for Landscape Assessments (ATtILA). ATtILA provides a simple ArcView graphical user interface for landscape assessments. It includes the most common landscape/watershed metrics, with an emphasis on water quality influences. (➥ To read about or download ATtILA, see **www.epa.gov/nerlesd1/land-sci/attila/index.htm**.)

The result of a good land-use/land-treatment monitoring program is a database that will help you explain the current situation and potential changes in water quality down the road. The ability to attribute water quality changes to your implementation program or to other factors will be critical as you evaluate the effectiveness of your plan.

Another important consideration during study design is how other groups and partners can be enlisted to support your monitoring effort. Think back to the issues of concern expressed by the different groups and the potential partnerships you can build among local governments, agencies, private organizations, and citizen groups. Collaborative monitoring strategies can effectively address multiple data needs and resource shortfalls.

Finally, it's also important to consider how this initial monitoring might be used to support a long-term monitoring program that addresses evaluation of watershed condition and restoration. The sampling and analysis done during this phase can be used to provide an evaluation of baseline or existing conditions. As long as continued monitoring during implementation is done consistently, it can be used to track trends, evaluate the benefits of specific management measures, or assess compliance with water quality standards (➥ chapter 12).

6.4.2 Develop Data Quality Objectives

DQOs are qualitative and quantitative statements that clarify the purpose of the monitoring study, define the most appropriate type of data to collect, and determine the most appropriate methods and conditions under which to collect them. The DQO process, developed by EPA (GLNPO 1994, USEPA 2000a), is a flexible planning framework that articulates project goals and objectives, determines appropriate types of data, and establishes tolerable levels of uncertainty. The purpose of this process is to improve the effectiveness, efficiency, and defensibility of decisions made, based on the data collected. A team of data users develops DQOs based on members' knowledge of the data's richness and limits, and their own data needs. You'll use the information compiled in the DQO process to develop a project-specific QAPP, which should be used to plan most of the water quality monitoring or assessment studies.

Seven Steps In the DQO Process

Step 1. State the problem. Review existing information to concisely describe the problem to be studied.

Step 2. Identify the decision. Determine what questions the study will try to resolve and what actions might result.

Step 3. Identify inputs to the decision. Identify information and measures needed to resolve the decision statement.

Step 4. Define the study boundaries. Specify temporal and spatial parameters for data collection.

Step 5. Develop a decision rule. Define statistical parameters, action levels, and a logical basis for choosing alternatives.

Step 6. Specify tolerable limits on decision errors. Define limits based on the consequences of an incorrect decision.

Step 7. Optimize the design. Generate alternative data collection designs and choose the most resource-effective design that meets all DQOs.

The DQO process addresses the uses of the data (most important, the decisions to be made) and other factors that will influence the types and amount of data to be collected (e.g., the problem being addressed, existing information, information needed before a decision can be made, and available resources). The products of the DQO process are criteria for data quality, measurement quality objectives, and a data collection design that ensures that data will meet the criteria. ↳ For more information on DQOs, see EPA's *Guidance for the Data Quality Objectives Process* at **www.epa.gov/quality/qs-docs/g4-final.pdf**.

The purpose of the study, or the question that needs to be answered, drives the input for all steps in the DQO process. Thus, sampling design, how samples are collected and manipulated, and the types of analyses chosen should all stem from the overall purpose of the study.

Example DQO: *Determine, to a 95% degree of statistical certainty, whether there is a significant (50%) change in average nitrate concentration over time at given sampling locations.*

6.4.3 Develop Measurement Quality Objectives and Performance Characteristics

A key aspect of your sampling plan design is specifying MQOs—qualitative or quantitative statements that describe the amount, type, and quality of data needed to address the overall project objectives. These statements explicitly define the acceptable precision, bias, and sensitivity required of all analyses in the study, and therefore they should be consistent with the expected performance of a given analysis or test method (ITFM 1995). You'll use this information to help derive meaningful threshold or decision rules, and the tolerable errors associated with those rules. MQOs are used as an indicator of potential method problems. Data are not always discarded simply because MQOs are not met. Instead, failure to met MQOs is a signal to further investigate and to correct problems. Once the problem(s) are rectified, the data can often still be used.

MQOs should be realistic and attainable. For example, establishing an MQO of less than 10 percent relative percent difference (RPD) for biological data would most likely result in failure simply because of the data's natural variability. Often, the best way to establish MQOs is to look at reliable existing data and choose MQOs that can be met by existing data. They can be adjusted (made more or less stringent) if protocol and program capabilities are improved.

Every sampling program should find a balance between obtaining information to satisfy the stated DQOs or study goals in a cost-effective manner and having enough confidence in the data to make appropriate decisions. Understanding the performance characteristics of methods is critical to the process of developing attainable data quality goals, improving data collection and processing, interpreting results, and developing feasible management strategies. By calculating the performance characteristics of a given method, it is possible to evaluate the robustness of the method for reliably determining the condition of the aquatic ecosystem. A method that is very labor-intensive and requires a great deal of specialized expertise and, in turn, provides a substantial amount of information is not necessarily the most appropriate method if it lacks precision and repeatability. A less-rigorous method might be less sensitive in detecting perturbation or have more uncertainty in its assessment. All of these attributes are especially important to minimizing error in assessments. The number of samples collected and analyzed will reflect a compromise between the desire of obtaining high-quality data that fully address the overall project objectives (the MQOs) and the constraints imposed by analytical costs, sampling effort, and study logistics. The ultimate question resides in a firm balance between cost and resolution, i.e., Which is better—more information at a higher cost or a limited amount of the right information at less cost?

Remember that you still might need to identify funding sources for the new sampling effort. When determining the number of samples and constituents to be analyzed, consider the resources available, cost and time constraints, and quality assurance and quality control requirements to ensure that sampling errors are sufficiently controlled to reduce uncertainty and meet the tolerable decision error rates. For a list of links to DQO-related items, go to **http://dqo.pnl.gov/links.htm**.

6.4.4 Develop a Quality Assurance Project Plan

A QAPP is a project-specific document that specifies the data quality and quantity requirements of the study, as well as all procedures that will be used to collect, analyze, and report those data. EPA-funded data collection programs must have an EPA-approved QAPP before sample collection begins. However, even programs that do not receive EPA funding should consider developing a QAPP, especially if data might be used by state, federal, or local resource managers. A QAPP helps monitoring staff to follow correct and repeatable procedures and helps data users to ensure that the collected data meet their needs and that the necessary quality assurance (QA) and quality control (QC) steps are built into the project from the beginning.

A QAPP is normally prepared before sampling begins, and it usually contains the sampling plan, data collection and management procedures, training and logistical considerations, and their QA/QC components. The intent of the QAPP is to help guide operation of the program. It specifies the roles and

> ***Quality control*** (QC) is a system of technical activities that measure the attributes and performance of a process, product, or service against defined standards to verify that they meet the stated requirements.
>
> ***Quality assurance*** (QA) is an integrated system of management activities involving planning, quality control, quality assessment, reporting, and quality improvement to ensure that a product or service meets defined standards of quality with a stated level of confidence.

QA and QC Procedures, Detailed in the QAPP, Address…

- The sampling (data collection) design
- The methods to be used to obtain the samples
- How the samples will be handled and tracked
- What control limits or other materials will be used to check performance of the analyses (quality control requirements)
- How instruments or other equipment used will be calibrated
- How all data generated during the monitoring program will be managed and how errors in data entry and data reduction will be controlled (Keith 1991).

responsibilities of each member of the monitoring program team from the project manager and QA/QC officer to the staff responsible for field sampling and measurement. Project management responsibilities include overall project implementation, sample collection, data management, and budget tracking. Quality management responsibilities might include conducting checks of sample collection or data entry, data validation, and system audits. The QAPP also describes the tasks to be accomplished, how they will be carried out, the DQOs for all kinds of data to be collected, any special training or certification needed by participants in the monitoring program, and the kinds of documents and records to be prepared and how they will be maintained.

A key element of a QAPP is the SOP. SOPs help to maintain data comparability by providing a step-by-step description of technical activities to ensure that project personnel consistently perform sampling, analysis, and data-handling activities. The use of standard methods of analysis for water quality parameters also permits comparability of data from different monitoring programs.

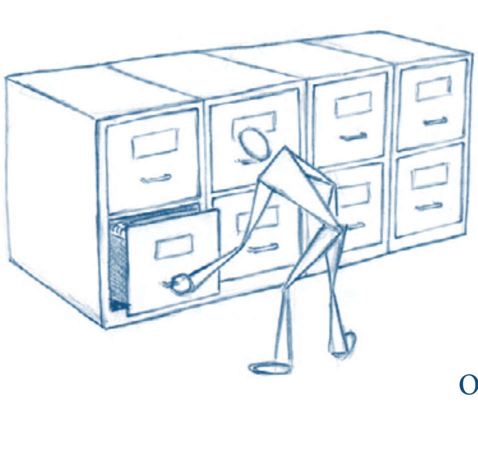
The QAPP also contains the types of assessments to be conducted to review progress and performance (e.g., technical reviews, audits), as well as how nonconformance detected during the monitoring program will be addressed. Finally, procedures are described for reviewing and validating the data generated; dealing with errors and uncertainties identified in the data; and determining whether the type, quantity, and quality of the data will meet the needs of the decisionmakers. QAPPs should be continually refined to make them consistent with changes in field and laboratory procedures. Each refinement should be documented and dated to trace modifications to the original plan.

↳ For assistance in developing an effective QAPP, visit EPA's Web site to read *Quality Management Tools—QA Project Plans* at **www.epa.gov/quality/qapps.html**, *The Volunteer Monitor's Guide to Quality Assurance Project Plans* at **www.epa.gov/volunteer/qapp/vol_qapp.pdf**, or *Guidance for Quality Assurance Project Plans for Modeling* at **www.epa.gov/quality/qs-docs/g5m-final.pdf**.

An excerpt from the sampling plan for Spa Creek, Maryland, is provided as figure 6-1.

6.4.5 Develop a Plan for Data Management

Any monitoring program should include a plan for data management. You should determine how data will be stored, checked, and prepared for analysis. Often, these issues are addressed in the QAPP. This type of plan usually dictates that data be entered into databases that can help keep track of information collected at each site and can be used to readily implement analyses.



There are many types of platforms to house databases. The simplest databases are spreadsheets, which might be adequate for small projects. For more complex watershed measurements involving many sites or variables, a relational database is usually preferable. The biological/habitat database EDAS (Ecological Data Application System; Tetra Tech 2000) runs on a Microsoft Access platform. Very large databases often use ORACLE as a platform or a similar type of relational database that

Located in Annapolis, Maryland, Spa Creek begins at a large stormwater pipe and includes a few major tributaries before it opens into the Chesapeake Bay. Spa Creek provides recreational opportunities for boating, fishing, and hiking; it also provides habitat for Chesapeake Bay wildlife. The watershed has been developed with urban land uses, including residential, commercial, open space, and institutional uses (e.g., schools). Impairments associated with bacteria, pH, and dissolved oxygen exist in Spa Creek. A field observation revealed little evidence of a healthy aquatic life community and stream site habitat. However, there are insufficient data to understand the magnitude of the impairments and the sources and causes of impairment. As a result, a preliminary sampling plan was developed to better understand the quality of Spa Creek, its tributaries, and stormwater from a few targeted developed areas. The proposed monitoring will help stakeholders to develop a watershed management plan with specific water quality goals and actions.

The preliminary sampling plan recommends a minimum of two dry weather sampling events and two wet weather sampling events. Dry weather samples help to understand the instream water quality under minimal dilution conditions (when estuarine impacts are expected to be dominant), while wet weather samples help to understand the quality of stormwater from the surrounding watershed and its impact on Spa Creek. To understand the spatial distribution of impairment and to isolate hot spots, five instream locations and seven storm drain outlets were identified for sampling. Proposed locations and sampling frequency were recommended in the interest of developing a watershed plan with specific actions and restoration.

Parameters proposed for monitoring include flow, temperature, pH, dissolved oxygen, conductivity, turbidity, fecal coliform bacteria, total suspended solids, carbonaceous oxygen demand, total organic carbon, ammonia, nitrate + nitrite, total Kjeldahl nitrogen, orthophosphate, total phosphorus, copper, zinc, lead, hardness, and oil and grease. Ecological monitoring was proposed in the sampling plan to assess the ecological condition of Spa Creek. As part of the assessment, biological, physical habitat, and chemistry samples would be collected from three to five streams sites in the watershed. For example, benthic invertebrates and fish would be collected, and in situ toxicity testing would be performed using a caged oyster study.

The proposed plan emphasizes the importance of continuing to monitor Spa Creek to understand long-term water quality trends and to measure progress once the plan is implemented. Potential options to consider for long-term monitoring (every 3 years) include flow, metals, benthics/fish, dissolved oxygen, oyster baskets, and *E. coli*. Anticipated costs for monitoring are included in the table below.

Alternative Monitoring Description	Basic Chemistry and Biology	Benthic/Fish and Oyster Basket (3–5 locations)	Priority Pollutant Scan (4 locations)	Sampling in Tidal Area (4 locations)	Total Estimated Cost
Phase I (5 instream dry, 5 instream wet, and 3 outlet wet)	$20,000	$15,000	$14,500	$6,000 (1 dry, 1 wet)	$55,500
Complete screening level (2 dry and 2 wet at all locations)	$52,000	$15,000	$14,500	$11,000	$92,500
Only model parameter data collection (2 dry and 2 wet at 8 locations)	$33,000	$15,000			$48,000
Long-term trend monitoring, every 3 years (1 dry and 1 wet at 3–5 locations)	$12,000	$15,000			$27,000

Figure 6-1. Excerpt from Spa Creek Proposed Sampling Plan

is more readily Web-accessible. In a relational database, data, metadata, and other ancillary information reside in a series of relational tables including station information, sample information, analyses, methods used, and QC information. In this type of database, data can be organized in many different ways depending on how they are to be used (the types of analyses to be performed). It is useful to consider any requirements or options for uploading your data to other databases, such as EPA's STORET or a state agency database, as part of your overall data management process.

As mentioned earlier with respect to existing data, documentation of metadata (information about the data) is critical to ensure the proper understanding and use of the data now and in the future. Many organizations have recognized that adequately characterized data have more value to the program that collected the data, as well as to other organizations and programs, than inadequately characterized data. The Methods and Data Comparability Board and the National Water Quality Monitoring Council have developed a list of metadata categories that should be included in database design and should be reflected in all field sampling forms and other field and laboratory documentation generated as part of the monitoring (NWQMC 2005). These elements address the who, what, when, where, why, and how of collecting data. ↳ For more information on metadata and data elements, go to **http://acwi.gov/methods** or **www.epa.gov/edr**.

6.5 Collect New Data

Sampling plans often include a mixture of different types of data, including biological (e.g., benthic, fish, algae), physical (e.g., visual habitat assessment, geomorphic assessment), chemical (e.g., conductivity, nitrate, dissolved oxygen), and hydrologic measurements. Numerous methods are available for collecting these data, but the achieved data quantity and quality differ. Therefore, data collection techniques should be carefully selected to ensure that the data produced can be used to meet project goals completely.

6.5.1 Watershed Overview/Visual Assessment

A watershed survey, or visual assessment, is one of the most rewarding and least costly assessment methods. By walking, driving, or boating the watershed, you can observe water and land conditions, uses, and changes over time that might otherwise be unidentifiable. These surveys help you identify and verify pollutants, sources, and causes, such as streambank erosion delivering sediments into the stream and illegal pipe outfalls discharging various pollutants. (Note, however, that additional monitoring of chemical, physical, and biological conditions is required to determine whether the stressors observed are actually affecting the water quality.) Watershed surveys can provide a very accurate picture of what is occurring in the watershed and also can be used to familiarize local stakeholders, decisionmakers, citizens, and agency personnel with activities occurring in their watershed. ↳ For general information, read section 3.2, The Visual Assessment, in EPA's *Volunteer Stream Monitoring: A Methods Manual* (EPA 841-B-97-003), **www.epa.gov/owow/monitoring/volunteer/stream/vms32.html**. Included is a Watershed Survey Visual Assessment form, **www.epa.gov/owow/monitoring/volunteer/stream/ds3.pdf**.

Examples of Sources That Might Be Unidentifiable without a Watershed Survey

- Streambank erosion in remote areas
- Pipe outfalls with visible discharges
- Livestock (near or with access to streams)
- Wildlife (e.g., waterfowl populations on lakes and open streams)
- Small-scale land-disturbing activities (e.g., construction, tree-cutting)

Several agencies and organizations have developed visual assessment protocols that you can adapt to your own situation. For example, the Natural Resources Conservation Service (NRCS) has developed a Visual Stream Assessment Protocol (VSAP), which is an easy-to-use assessment tool that evaluates the condition of stream ecosystems. It was designed as an introductory, screening-level assessment method for people unfamiliar with stream assessments. The VSAP measures a maximum of 15 elements and is based on visual inspection of the physical and biological characteristics of instream and riparian environments. Go to **www.nrcs.usda.gov/technical/ECS/aquatic/svapfnl.pdf** to download a copy of the tool.

Some watershed survey tools are designed to examine specific issues in the watershed. For example, the Rapid Stream Assessment Technique (RSAT), developed for Montgomery County, Maryland, is a simple, rapid, reconnaissance-level assessment of stream quality and potential pollutant sources. In this technique, visual evaluations are conducted in various categories—including channel stability, physical in-stream habitat, riparian habitat conditions, and biological indicators—to gauge stream conditions. Additional information about RSAT is available at **www.stormwatercenter.net/monitoring%20and%20assessment/rsat/smrc%20rsat.pdf**.

Watershed planners often incorporate photographs into their surveys. Photographic technology is available to anyone, does not require intensive training, and is relatively inexpensive considering its benefits. Photos serve as a visual reference for the site and provide a good "before" image to compare with photos taken after restoration, remediation, or other improvements or changes. In addition to illustrating problems that need to be corrected, photos provide a watershed portrait for those that might not have the opportunity to visit monitoring sites. They help generate interest in the watershed, and they can be used in reports, presentations, grant proposals, and on Web sites and uploaded to GIS programs. In addition to taking your own photographs, you can also obtain aerial photographs from USGS (Earth Science Information Center), USDA (Consolidated Farm Service Agencies, Aerial Photography Field Office), and other agencies. California's State Water Resources Control Board Clean Water Team produced *Guidance Compendium for Watershed Monitoring and Assessment*, which contains a section on SOPs for stream and shoreline photo documentation: **www.swrcb.ca.gov/nps/cwtguidance.html#42**.

More detailed visual assessment tools to determine aquatic habitat conditions or stream stability are provided below.

6.5.2 Physical Characterization

The physical conditions of a site can provide critical information about factors affecting overall stream integrity, such as agricultural activities and urban development. For example, runoff from cropland, pastures, and feedlots can carry large amounts of sediment into streams, clogging existing habitat and changing geomorphological characteristics. An understanding of stream physical conditions can facilitate stressor identification and allow for the design and implementation of more effective restoration and protection strategies. Physical characterization should extend beyond the streambanks or shore and include a look at conditions in riparian areas.

6.5.3 Geomorphic Assessment

Geomorphic assessments range from cursory evaluations that provide general descriptions of channel shape and pattern to rigorous assessments designed to describe the geomorphic features in detail and assess stream channel alterations over time. They can help you answer various questions about the streams and rivers in your watershed, such as these used by the Vermont Department of Environmental Conservation:

- What are the physical processes and features that characterize the stream and its watershed?
- How have human activities affected these processes and features over time?
- Which of these physical processes and features are more sensitive to change, and how are they likely to change in the future?
- Which of these processes and features are important for creating and sustaining quality habitat for fish and other aquatic biota?
- Which of these processes and features present high erosion and flood hazard risks?

Geomorphology protocols commonly describe such stream and river characteristics as channel dimensions, reach slope, channel enlargement and stability, and bank-full and related measurements. The measures will help you understand current stream conditions and can be evaluated over time to describe stream degradation or improvements. The measures can also be used to predict future stream conditions, which can help you choose appropriate restoration or protection strategies.

➡ For examples of standard geomorphic protocols, see EPA's Environmental Monitoring and Assessment Program (EMAP), **www.epa.gov/emap**, or Vermont's Stream Geomorphic Assessment Protocols, **www.anr.state.vt.us/dec/waterq/rivers/htm/rv_geoassesspro.htm**.

The Rosgen geomorphic assessment approach (Rosgen 1996) groups streams into different geomorphic classes on the basis of a set of criteria. The criteria include entrenchment ratio, width/depth ratio, sinuosity, channel slope, and channel materials. This method is commonly used throughout the country. The Rosgen stream types can be useful for identifying streams at different levels of impairment, determining the types of hydrologic and physical factors affecting stream morphologic conditions, and choosing the best management measures to implement if necessary. ➡ For a summary of the Rosgen Stream Classification System, go to **www.epa.gov/watertrain/stream_class/index.htm**.

One of the common goals of a Rosgen assessment and other types of geomorphic assessments is to compare site-specific data from a given stream reach to data from other reaches of similar character to help classify a stream reach and determine its level of stability. A good way to do this is to use a reference channel reach near the watershed or stream reach being evaluated. When looking for a representative reach in your watershed, it is possible that one has already been surveyed, but it is often unlikely that you will be able to find the data. Therefore, it might be necessary to survey a local reference reach by determining its longitudinal profile, representative cross sections, bed materials, and meander pattern. It might be difficult to find a quality channel that exists locally. However, local data from a similar watershed are valuable to use for comparison purposes. ➡ For more information on stream channel reference sites, go to **www.stream.fs.fed.us/publications/PDFs/RM245E.PDF**.

Another common geomorphic assessment method is the Modified Wolman Pebble Count, which characterizes the texture (particle size) in the stream or riverbeds of flowing surface waters. It can be used in conjunction with Rosgen-type physical assessments or as a standalone method. The composition of the streambed can tell you a lot about the characteristics of the stream, including the effects of flooding, sedimentation, and other physical impacts. For detailed descriptions of the Modified Wolman Pebble Count, see Harrelson et al. (1994) and Rosgen (1996) or check out the Virginia Save Our Streams pebble count factsheet and worksheets at **www.vasos.org/pebblecountandworksheets.pdf** or the *Sampling Surface and Subsurface Particle-Size Distributions in Wadable Gravel- and Cobble-Bed Streams for Analyses in Sediment Transport, Hydraulics, and Streambed Monitoring* document on the USDA Forest Service's Stream Team Web site at **www.stream.fs.fed.us/index.html**.

The Ohio Department of Natural Resources and Ohio State University developed a suite of spreadsheet tools (the STREAM Modules) that is commonly used across the country for stream assessments, including the Rosgen classification described earlier in this section. This ongoing project provides the following module at present: (1) Reference Reach Spreadsheet for reducing channel survey data and calculating basic bank-full hydraulic characteristics; (2) Regime Equations for determining the dimensions of typical channel form; (3) Meander Pattern, which dimensions a simple arc and line best fit of the sine-generated curve; (4) Cross-section and Profile, which can be used to illustrate the difference between existing and proposed channel form; (5) Sediment Equations, which includes expanded and condensed forms of critical dimensionless shear, boundary roughness and common bed load equations (can be used with the Wolman Pebble Counts); and (6) Contrasting Channels, which computes hydraulic and bed load characteristics in a side-by-side comparison of two channels of different user-defined forms. The spreadsheet is available at **www.ohiodnr.com/soilandwater/streammorphology/default/tabid/9188/Default.aspx**.

6.5.4 Hydrologic Assessment

Nonpoint source pollution is driven by climate and watershed hydrology. Hydrologic assessments deal specifically with measuring stream flow, which can provide important information about streams, lakes, and even watersheds. Stream flow data are essential to estimate nonpoint source loads. Good hydrologic data are also useful in assessing relationships between precipitation and stream flow, potentially an important indicator of watershed development. Some management measures in both agricultural and urban settings directly affect the stream flow regime, so hydrologic data from before and after implementation of BMPs can be an important element of plan evaluation.

Weather data are relatively easy to obtain from existing National Weather Service stations, or the cooperative network. For information on weather data available for your watershed, see the National Climatic Data Center Web site at **www.ncdc.noaa.gov/oa/ncdc.html** or the National Water and Climate Center at **www.wcc.nrcs.usda.gov**.

Streamflow data are more difficult to obtain. USGS conducts most of the routine streamflow monitoring in the United States, usually in cooperation with state agencies. For information on available USGS streamflow data for your region, see **http://waterdata.usgs.gov/nwis**, which contains current-condition, real-time data transmitted from selected surface water, ground water, and water quality monitoring sites. You can also visit **http://water.usgs.gov/osw/programs/nffpubs.html** to find information on regional regression equations that were developed for states and regions and can be used to predict peak flows. If you're lucky enough to have a USGS stream gauging station in your watershed, both current and historical data will be available to help estimate pollutant loads. Otherwise, you might need to look for USGS stations in adjacent, similar watersheds (similar in terms of size, topography, stream type, and so forth) to provide estimates of hydrologic behavior. For example, you might need to apply long-term average annual runoff estimates to your situation. If you need detailed streamflow monitoring, it is possible (but expensive) to install a new gauging station. If you go this route, consider installing a full-flow monitoring station at your watershed outlet and supplementing it with periodic manual measurements at the upstream locations to derive a relationship between the outlet and upstream locations. Such a relationship could be useful in estimating flow at ungauged sites.

Washington State's Department of Ecology put together *A Citizen's Guide to Understanding and Monitoring Lakes and Streams*, which has an entire chapter devoted to hydrology. Go to **www.ecy.wa.gov/programs/wq/plants/management/joysmanual/chapter5.html**.

6.5.5 Water Quality Assessment

Water quality can be assessed using a variety of different methods for a multitude of analytes. The types of analytes measured should reflect the DQOs specified, as well as previously collected data for the watershed if available. For water quality assessments in support of Total Maximum Daily Loads (TMDLs), the specific pollutants identified in the TMDLs will be analyzed. For nonpoint source assessments, a variety of parameters might be analyzed, depending on the specific questions being asked and the land uses in the watershed. It is often appropriate to analyze pesticides, nutrients, and biochemical oxygen demand in agricultural areas, for example, whereas oil and grease, polycyclic aromatic hydrocarbons (PAHs), metals, and dissolved solids are more useful in urban areas. The form of the analyte being measured might need to be carefully considered; for example, if dissolved metals concentrations are needed, filtering the sample before preservation is required.

For many types of pollutants, you'll want to analyze some specific parameters simultaneously to better interpret the potential effects of those pollutants (table 6-1). For example, the bioavailability and toxicity of many metals are regulated by the suspended solids, alkalinity, hardness, pH, or dissolved organic carbon present in the water. If metals are of concern, it is recommended that many of these other analytes be measured as well. Similarly, if ammonia is a concern, simultaneous pH and temperature measurements are needed to help interpret its potential effects.

Table 6-1. Sources and Associated Pollutants

Source	Common Associated Chemical Pollutants
Cropland	Turbidity, phosphorus, nitrates, temperature, total suspended solids
Forestry harvest	Turbidity, temperature, total suspended solids
Grazing land	Fecal bacteria, turbidity, phosphorus, nitrates, temperature
Industrial discharge	Temperature, conductivity, total solids, toxic substances, pH
Mining	pH, alkalinity, total dissolved solids, metals
Septic systems	Fecal bacteria (i.e., *Escherichia coli*, enterococci), nitrates, phosphorus, dissolved oxygen/biochemical oxygen demand, conductivity, temperature
Sewage treatment plants	Dissolved oxygen and biochemical oxygen demand, turbidity, conductivity, phosphorus, nitrates, fecal bacteria, temperature, total solids, pH
Construction	Turbidity, temperature, dissolved oxygen and biochemical oxygen demand, total suspended solids, and toxic substances
Urban runoff	Turbidity, total suspended solids, phosphorus, nitrates, temperature, conductivity, dissolved oxygen and biochemical oxygen demand

Source: USEPA 1997a, 1997d.

In most nonpoint source-dominated watersheds, the concentration of a constituent in the stream is positively related to flow; most nonpoint source activity occurs at high flows. Therefore, an appropriate sampling schedule should be followed to avoid bias in measuring concentrations of pollutants. Data from time-based sampling (e.g., weekly, monthly by the calendar) are nearly always biased to low-flow conditions because high-flow events occur relatively infrequently. Flow-proportional sampling produces less biased information on true concentration and load.

Sampling methods can range from intensive efforts that require analytical laboratory analyses to in situ (field) measurements using a multiparameter monitoring and data-logging system. For more information and detailed descriptions of water quality sampling methods, see the USGS's *National Field Manual for the Collection of Water-Quality Data* at **http://water.usgs.gov/owq/FieldManual**.

Consider specialized monitoring requirements for your watershed. For example, if sediment pollutants are being analyzed, methods for sediment sampling and processing might be critical (Refer to EPA's sediment manual at **www.epa.gov/waterscience/cs/collection.html,** USGS sediment sampling techniques at **http://water.usgs.gov/osw/techniques/sediment.html**, and the section on sediment monitoring in Edward's and Glysson's field manual at **http://water.usgs.gov/osw/techniques/Edwards-TWRI.pdf** for good reviews on techniques). Some sediment quality parameters such as pH; percent moisture; total organic carbon; and, in the case of metals, simultaneously extracted metals (SEM) and acid-volatile sulfide (AVS) should be analyzed to help interpret pollutant data.

6.5.6 Assessment of Stream Habitat Quality

When conducting biological assessments, you should assess physical habitat quality to supplement the biological data. Habitat quality characteristics such as stream substrate and canopy cover influence the biotic communities that can inhabit the site, regardless of water quality conditions. Alterations in stream and watershed hydrology can potentially lead to accelerated stream channel erosion, which, in turn, leads to habitat degradation and reduces the capacity of the stream to support a healthy biota. Though combining the results of biological and physical habitat assessments does not directly identify specific cause-effect relationships, it can provide insight into the types of stressors and stressor sources affecting watersheds of interest, allowing for more detailed diagnostic investigations based on the severity of observed biological responses.

Other Visually Based Habitat Assessments

The Mississippi Department of Environmental Quality developed a visually based approach (MDEQ 2001) that is similar to the EPA Rapid Bioassessment Protocols (RBPs) but is more regimented with respect to habitat quality categories; that is, the criteria used for defining optimal, suboptimal, fair, and poor habitat are divided in more detail. This strategy was intended to make the protocol more objective and less reliant on field training.

Maryland Biological Stream Survey methods for assessing habitat quality are also based on the RBPs, but the parameters are slightly different and are rated on various scales depending on the parameter. The individual habitat parameters in this protocol are assembled into a final physical habitat index that assigns different weights to the various parameters. For a complete description of these methods, go to **www.dnr.state.md.us/streams/pubs/2001mbss_man.pdf**.

Additional descriptions of state protocols for assessing habitat quality can be found in EPA's Summary of Assessment Programs and Biocriteria Development for States, Tribes, Territories, Interstate Commissions: Streams and Wadeable Rivers at **www.epa.gov/bioindicators**.

The Stream Mitigation Compendium can be used to help select, adapt, or devise stream assessment methods appropriate for impact assessment and mitigation of fluvial resources in the CWA section 404 program: **www.mitigationactionplan.gov/Physical%20Stream%20Assessment%20Sept%2004%20Final.pdf**.

As a necessary component of its Rapid Bioassessment Protocols (RBPs), EPA developed a very useful and simple method for conducting visual assessments of physical habitat. In this method, 10 parameters describing physical habitat, stream morphology, riparian zones, and streambanks are visually assessed and ranked as optimal, suboptimal, marginal, or poor. Each parameter is scored on a 20-point scale (20 = optimal; 0 = poor), and then the scores are summed for a total habitat score.

Many states have developed visual habitat assessments that are based on EPA's RBPs but are designed to account for regional stream habitat characteristics. Check with your state Department of Natural Resources or a similar state agency to determine whether it has its own visually based habitat assessment approaches. For example, Ohio EPA developed a visual habitat assessment approach, the Qualitative Habitat Evaluation Index, or QHEI (Ohio EPA 1989). The QHEI considers the ability of various habitat characteristics to support viable, diverse aquatic faunas. It assesses the type and quality of substrate, amount of instream cover, channel morphology, extent of riparian canopy, pool and riffle development and quality, and stream gradient. The individual habitat metric scores are then combined into an aggregate habitat score. It should be noted, however, that the QHEI was specifically designed to meet warm-water habitat requirements for aquatic organisms in Ohio and might not be suitable for all stream types or all ecoregions. For more information visit **www.epa.state.oh.us/dsw/bioassess/ohstrat.html**.

Many of these habitat assessment protocols contain components that qualitatively measure particular stream characteristics and provide useful descriptions of overall site conditions. These physical characteristics can also be documented during a watershed survey, as discussed in section 6.5.1. Such parameters include water and sediment odors, water color and clarity, presence of trash or algae, aesthetic quality of the site, conditions of riparian areas, adjacent land use activities, and other on-site observations that could indicate stream degradation.

6.5.7 Watershed Habitat Assessment

In addition to assessing stream habitat quality, you should also assess overall watershed habitat quality. There are many components of habitat assessment for your watershed. When looking at your watershed area, you must identify the different types of habitats that compose it. Are there areas that are part of a larger habitat that spans more than one watershed? What conditions are key in forming and maintaining the major habitats in your watershed? What is the optimal patch size (i.e., size of the fragmented habitat) and spacing for each habitat?

Your watershed could contain many small habitats that were once a part of a larger, uninterrupted habitat. In many cases, parts of habitat are destroyed by community infrastructure. Highways and roads might cut areas into many smaller pieces. Residential and commercial development might have altered the shape of former habitat. When a larger habitat is split by these kinds of activities, the smaller parts left over can act as biological islands. They are no longer a fully functioning habitat, but a smaller area where numbers of species can fluctuate depending on changes in the factors that control their colonization and extinction rates. Though these smaller areas are composed of the same type of habitat as the larger area was, the smaller size could limit the number of species the area can support.

In some cases, these smaller (fragmented) habitats have been joined to form a wildlife corridor. Corridors encourage more interbreeding and result in healthier, more sustainable populations. Riparian or streamside buffers can serve as habitat corridors. Knowing where your fragmented habitats are can help you decide if forming corridors should be a part of your management plan. ↳ As mentioned in section 5.4.8, The Wildlands Project (**www.twp.org**) is a nonprofit organization that is involved in numerous large-scale projects to create corridors between habitat areas all across the nation. In addition to its Minnesota Ecosystems Recovery Project, the project is extensively involved in the Comprehensive Everglades Restoration Project in southern Florida. The assessment tools used in those projects might be useful to you. In addition, the works of Reed F. Noss (↳ also mentioned in section 5.4.8) are good resources for further study of wildlife corridors. A good place to start would be *A Checklist for Wildlands Network Design* (↳ **www.twp.org/files/pdf/Noss_consbio_final.pdf**).

Your habitat assessment should consider locations of small isolated populations of species (particularly fish) that use specific critical habitat when there are drought conditions due to natural variations in climate. These areas of habitat are referred to as refugia.

Your habitat assessment should also consider the hydrological connections within your watershed. Hydrological connectivity is the process that transfers water, matter, energy, and organisms both within habitats themselves and between different habitats. Changes in this connectivity can have devastating consequences both locally and possibly at a larger, more national scale. For example, a series of dams on a river can result in negative impacts on the migration and reproduction of anadramous fish. Your watershed could be affected by these kinds of conditions.

Landscape composition and pattern measures are other tools that can be used to diagnose ecological and hydrological condition and thus can be used as an effective method for characterizing landscape vulnerability to disturbance associated with human-induced changes and natural stress, as well as assess watershed habitat quality. In the San Pedro River watershed, which spans southeastern Arizona and northeastern Mexico, EPA scientists are using a system of landscape pattern measurements derived from satellite remote sensing, spatial statistics, process modeling, and geographic information systems technology to develop landscape composition and pattern indicators to help evaluate watershed condition. One of the tools that the San Pedro River landscape assessment scientists are using is ATtILLA, ↳ described in section 6.4.1) to measure and detect landscape change over this broad watershed area of concern. ↳ For more information on the San Pedro River landscape assessment, go to **www.epa.gov/nerlesd1/land-sci/san-pedro.htm**). The landscape characterization and change detection work helped to identify the significant changes that have taken place in the last quarter century. The information was also used as input variables for hydrologic response models which demonstrated the affect landscape change has on stream runoff (erosion) and loss of ground water infiltration. Additionally, the information has been used to model for potential wildlife habitat and has been preliminary tested for development into a watershed assessment atlas. The information is also being used by the interagency San Pedro Partnership Committee as the data source for community planning and development decisions relative to watershed protection and wildlife corridors and thus provides a focus for exchanging ideas and building consensus on significant environmental issues.

Using an approach that considers green infrastructure[2] is also a good way to help assess watershed habitats. In addition to identifying ways to connect open space areas, this type of approach also helps to identify riparian and upland habitat as well as habitat restoration and linking opportunities. In the Beaver Creek watershed in Knox County, Tennessee, the Beaver Creek Task Force and its partners developed the Beaver Creek Green Infrastructure Plan

[2] The term "green infrastructure" is commonly used within the field of watershed management with several variations for its definition. In this example, the Beaver Creek watershed partners have defined green infrastructure as an interconnected system of natural areas and other open spaces managed for the benefits to both people and the environment. See page 10-4 for a full explanation of how EPA generally defines green infrastructure.

to help protect and restore naturally functioning ecosystems, propose solutions to improve water quality, and provide a framework for future development. The entire creek is listed on the state's list of impaired waters. The Task Force identified and assessed existing habitat using land cover data from the Tennessee Wildlife Resources Agency. They then ranked and scored upland and riparian areas based on patch size, connectivity to other habitat patches, distance to water, and species richness. Using the scores, they evaluated the spatial pattern of the existing habitat to identify gaps and focus areas for restoration and protection.

In summary, many technical tools are available when undertaking a habitat assessment. Habitat assessment tools used in state wildlife action plans, GAP and Aquatic GAP (discussed in section 5.4.7), as well as statewide wetland and riparian buffer habitat assessment tools might be helpful. In addition to field data and observational efforts, modeling and remote sensing information can also be invaluable. In addition, Wetlands Mapper from the USFWS provides easy-to-use tools to display, manipulate, and query data so that you can produce your own information. The Wetlands Mapper is intended to provide a map-like view of wetland habitat data that has been collected by the USFWS (**http://wetlandsfws.er.usgs.gov/NWI/index.html)**.

Another great resource is the USGS's National Biological Information Infrastructure (NBII) Web site (**http://www.nbii.gov/portal/server.pt**). NBII is a program that provides increased access to data and information on the nation's biological resources.

Benefits of Biological Information

Biological data can be used to track water quality trends, list and delist waters under section 303(d) of the Clean Water Act, and assess the effectiveness of TMDLs.

Biological organisms provide a measure of the combined impact of stressors because they're exposed to the effects of almost all the different stressors in a waterbody.

Biological organisms integrate stress over time and thus are good measures of fluctuating water quality conditions.

Routine bioassessments can be relatively inexpensive, especially compared to the cost of monitoring individual toxic pollutants.

The public views the status of aquatic life as a measure of a pollution-free environment.

6.5.8 Biological Assessment

Biological assessments, or *bioassessments*, are highly effective for understanding overall water quality and watershed health. They consist of surveys and other direct measurements of aquatic life, including macroinvertebrates, fish, and aquatic vegetation. Changes in the resident biota are ultimately caused by changes in their surrounding environment. Therefore, by determining how well a waterbody supports aquatic life, bioassessments directly assess the condition of ecosystem health; that is, when a waterbody's biology is healthy, the chemical and physical components are also typically in good condition. To determine impairment in a waterbody of concern, the structure and function of the biological assemblages are compared with those of a known reference assemblage that approximates the undisturbed or natural condition. The greater the difference between conditions measured, the greater the extent of impairment.

In addition to benefits (see box), biological assessments have some shortcomings. Natural variability in biological communities is often extremely high, making it difficult to detect small or gradual changes in response to changes in pollutant loads. Conclusions drawn from a biological assessment might be somewhat ambiguous: Is a site poor in macroinvertebrate fauna because of a large sedimentation event, a transient toxic release, or continuously low dissolved oxygen? Finally, biomonitoring typically requires a significant investment in time and specialized skills. It is fairly easy to collect a water sample, submit it to a lab, and wait for the results; collecting, identifying, and counting benthic invertebrates is a more demanding task.

Numerous protocols are available for conducting biological assessments. One of the most accepted and commonly used methods nationwide is EPA's *Rapid Bioassessment Protocols (RBPs) for Use in Wadeable Streams and Rivers* (Barbour et al. 1999). This guidance document outlines the methods and steps required for conducting rapid bioassessments of three different assemblages—periphyton, benthic macroinvertebrates, and fish. It also contains useful information on conducting physical habitat assessments, performing data analysis, and integrating data and reporting. Go to **www.epa.gov/owow/monitoring/rbp/download.html** to download a copy of the document. The Izaak Walton League also has materials available to help with bioassessment, including a bug card, video, and score sheet for rapidly determining relative water quality. It also conducts training workshops. Go to **www.iwla.org/index.php?id=412** for more information.

Some states, such as Connecticut, have developed and tested streamlined bioassessment protocols for volunteer monitors. Go to **http://www.ct.gov/dep/cwp/view.asp?a=2719&q=325606&depNav_GID=1654** for more information.

Once you've collected the additional data needed to adequately characterize your watershed, you'll add the results to your data inventory. You can now move on to the next step. In chapter 7, you'll analyze the data to determine sources and causes of water quality impairments.

Handbook Road Map

7. Analyze Data to Characterize the Watershed and Pollutant Sources

Chapter Highlights

- Identifying locations of impairments and problems
- Determining timing of impairments and problems
- Identifying potential sources
- Determining areas for quantifying source loads

Read this chapter if...

- You want to satisfy element a of the section 319 guidelines—identification of causes and sources that need to be controlled
- You want to characterize the general environmental conditions in your watershed
- You're not sure what types of data analyses you should use
- You want to conduct a visual assessment as part of your data analysis
- You want to link your analysis results with the causes and sources of pollutants in the watershed
- You want to identify critical areas in the watershed that will need management measures to achieve watershed goals

7.1 Analyze Data to Identify Pollutant Sources

Chapter 5 discussed the first step of the watershed characterization process—identifying and gathering available data and information to assess the watershed and create a data inventory. Chapter 6 discussed the next step—conducting a preliminary data review, identifying any data gaps, and then collecting additional data if needed. All of this information will now be used in the next step—data analysis to characterize the watershed. This analysis supports the identification of watershed pollutant sources and causes of impairment, which is essential to defining watershed management needs. This chapter highlights the types of data analyses commonly used to characterize water quality and waterbody conditions and to identify watershed sources contributing to impairments and problems.

This phase of the watershed planning process should result in the first of the nine elements that EPA requires in a section 319-funded watershed plan. Element *a* is "*Identification of causes and sources or groups of similar sources that need to be controlled to achieve load reductions, and any other goals identified in the watershed plan.*"

Remember that data gathering and analysis is an ongoing, iterative process. Data examined in this phase will continue to be used in subsequent activities, such as identifying and evaluating management measures and tracking implementation efforts.

7.1.1 Focus Your Analysis Efforts

Although many techniques are described in this chapter, you will likely choose only a selected combination of the techniques in your watershed. The process of conducting data analyses to characterize your watershed and its pollutant sources begins with broad assessments such as evaluating the averages, minimums, and maximums of measured parameters at all watershed stations. The analyses are then systematically narrowed, with each step building on the results of the previous analysis. Through careful analysis you'll obtain a better understanding of the major pollutant sources, the behavior of the sources, and their impacts on the waterbodies. An understanding of the watershed conditions and sources is also the basis for determining the appropriate method for quantifying the pollutant loads.

In addition, the kinds of data analyses you perform will be determined by the amount of available data. For example, if you have data for several stations in a watershed, you'll be able to evaluate geographic variations in water quality throughout the watershed—an analysis you could not do with data for only one station.

Table 7-1 provides examples of data analysis activities and the tools used in various steps of the watershed planning process. It gives you an idea of how the parameter or analytical techniques might vary depending on where you are in the process and your reasons for analysis.

7.1.2 Use a Combination of Analysis Types

Because data analysis techniques are used to support a variety of goals and involve multiple types of data, a combination of techniques is usually used. Less-detailed analyses, such as evaluating summary statistics, might be conducted for certain pollutants, whereas more detailed analyses might be conducted for others, depending on the goals of the plan and the pollutants of concern. Data analysis is typically an iterative process that is adapted as results are interpreted and additional information is gathered.

Table 7-1. Examples of the Types of Data-related Activities Conducted throughout the Watershed Planning Process

Watershed Planning Step	Type of Data	Goal of Data Analysis	Example Activity
Characterize Watershed	• Previously conducted studies (e.g., TMDLs, 305(b) report, USGS water quality reports, university studies)	Generally characterize the watershed and identify the most important problems for further analysis.	• Review available reports and assessments.
	• Watershed data (e.g., land use, soils, habitat) • Chemical instream data • Biological instream data • Physical data • Habitat data	Perform targeted analysis of available data to characterize the waterbody and watershed. Examples: • Identify sources • Characterize the impairment • Evaluate spatial trends • Evaluate temporal trends • Identify data gaps	• Compare data to water quality standards to identify timing and magnitude of impairment. • Review monthly statistics to identify seasonal variations. • Use GIS at watershed stations to identify spatial variations in water quality and potential sources of pollutants.
Set Goals and Identify Solutions	• Watershed data (e.g., land use, soils, population, habitat) • Chemical instream data • Biological instream data • Physical data • Meteorological data • Habitat data	Appropriately represent watershed and waterbody in the model for the most accurate simulation of watershed loads.	• Use data to establish a non-modeling analysis (e.g., use observed data to establish a spreadsheet mass balance calculation). • Use data for model setup (e.g., identify appropriate model parameter values, establish watershed characteristics such as land use and soils). • Compare observed data to model output for calibration and validation.
Implement and Evaluate	Instream monitoring data for the parameters of concern (e.g., nutrients)	Evaluate the effectiveness of management measures and track the progress of water quality improvement.	• Compare data collected upstream and downstream of management practices. • Compare data collected before and after implementation of management practices to track water quality improvement.

Note: TMDL = Total Maximum Daily Load; USGS = U.S. Geological Survey; GIS = geographic information system.

7.1.3 Consider Geographic Variations

The kinds of analyses and the level of detail used in your data analysis will vary within the watershed depending on the pollutants of concern. For example, if bacteria loading from livestock operations is a primary concern in the watershed, detailed land use analysis might be necessary to identify pasturelands and evaluate proximity to streams and water access for livestock, as well as to identify and characterize areas of cropland that receive manure applications. In addition, detailed water quality analyses might be needed for the areas that contain livestock to evaluate the timing and magnitude of impacts as related to livestock grazing schedules and access to waterbodies. For other areas of the watershed, general water quality characterization will be sufficient, and low-level evaluations of stream characteristics, watershed soils, and other types of data will be acceptable given the focus of the data analysis.

7.1.4 Incorporate Stakeholders' Concerns and Observations

Stakeholder concerns and goals will also help to determine what kinds of analyses are needed. If the stakeholders and the earlier characterization identified bacteria- and metals-associated impacts from developed areas as a primary concern, the data analysis will focus on characterizing those parameters and the locations, types, or timing of pollutant loading from urban and residential sources in the watershed. If a specific source is expected to be contributing to water quality problems, more detailed analyses might be conducted on data collected upstream and downstream of that source, or smaller time scales (e.g., daily concentrations) might be evaluated. Data analysis in the remainder of the watershed would be more coarse, identifying simple summary statistics (e.g., monthly minimum, maximum, average) sufficient for general characterization of identified subwatersheds. Table 7-2 illustrates this concept with examples of different levels of effort for the various types of data used in watershed characterization. Other factors to consider regarding level of detail include relative costs of remediation, risks to human health and aquatic life, and level of disagreement among stakeholders—all of which would likely increase the level of detail needed.

Table 7-2. Examples of the Level of Detail and Effort for Typical Types of Data

Type of Data	Increasing level of complexity		
	Low	**Moderate**	**High**
Instream (e.g., water quality, flow)	Summary statistics (e.g., minimum, average, maximum) for watershed stations	Spatial analysis of water quality using instream water quality data and GIS coverages	Spatial and temporal analysis of multiple instream parameters and GIS mapping data (often combined with modeling and supplemental monitoring)
Land use	General distribution of land use types throughout the watershed, using broad categories (e.g., agriculture, urban)	Specific identification of land use areas by subwatershed, including more detailed categories (e.g., cropland, pasture, residential, commercial)	Statistical analysis of land use areas in relation to water quality conditions (e.g., regression analysis between amount of impervious area and average flow or water quality)
Soils	General distribution of soil types based on available information	GIS analysis of the locations and types of soil series	Detailed analysis of soil distribution, including identification of proximity to streams, erosion potential, and other soil characteristics affecting soil erosion and transport
Habitat	General distribution of habitats based on available data	Mapping of critical habitats and their buffers	Landscape pattern measurement near critical habitat areas with GIS modeling

Once the focus of the data analysis has been identified, the relevant data are compiled and analyses are conducted. The following sections discuss the typical types of data analyses used to support watershed characterization and the primary data analysis techniques available to evaluate the watershed and identify causes and sources.

7.2 Analyze Instream and Watershed Data

Data analysis helps to evaluate spatial, temporal, and other identifiable trends and relationships in water quality. Analysis of instream data is needed to identify the location, timing, or behavior of potential watershed sources and their effect on watershed functions such as hydrology, water quality, and aquatic habitat. Analysis of habitat data is needed to identify areas that need to be restored or protected. You developed a preliminary assessment of the watershed during the first and second phases of watershed characterization. Now, with a more comprehensive dataset, you can perform a more detailed and definitive analysis.

One way to organize and focus the data analysis is to consider the specific watershed characteristics and the questions that need to be answered before an appropriate management strategy can be developed. Use Worksheet 7-1 to help determine the types of analyses you might need to conduct for water quality. Use Worksheet 7-2 to help determine the types of analyses you might need to conduct for habitat assessment and protection. Blank copies are provided in appendix B.

Worksheet 7-1 *What Data Analysis Do We Need to Conduct for Water Quality?*

Questions to help determine what kinds of data analyses are needed

Question	Section to refer to for assistance
1. Are water quality standards being met? If so, are they maintaining existing levels?	7.2.1 (Confirm Impairments) 7.2.2 (Summary Statistics)
2. Is water quality threatened?	7.2.1 (Confirm Impairments) 7.2.2 (Summary Statistics)
3. Is water quality impaired?	7.2.1 (Confirm Impairments) 7.2.2 (Summary Statistics)
4. Are there known or expected sources causing impairment?	77.2.7 (Visual Assessment)
5. Where do impairments occur?	7.2.3 (Spatial Analysis)
6. When do the impairments occur? Are they affected by seasonal variations?	7.2.4 (Temporal Analysis)
7. Under what conditions (e.g., flow, weather) are the impairments observed?	7.2.4 (Temporal Analysis) 7.2.5 (Other Trends and Patterns)
8. Do multiple impairments (e.g., nutrients and bacteria) coexist?	7.2.5 (Other Trends and Patterns)
9. Are there other impairments that are not measured by water quality standards?	7.2.6 (Stressor Identification)

Questions to answer based on the results of the data analysis:

1. What beneficial uses for the waterbodies are being impaired? What pollutants are impairing them?
2. What are the potential sources, nonpoint and point, that contribute to the impairment?
3. When do sources contribute pollutant loads?
4. How do pollutants enter the waterbody (e.g., runoff, point sources, contaminated ground water, land uses, ineffective point source treatment, pipe failures)?
5. What characteristics of the waterbody, the watershed, or both could be affecting the impairment (e.g., current or future growth, increased industrial areas, future NPDES permits, seasonal use of septic systems)?
6. Revisit the conceptual model showing the watershed processes and sources, and revise it if necessary

Worksheet 7-2 *What Data Analysis Do We Need to Conduct for Habitat Assessment and Protection?*

1. Where are critical habitats (e.g., headwaters, wetlands, forests, springs and seeps) and their buffers located?
2. What is their conservation status?
3. What is their condition?
4. Are they threatened?
5. Are there opportunities to protect or restore buffers or fill a habitat connectivity gap to reduce fragmentation and protect source water?
6. How does spatial hierarchy (e.g., site, subwatershed, watershed, basin, and region) factor into habitat protection and restoration goals?
7. What are the current and future development projections and how will they affect habitats and their buffers?

Typical analyses used to address these questions include statistical analysis, spatial analysis, temporal analysis, trends and relationships, and flow and load duration curves. It's important to note that most of the analyses discussed in this section focus on water quality monitoring data because many watershed goals can be directly or indirectly linked to instream water quality conditions. In addition, water quality is an indicator of the general watershed conditions and pollutant source types, locations, and behavior. However, you should also broaden the evaluation of watershed conditions by incorporating additional data types (e.g., land use, weather, and stream morphology) discussed in chapter 5, as necessary or appropriate for your watershed. Further, to meet watershed conservation, protection, and restoration goals and management measures, you should analyze habitat data and use assessment tools to identify priority habitats and their buffers, their configuration in a watershed, and the key habitat conditions and habitat-forming processes. A summary of the various types of analyses used in a watershed characterization is provided below.

7.2.1 Confirm Impairments and Identify Problems

The first step in characterizing your watershed involves understanding the water quality impairments and designated use impacts occurring in the watershed. The following reports and databases are available to support this activity:

- **305(b) report (as part of the Integrated Report)**—summarizes designated use support status for waters in the state
- **303(d) lists (as part of the Integrated Report)**—identify waters not meeting water quality standards
- **EPA's Assessment Database (ADB)**—includes data used in 305(b) and 303(d) assessments
- **TMDL Tracking System (stand-alone or through WATERS)**—includes locations of 303(d)-listed waterbodies and provides downloadable geographic information system (GIS) coverages

Although these references provide the necessary information to *identify* the types of water quality problems occurring in your watershed, it's likely that you'll have to analyze the available monitoring data yourself to fully *characterize and understand* the problems. This analysis typically involves comparing available monitoring data to water quality standards, but in a way that goes beyond the assessment already completed by the state for section 303(d) and 305(b) assessments. When identifying impaired waterbodies for the 303(d) list, states usually compare available monitoring data to applicable water quality criteria and, on the basis of their listing guidelines and criteria (e.g., percentage of samples above the criteria), determine which waters don't meet the criteria. In evaluating impairments in your watershed, you don't want to simply duplicate the state's efforts. ◎ Instead, use the 305(b) and 303(d) information to target your analyses—to identify which waterbodies are impaired or threatened—and begin your analysis there. (You should also include in your analysis those waterbodies identified by stakeholders as degraded but not included in the state assessments.)

EPA's Assessment Database

EPA's new Assessment Database (ADB) application provides a framework for managing water quality assessment data. The ADB is designed to serve the needs of states, tribes, and other water quality reporting agencies for a range of water quality programs (e.g., CWA sections 305(b), 303(d), and 314). The ADB stores assessment results related to water quality standards designated use attainment, the pollution associated with use impairments, and documentation of probable pollution sources. The ADB can be used to generate several pre-formatted reports, as well as conventional data tables and lists. For more information on using the ADB, go to **www.epa.gov/waters/adb**. The most recent EPA Integrated Report guidance includes an increased emphasis on using the ADB to meet reporting requirements.

It's a good idea to do a general analysis (e.g., summary statistics) of all the waterbodies and associated data in your watershed, but you can focus the more in-depth evaluation of impairment on those waterbodies known to have problems. To better understand the watershed impairments, you can analyze the water quality and instream data in a variety of ways. The first likely analysis is simply the magnitude of the impairment—how bad is the problem? Identifying the percentage of samples that violate standards provides insight into the level of impairment in the watershed, or at a particular location. Using a graphical display of water quality data compared to applicable criteria is also an easy way to generally illustrate the frequency and magnitude of standards violations, as shown in figure 7-1. A temporal analysis of water quality versus standards can be used to identify the times of year, season, month, and even day when the impairment is occurring or is the worst. Temporal and other analyses are discussed further in this section. These analyses are used to understand the general watershed conditions and to support identification of pollutant sources, but they also provide information specific to the distribution, timing, and magnitude of water quality impairment.

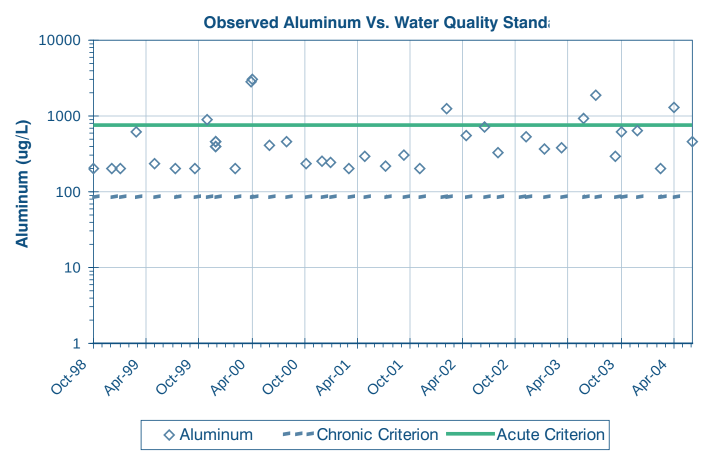


Figure 7-1. Example Graph of Observed Aluminum Concentrations Compared to Water Quality Criteria

7.2.2 Summary Statistics

Statistical analyses are essential tools for describing environmental data and evaluating relationships among different types of data. You might not need to conduct in-depth statistical testing to characterize your watershed, but it's often useful to develop summary statistics to summarize your available datasets, to help in preliminary analysis, and to communicate your results to stakeholders and the public. Summary statistics include such characteristics as range (e.g., minimum, maxi-

More on Statistics

This section discusses the typical types of data analyses used to support watershed characterization and identification of pollutant sources. Each analysis can be conducted with varying degrees of detail and complexity. In addition, it might be useful to perform more detailed statistical tests. For example, a Mann-Kendall test can be applied to long-term datasets to indicate whether there is a statistically significant increasing or decreasing trend in the water quality data. Available references with information on statistical analysis of environmental data include

Helsel, D.R., and R.M. Hirsch. 2002. Statistical Methods in Water Resources. Chapter A3 in Book 4, Hydrologic Analysis and Interpretation, of Techniques of Water-Resources Investigations of the United States Geological Survey. **http://water.usgs.gov/pubs/twri/twri4a3**.

NRCS (Natural Resources Conservation Service). 1997. *National Handbook of Water Quality Monitoring*. 450-vi-NHWQM. National Water and Climate Center, Portland, Oregon.

mum), central tendency (e.g., mean, median), and variability (standard deviation, coefficient of variation). Figure 7-2 defines many of the commonly used statistical terms. Summary statistics should be computed for all stations and relevant data (e.g., pollutants of concern) as one of the first steps in your data analysis. Microsoft Excel and other spreadsheet programs make developing summary statistics simple. The program can automatically calculate any of the statistical functions based on the dataset. In addition, you can create Pivot tables in Excel that calculate several statistical functions for any combination of the data at once (e.g., by pollutant by station). It is useful to also calculate the number or percentage of samples violating water quality criteria to include in your summary statistics for each station.

Measures of Range: Identify the span of the data from low to high.

Minimum: The lowest data value recorded during the period of record.

Maximum: The highest data value recorded during the period of record.

Measures of Central Tendency: Identify the general center of a dataset.

Mean: The sum of all data values divided by the sample size (number of samples). Strongly influenced by outlier samples (i.e., samples of extreme highs or lows); one outlier sample can shift the mean significantly higher or lower.

Median ($P_{0.50}$): The 50th percentile data point; the central value of the dataset when ranked in order of magnitude. The median is more resistant to outliers than the mean and is only minimally affected by individual observations.

Measures of Spread: Measure the variability of the dataset.

Sample variance (s^2) and its square root, standard deviation (s): The most common measures of the spread (dispersion) of a set of data. These statistics are computed using the squares of the difference between each data value and the mean, and therefore outliers influence their magnitudes dramatically. In datasets with major outliers, the variance and standard deviation might suggest much greater spread than exists for most of the data.

Interquartile range (IQR): The difference between the 25th and 75th percentile of the data. Because the IQR measures the range of the central 50 percent of the data and is not influenced by the 25 percent on either end, it is less sensitive to extremes or outliers than the sample variance and standard deviation.

Measures of Skewness: Measures whether a dataset is asymmetric around the mean or median and suggests how far the distribution of the data differs from a normal distribution.

Coefficient of skewness (g): Most commonly used measure of skewness. Influenced by the presence of outliers because it is calculated using the mean and standard deviation.

Quartile skew coefficient (qs): Measures the difference in distances of the upper and lower quartiles (upper and lower 25 percent of data) from the median. More resistant to outliers because, like the IQR, uses the central 50 percent of the data.

Figure 7-2. Commonly Used Summary Statistics

7.2.3 Spatial Analysis

If evaluation of the summary statistics for the water quality stations in your watershed indicates noticeable differences in water quality throughout the watershed, you should do a more focused analysis of spatial variation in water quality and other waterbody monitoring data. Spatial analysis of available waterbody data can be useful to

- Determine the general distribution of water quality or habitat conditions
- Identify the locations of areas of concern or potential major sources
- Determine the impact of a specific source
- Identify the effect of a management practice or control effort

The spatial distribution of water quality conditions in the watershed might indicate the location of "hot spots" and sources potentially affecting impairment. Spatial analysis of data is also useful in evaluating the potential impacts of specific sources, when sufficient data are available. Evaluating the difference in paired observations from stations upstream and downstream of a potential source can indicate the impact of the source on instream conditions. Similar data analysis can be conducted on data available upstream and downstream of a management practice to evaluate the effectiveness of the management practice in reducing pollutant loads to the waterbody.

Simply reviewing a table of summary statistics for each station in the watershed can identify areas of varying water quality. When dealing with a large watershed with multiple stations, however, a GIS can be used to effectively present and evaluate spatial variations in water quality conditions, as shown in the example map in figure 7-3. Presenting water quality summaries by station throughout a watershed in GIS also allows for identification of corresponding watershed conditions or sources that might be causing the spatial variations, such as land use distribution and location of point sources. This information is important for identifying the potential sources that might be causing the watershed problems and impairments.

Even if sufficient monitoring data are not available to adequately evaluate spatial variation in water quality, you should still evaluate other available watershed data to understand the spatial distribution of characteristics that are likely influencing waterbody conditions, such as land use, soils, and location of permitted sources. GIS is a very useful tool for displaying and evaluating these kinds of data.

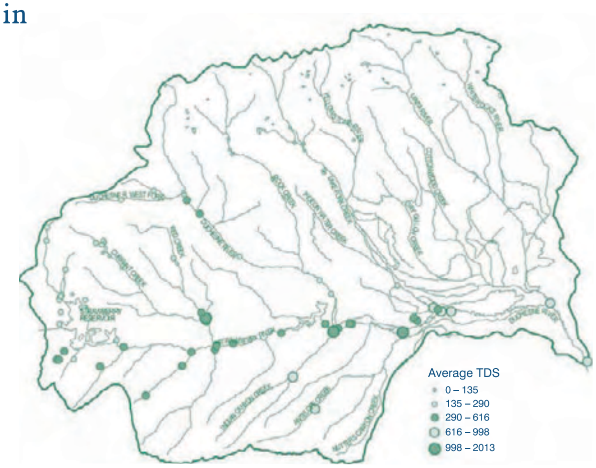


Figure 7-3. Example Map of Average Total Dissolved Solids Concentration Throughout a Watershed

7.2.4 Temporal Analysis

Another important analysis is the evaluation of temporal trends in water quality conditions. Evaluating temporal patterns can assist in identifying potential sources in the watershed, seasonal variations, and declining or improving water quality trends. Temporal analyses can include long-term trend analysis to identify generally increasing or decreasing trends in data and more focused analysis of monthly, seasonal, and even daily and hourly variations.

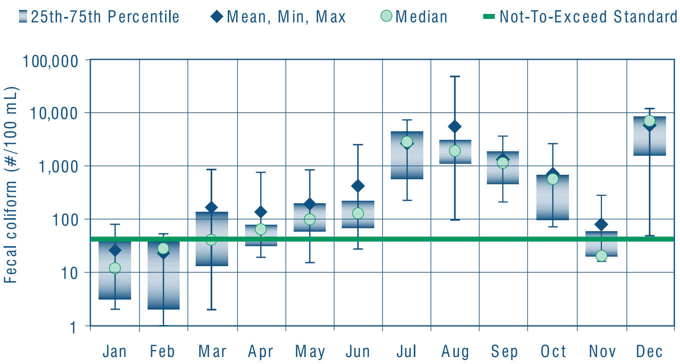


Figure 7-4. Example Graph of Monthly Statistics for Fecal Coliform Bacteria

Degraded water quality during certain months or seasons can indicate the occurrence of a source that is active only during those times. For example, elevated concentrations of nutrients or bacteria during the summer months (figure 7-4) might indicate increased source activity, such as livestock grazing, during those months. It might also indicate a need for further analysis of other watershed conditions (e.g., weather, flow) that can exacerbate the impairment during the summer months. For example, warmer temperatures during the summer might increase the productivity of algae, leading to greater decreases in dissolved oxygen.

7.2.5 Other Trends or Patterns

It is often beneficial to evaluate relationships and trends in the available data other than spatial and temporal trends. Important examples include

- Evaluating the relationship between flow and instream water quality (see chapter 5 for data sources)
- Documenting the relationship between related pollutants
- Evaluating the relationship of instream conditions to other watershed factors (e.g., land use, source activity)

Flow Versus Water Quality

An identifiable relationship between flow and instream water quality concentrations can indicate what types of pollutant sources dominate the instream impairment and can help to identify critical conditions surrounding the impairment. For example, runoff-driven nonpoint sources typically dominate instream water quality conditions during periods of high flow resulting from rainfall/runoff events, whereas point sources that provide relatively constant discharges to receiving waters usually dominate water quality during low flow, when there is less water to dilute effluent inputs.

There are several options for evaluating the relationship between flow and a water quality parameter, including visually evaluating time series data, developing a regression plot, calculating flow-weighted averages, evaluating monthly averages, and developing a flow duration curve.

A flow duration curve can be a useful diagnostic tool for evaluating critical conditions for watershed problems and the types of sources that could be influencing waterbody conditions. Flow duration curves graph flows based on their occurrence over the period of record. Flows are ordered according to magnitude, and then a percent frequency is assigned to each, representing the percentage of flows that are less than that flow. For example, a flow percentile of zero corresponds to the lowest flow, which exceeds none of the flows in that

Using Duration Curves to Connect the Pieces

America's Clean Water Foundation published an article discussing duration curves and their use in developing TMDLs (Cleland 2002). The duration curves act as an indicator of relevant watershed processes affecting impairment, important contributing areas, and key delivery mechanisms. To read the full article and get more information on the use of duration curves to diagnose seasonal impacts and potential sources, go to **www.tmdls.net/tipstools/docs/BottomUp.pdf**.

record. The percentage of 100 corresponds to the highest flow, which exceeds all the flows in that record. The flow duration is often plotted with corresponding pollutant concentrations to evaluate the relationship between water quality and flow. To do this, you should isolate matching flow and water quality and plot the flow and concentration data as a function of flow percentile.

A variation of the flow duration curve is the load duration curve, which plots observed pollutant loads as a function of flow percentile. Matching water quality and flow (measured on the same day) are used to calculate observed loads, by multiplying flow by pollutant concentration and an appropriate conversion factor. The loads are then plotted along with the flow in order of flow percentile. The load duration curve provides information on when loading occurs.

As shown in the example load duration curve (figure 7-5), the total dissolved solids (TDS) concentrations tend to follow a pattern similar to the flow, with lower concentrations occurring during lower flows and elevated concentrations during higher flows. This indicates that surface runoff (nonpoint source runoff or stormwater discharges) is likely the source of elevated TDS rather than point source discharges. The flow duration method does not allow you to identify specific sources (e.g., residential versus agricultural), but it provides useful information on the conditions under which problems occur and the general types of sources affecting the waterbody.

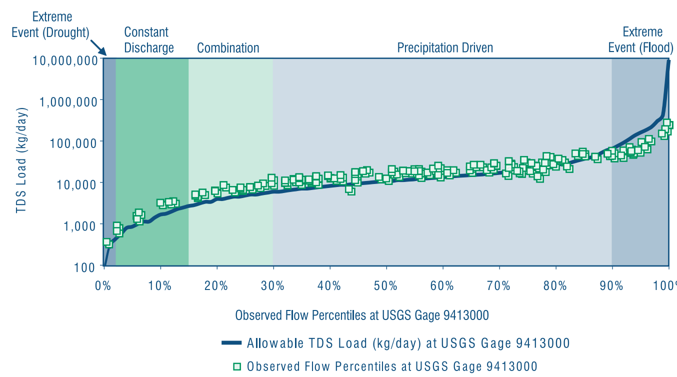


Figure 7-5. Example Load Duration Curve

Relationships between Pollutants

It's also important to evaluate the correlation of instream concentrations (and loading) of pollutants of concern to other parameters that represent the same impairment or are likely being contributed by similar sources. For example, metals often attach to sediments, resulting in increased metals loading during times of high sediment erosion and runoff. Establishing a correlation between instream sediment and metal concentrations can indicate that metals loading in the watershed is sediment-related. Understanding these relationships will be important when establishing load reductions and selecting appropriate management activities.

Using the Correlation of Phosphorus, pH, and Chlorophyll *a* to Understand Instream Conditions and Focus Management Efforts

The Vandalia Lake, Illinois, TMDL establishes load reduction goals for total phosphorus to address impairments from both phosphorus and pH. Fluctuations in pH can be correlated to photosynthesis from algae. Chlorophyll *a* indicates the presence of excessive algal or aquatic plant growth, which is a typical response to excess phosphorus loading. Reducing total phosphorus is expected to reduce algal growth, thus resulting in attainment of the pH standard. Available monitoring data for the lake were used to evaluate the relationship between pH, chlorophyll *a*, and total phosphorus. The general relationships suggested that controlling total phosphorus will decrease chlorophyll *a* concentrations, which will in turn reduce pH into the range required for compliance with water quality standards. For more information, go to **www.epa.state.il.us/water/tmdl/report/vandalia/vandalia.pdf**.

Waterbody Conditions Versus Watershed Characteristics

Evaluating relationships between instream conditions and watershed features or conditions will also facilitate identifying sources and establishing successful management goals and focused implementation efforts. For example, performing statistical analyses on instream data and watershed features, such as weather patterns, land use (e.g., percent impervious, area of urban), or soils (e.g., erodibility), can establish a quantitative link between watershed conditions and the resulting instream conditions. It might also be appropriate to divide data into separate datasets representing certain time periods or conditions for evaluation (e.g., storm event versus base flow, irrigation season, grazing season).

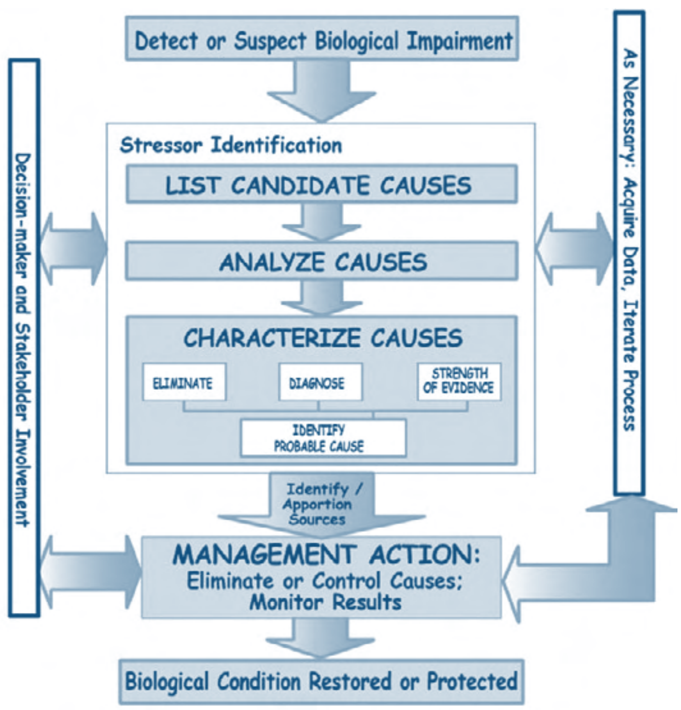


Figure 7-6. Stressor Identification Process

7.2.6 Stressor Identification

When waterbodies experience biological impairment due to unknown causes, stressor identification is used to identify the most likely causes of the impairment (figure 7-6). This formal method of causal evaluation can be used in a number of ways:

- To increase confidence that costly remedial or restoration efforts are targeted at factors that can truly improve biological condition
- To identify causal relationships that are otherwise not immediately apparent
- To prevent biases or lapses of logic that might not be apparent until a formal method is applied

For a detailed description of the stressor identification process, see EPA's *Stressor Identification Guidance Document* (USEPA 2000b; **www.epa.gov/waterscience/biocriteria/stressors/stressorid.html**). In addition, two stressor identification modules originally developed as part of EPA's 2003 National Biocriteria Workshop are available online. The SI 101 course contains several presentations on the principles of the stressor identification process: **www.epa.gov/waterscience/biocriteria/modules/#si101**.

EPA recently released the Causal Analysis/Diagnosis Decision Information System (CADDIS) to support determination of causes of biological impairment. CADDIS is an online tool that helps investigators in the regions, states, and tribes to find, access, organize, use, and share information to produce causal evaluations of aquatic systems. It is based on the EPA's stressor identification process. Current features of CADDIS include

- Step-by-step guide to conducting a causal analysis
- Downloadable worksheets and examples
- Library of conceptual models
- Links to helpful information

Go to the CADDIS Web site at **http://cfpub.epa.gov/caddis/home.cfm** to access CADDIS and obtain more information.

Ecological Risk Assessment

EPA has developed a wide range of tools that consider place-based, multimedia approaches to environmental management. Watershed ecological risk assessments provide resource managers with predictions of what ecological changes will occur from the stressors associated with existing conditions and alternative management decisions. For more information, go to **www.epa.gov/waterscience/biocriteria/watershed/waterrisk.html**.

7.2.7 Visual Assessments and Local Knowledge

It's important to remember that monitoring and GIS data can provide only a representation of your watershed. Depending on the frequency of monitoring, the data might not reflect chronic conditions but rather provide a snapshot of conditions unique to the time of sampling, especially when dealing with parameters that are highly variable and sensitive to localized impacts (e.g., bacteria counts). To make the most of your data analysis, it's important to analyze the data with an understanding of the real world. Use the data analysis to support what you already know about the watershed from the people that live and work there. As discussed in sections 4.3.2 and 6.5.1, visual assessments (e.g., streamwalks, windshield surveys) are useful for identifying and connecting potential sources of impairment and watershed conditions and should be used to guide and support data analysis for identifying watershed sources. In watersheds with limited monitoring data, visual assessments are especially important, providing the basis for source identification.

Not only are visual assessments useful for identifying potential pollutant sources and areas on which to focus your data analysis, but they can also answer questions raised by your data analysis. For example, if your data analysis shows a dramatic decrease in water quality in a portion of your watershed, but the land use and other watershed coverages don't indicate any major sources in that area, it's a good idea to walk the stream or drive through the area to identify any possible reasons for the change. For example, your data might indicate sharp increases in sediment measures (e.g., turbidity, total suspended solids) between two monitoring stations. However, reviewing the land use maps does not suggest any activities that would account for such a dramatic increase. When you drive through the watershed, you might find a source that you would never know about without surveying the area, such as a severely eroding streambank or livestock or wildlife watering in the stream and causing resuspension of streambed sediments.

Examples of Sources You Might Miss without a Watershed Tour

- Streambank erosion
- Pipe outfalls
- Livestock (near or with access to streams)
- Wildlife (e.g., waterfowl populations on lakes and open streams)

In addition to visual inspection of the watershed, local knowledge and anecdotal information from stakeholders are often very important to successfully analyzing and interpreting your watershed data. They, too, can provide useful insight to support or guide data analysis, especially if they provide historical information that would not be identified through a present-day visual assessment. A data analysis conducted for Lake Creek, Idaho, provides an example of stakeholder anecdotal information's being crucial to identifying a watershed source. The data analysis indicated an unexplained increase in turbidity and sediment between two stations in the stream (figure 7-7). Discussing the data analyses with stakeholders allowed TMDL developers to understand that the increase was the result of localized logging that had occurred near the stream several years earlier. Knowing that the logging had occurred explained why the turbidity levels had dramatically and quickly increased at the downstream station and were now still recovering. Without this knowledge, the TMDL might have inappropriately targeted areas that were not affecting the stream.

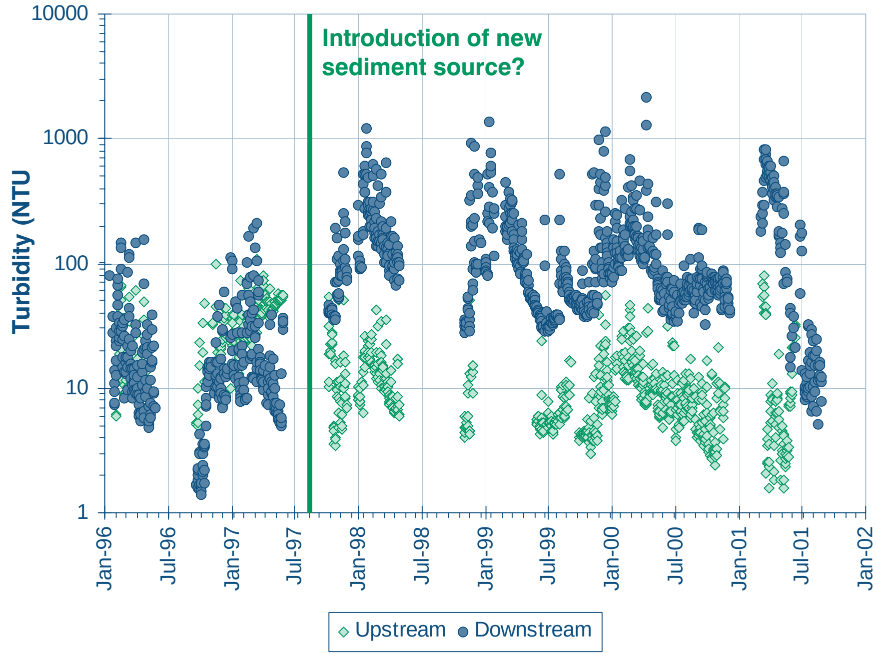


Figure 7-7. Long-term Turbidity Levels at Two Stations in Lake Creek, Idaho

7.3 Evaluate Data Analysis Results to Identify Causes and Sources

Together with the input from stakeholders and your local knowledge of the watershed, analyzing your data should lead you to an understanding of where and when problems occur in your watershed and what could be causing the problems. Ideally the data analysis phase will progress in such a manner that each analysis leads to greater understanding of the problems, causes, and sources. Suppose, for example, that you started your analysis with a calculation of summary statistics for bacteria at all the stations in your watershed. In doing so, you noticed that stations in the upstream portion of the watershed had higher averages, maximums, and minimums than the rest of the watershed. Focusing on those stations, you began to evaluate temporal variations, noting that bacteria levels were consistently higher during the spring and summer. From there you began to look at other factors that might change seasonally, including weather, flow, and surrounding land activities. You discovered that although rainfall and flow are higher during the spring, possibly delivering higher bacteria loads, they are lower during the summer. Also, rainfall and flow are higher throughout the watershed, not in only this “problem area.” So, what else might be causing the higher levels during those two seasons? By evaluating land use data for the surrounding area, you realize there are some concentrated pockets of agricultural land in the area. After talking to stakeholders and driving the watershed, you identify several acres of pastureland used for horse and cattle grazing

Watershed Assessment of River Stability and Sediment Supply

EPA provided support for the development of a three-phase technical framework of methods for assessing suspended and bedload sediment in rivers and streams. The *Watershed Assessment of River Stability and Sediment Supply* (WARSSS) tool focuses on natural variability in sediment dynamics, geologic versus anthropogenic sediment sources, erosional and depositional processes, prediction of sediment loads, streamflow changes, and stream channel stability and departure from reference conditions. WARSSS was developed by Dr. David L. Rosgen to help watershed managers analyze known or suspected sediment problems, develop sediment remediation and management components of watershed plans, and develop sediment TMDLs, and for other uses. This Web-based assessment tool was designed for scientists that need to assess sediment-impaired waters in planning for their restoration. For more information, go to **www.epa.gov/warsss/**.

during the spring and summer. Much of the pastureland is in close proximity to the streams with elevated observed bacteria, and in some of the pastures animals have direct access to the streams. Such a combination of focused data analyses, visual assessments, and local knowledge is critical to identifying and understanding watershed sources.

In addition, the data analysis will identify on which sources you'll need to focus during the loading analysis discussed in chapter 8. Some sources will be expected to have a greater impact on watershed problems than others and might require more detailed analysis. For example, if runoff from developed areas is expected to be the primary cause of elevated metals in watershed streams, it might not be necessary to evaluate subcategories of agricultural or other undeveloped lands in the loading analysis. You can likely group those land uses or sources and focus on the developed areas, possibly even breaking them into more detailed categories (e.g., suburban, commercial).

7.3.1 Grouping Sources for Further Assessment

Once you understand the potential causes and sources of the watershed problems, you should decide at what level you want to characterize those sources. The next step of the process is to quantify the watershed sources—to estimate the pollutant loads contributed by the sources (chapter 8). Therefore, you should identify the sources you want to quantify. The level of detail in estimating the source loads can vary widely and will depend largely on the results of your data analysis. The analysis should give you an understanding of the sources that are affecting watershed and waterbody conditions, providing a guide for which sources need to be controlled. Therefore, it's important to identify sources at a level that will result in effective control and improvement. For example, if you have identified specific pastures in one portion of the watershed as dominating the bacteria levels in your watershed during the summer, it would not be appropriate to quantify agricultural or even pastureland sources as an annual gross load for the *entire* watershed.

Example Categories for Grouping Pollutant Sources

- Source type (e.g., nonpoint, point)
- Location (e.g., subwatershed)
- Land use type
- Source behavior (e.g., direct discharge, runoff, seasonal activities)

To facilitate estimation of source loads, and later source control, sources should be grouped into logical categories that help to prioritize and address certain pollutants, sources, or locations for more efficient and effective management. Consider the following factors and methods when grouping sources for assessment. You can combine many of the methods to create various groupings and layers of sources, relevant to the needs and priorities of the watershed plan.

Nonpoint Source Versus Point Source

Although watershed plans typically focus on nonpoint sources, they should consider and integrate point sources for effective watershed protection. You should separate nonpoint sources from point sources for assessment for both technical and programmatic reasons. Nonpoint and point sources typically behave differently and affect the receiving waters under different conditions. For example, nonpoint sources usually contribute pollutant loads that are washed off and transported during precipitation events, affecting waterbody conditions during times of higher surface runoff and, therefore, higher flow. Point sources usually discharge constant loads to receiving waters, affecting waterbody conditions during times of low flow when there is less water to dilute incoming effluents. Not only do point and nonpoint sources behave and affect waterbodies differently, but their management and control mechanisms are also different. Grouping them separately when considering future implementation of control measures is logical.

Spatial Distribution and Location

Grouping sources by location facilitates their assessment by dividing the area of concern into smaller, more focused areas, and it often supports future implementation. Spatially grouping sources helps to identify priority regions or locations that should be targeted for control. The method of grouping sources typically involves creating subwatersheds within the larger watershed of concern and also prioritizing sources within the subwatershed by some other methodology (e.g., proximity to a stream, land use).

Land Use Distribution

Sources are often specific to certain land uses, making it logical to group them by land use. For example, sources of nutrients such as livestock grazing and fertilizer application, which occur in conjunction with agricultural land use, would not likely contribute the same loads as other land uses such as urban or forest uses. Likewise, urban land uses typically have a set of pollutants of concern (e.g., metals, oil, sediment) different from those of rural land uses based on the active sources. Although it is difficult to isolate inputs from individual sources within a land use, assessing them as land use inputs can still support evaluation of loading and identification of future controls. Sources can be grouped and characterized by land use at a large scale, such as all agricultural lands, or at a very detailed level, such as specific crop type. In some cases, subcategories of nonpoint sources should be used to estimate the source contribution. For example, a land use like agriculture would often be further broken down into grazing or cropland, allowing a more accurate estimate of the sources coming from each subcategory and the ability to choose the most effective management practices for each subcategory.

Grouping sources according to their land use also facilitates identification of future implementation efforts because certain management practices are most effective when applied to a certain land use.

Delivery Pathway and Behavior

Nonpoint sources, depending on their behavior, can contribute pollutants to receiving waters through different delivery pathways. The nature of the delivery might support separate assessment of the source. For example, grazing cattle might be treated as a separate source depending on the activity or location of the cattle. Livestock on rangeland can contribute pollutants to the land that are picked up in runoff, whereas livestock in streams deposit nutrient and bacteria loads directly to the streams. Different methods might be required to evaluate the effect of each group on waterbody conditions. Another example is failing septic systems that might be contributing pollutant loads to waterbodies. Because loads from the septic systems can be delivered through ground water and also through surface breakouts, you might decide to conduct separate analyses to estimate their loads.

Other Factors

Additional factors that can influence the grouping of sources include the following:

- **Social and economic factors.** Certain sources and their impact might be of higher priority to the affected public because they are more visible than other sources or because they could have negative impacts on the local economy. Public buy-in and priorities can influence the evaluation and grouping of sources, as well as subsequent source control.
- **Political jurisdictions.** Because source control can ultimately fall to different jurisdictions (e.g., counties), it might be necessary to evaluate sources based in part on jurisdictional boundaries. In some cases, the sources might even be subject to different laws and control options, depending on where they're located.

7.3.2 Time Frame for Source Assessment

Another important consideration when deciding how to quantify your sources is the time frame you want to capture. Your data analysis should provide insight into the timing of watershed problems and, therefore, into the temporal scale you need to evaluate sources. For example, instream dissolved oxygen might decrease only during summer months because of increased nutrient loading, higher temperatures, and lower flows. Therefore, it will be important to characterize and quantify sources on a time scale that allows for evaluation during the summer months. It would not be appropriate to evaluate annual loading for a problem that occurs only during the summer.

7.4 Summarize Causes and Sources

9 On the basis of your data analysis, you should now be able to identify the key sources you will quantify in the next step of the watershed planning process (elements a and b). You should identify the source type, locations, and timing for load estimation (chapter 8). It might be helpful to identify the areas for evaluation on a watershed map to determine the key locations for conducting the loading analysis and which sources will be included in the analysis. You should also develop a brief report summarizing your data analyses and their results and describing the watershed sources, including their location, associated pollutants, timing, and impact on the waterbody.

9 In identifying your sources and grouping them for load estimation, you'll also begin to identify the critical areas needed for implementing management measures, as required as element c of the nine minimum elements. Element *c* is "*A description of the nonpoint source management measures that will need to be implemented to achieve load reductions and a description of the critical areas in which those measures will be needed to implement this plan.*" At this step, you have identified the recommended source groupings and priorities and you'll continue to refine the groupings as you conduct your loading analysis (chapter 8) and target your management measures (chapters 10 and 11). You'll identify the final critical areas when you select the management strategies for implementing your plan (chapter 11), but the sources and associated groupings and characteristics you have identified at this stage will provide the basis and groundwork for identifying those critical areas.

8. Estimate Pollutant Loads

Chapter Highlights

- Load estimation techniques
- Using models to estimate loads
- Available models
- Model selection
- Model application techniques
- Presenting pollutant loads

Read this chapter if...

- You're not sure how to estimate pollutant loads from your watershed sources
- You want information on simple or more detailed approaches for estimating loads
- You want to select a watershed model that's right for your watershed and needs
- You want information on the various watershed models available and their capabilities
- You want to review the typical steps used in applying watershed models to estimate pollutant loads and evaluate source contributions
- You want some ideas on how to organize the results of your load estimation analysis and present pollutant loads

8.1 How Do I Estimate Pollutant Loads?

Early in the watershed characterization process, you identified and gathered available data and information to assess the watershed and created a data inventory. Then you conducted a preliminary data review, identified gaps, and collected additional data if needed. ↳ Finally, you analyzed the data to characterize the waterbody conditions and identify causes and sources, using the techniques discussed in chapter 7. Your next step is to estimate pollutant loads from watershed sources to target future management efforts. This step is essential to eventually satisfy element *b* (i.e., necessary load reductions) of the nine minimum elements. (↳ Identifying load reductions is discussed in chapter 9.) This element is the component most often missing from current and past watershed plans, although it is one of the most important. Without knowing where the pollutants are coming from, you can't effectively control them and restore and protect your watershed. The loading analysis provides a more specific numeric estimate of loads from the various sources in the watershed. By estimating source loads, you can evaluate the relative magnitude of sources, the location of sources, and the timing of source loading. The loading analysis can help you plan restoration strategies, target load reduction efforts, and project future loads under new conditions. This chapter discusses the analysis and modeling techniques commonly used to estimate or to quantify pollutant loads.

An understanding of the watershed, built throughout the watershed planning process, is used as the basis for determining the appropriate method for quantifying the pollutant loads. You can use various approaches to do the loading analysis, and which one is right for you depends on several factors, including water quality parameters, time scale, source types, data needs, and user experience. Some loading analyses are focused on determining "how much" load is acceptable, whereas others focus on "source loads" that attribute loading to each category of sources in the watershed. For watershed planning purposes, source load estimates are desirable because the information can be used to support management planning and targeting of restoration resources. In general, the approach you choose should be the simplest approach that meets your needs.

Sometimes loading estimates have already been developed for watersheds. Check whether a previous study is available—a Total Maximum Daily Load (TMDL), Clean Lakes study, or other watershed-based program that might have required development of loading estimates. Such studies can often be used to provide loading estimates appropriate for developing the watershed plan.

Stakeholders have an interest in the analysis and modeling techniques used to support decisionmaking. Engaging stakeholders in evaluating and selecting analysis techniques can support more informed decisionmaking and buy-in for the approaches selected. However, the more complex techniques and modeling tools can be difficult to describe, review, and interpret. One consideration in selecting models

Can TMDLs Be a Source of Loading Information?

As part of developing a Total Maximum Daily Load (TMDL), loading estimates are typically developed for point and nonpoint sources for the pollutants of concern. Remember that TMDLs are developed for specific pollutants, so they might not include all the pollutants that the watershed plan considers. TMDL documents, including the report, supporting modeling studies, and model input files, are typically available from the state or EPA. In these materials are estimates of existing loads, allowable loads (that meet water quality standards), and the load estimates for point sources (wasteload allocations) and nonpoint sources (load allocations). The load estimates are specified by categories of sources, such as generalized land use types (e.g., pasture). A TMDL can be an excellent source of loading estimates that is well documented and available. If you're using a TMDL, consider its age and recognize that some changes might have occurred since the original analyses. Some areas might have new management activities that have reduced or changed loading. Other areas might have significant land use changes or development that could change estimates. In addition, TMDL analyses do not require implementation plans, so specific estimates of management techniques and their effectiveness are not necessarily included. Some additional or supplemental analysis is likely to be needed to estimate how the potential load reductions will be achieved.

is the transparency of results to the affected community. Even the most complex models can be effectively described and reviewed through public meetings, workshops, and technical transfer opportunities. However, simplified approaches, when sufficient for addressing the watershed concerns, can be more easily interpreted and adopted by the community.

Although approaches have different features, their application is typically best suited to many generalized watershed studies. Some of the more typical model selections are shown in table 8-1, although you should recognize that site-specific conditions might vary significantly. In each example the models are listed in order of complexity, simplest first. All of these approaches are discussed in this chapter.

Table 8-1. Example Approaches Used for Estimating Watershed Loads

Land Use	Sources/Concerns	Pollutants	Models
Agricultural	Grazing	Nutrients and sediment	GWLF AGNPS SWAT
Agricultural	Livestock and wildlife sources	Nutrients	Spreadsheet estimation STEPL SWAT HSPF
Agricultural	Cropland management Conservation tillage	Nutrients and pathogens	AGNPS SWAT
Mixed Use	Stormwater management Agriculture Residential	Sediment and nutrients	P8-UCM SWMM HSPF
Mixed Use	Stormwater management Agricultural	Pathogens	Spreadsheet estimation HSPF
Urban	Stormwater management Land use conversion Redevelopment	Sediment, nutrients, and metals	P8-UCM SWMM HSPF

Two general types of techniques for estimating pollutant loads are described in the following sections. First, techniques that directly estimate loads from monitoring data or literature values are discussed. These techniques are best suited to conditions where fairly detailed monitoring and flow gauging are available and the major interest is in total loads from a watershed. Second, watershed modeling techniques are described, including considerations in selecting models, available models, and the steps involved in applications. A wide range of models that can provide loads by sources, help predict future conditions, and evaluate multiple management practices are discussed.

8.2 Using Monitoring Data or Literature Values to Estimate Pollutant Loads

Commonly used approaches for estimating pollutant loads in watersheds involve using instream monitoring data or literature values (e.g., land use loading rates). These simple approaches can vary in detail or scope depending on the needs of the analysis and the available data. In most cases, they provide a coarse estimate of the pollutant loads entering a waterbody, without great detail on the contributing source or areas of concern. This section provides some examples of simple load estimation methods using available monitoring data and literature values.

8.2.1 Using Monitoring Data to Estimate Loads

Monitoring data can be used to directly estimate the pollutant loading entering a waterbody. Because the monitoring data represent instream conditions, the resulting estimate represents the total loading from a watershed upstream of the monitoring point. This type of estimate does not attribute loads to particular sources or areas. This generalized loading can help to evaluate downstream impacts, can be used to calculate a per acre loading, and can be used for comparing local loadings with those of other areas. This loading estimate is also based on historical conditions because it is directly estimated from monitoring data. It cannot be used to directly predict how loadings might change in the future.

Monitoring data typically include periodic samples of water quality concentrations of pollutants and flow gauging. Flow multiplied by concentration can be used to calculate the load for a specific period. However, water quality sampling is not continuous; it is normally done periodically (e.g., weekly, monthly). Load duration curves are a common approach to using sporadic flow and water quality data to estimate the average total loading at watershed monitoring stations (see section 7.2.5). In addition, various statistical techniques have been developed to estimate loading from periodic sampling and flow gauging data. These techniques build relationships between flow and concentration to help predict or estimate loading during time periods when there is no sampling. Flow gauging information is more likely to be available on a daily basis than the more expensive water quality sampling and laboratory analysis.

The major limitation of these approaches is the aggregate nature of the loading estimate. You can use statistical load estimation techniques to directly estimate loadings from a drainage area or watershed for which monitoring data are available, but this method is not applicable for estimating individual source loading or predicting future changes in loading. If you have a robust dataset throughout the watershed and can apply the load estimation at key areas (e.g., upstream and downstream of suspected sources), you can potentially evaluate the relative magnitude and impact of different sources. Often, however, data are not available for a full range of flow conditions at more than a couple locations in a watershed. If you use this type of methodology in developing your watershed plan, be sure to include future source characterization or monitoring as part of the implementation plan to further refine source loads and target control efforts.

These techniques are also completely reliant on a long period of record of monitoring information to develop the loading estimates. Uncertainty can be calculated from the statistical process, providing the advantage of a system for measuring accuracy. However, continuous flow gauging is available only in limited locations, and typically for large watersheds. You should carefully check the availability and relevance of the data when considering using direct calculations of load. Make sure to check that flow and water quality sampling were conducted at the same time. Ideally, a continuous flow gauging record is available so you can evaluate the changes in flow and seasonal patterns.

The following methods for directly calculating watershed loads are discussed in the sections below:

- FLUX
- Regression of pollutant load and flow using Minimum Variance Unbiased Estimator (MVUE)

FLUX

FLUX, developed by Walker (1996) for the U.S. Army Corps of Engineers, is an interactive computer program used to estimate the loads of nutrients or other water-quality constituents such as suspended sediment. This technique was developed as a companion to the Bathtub model, a commonly used lake modeling technique (Walker 1985, 1986, 1990). The following six estimation algorithms are available in FLUX: (1) direct-mean loading, (2) flow-weighted concentrations (ratio estimate), (3) modified ratio estimate, (4) first-order regression, (5) second-order regression, and (6) regression applied to individual daily streamflow. FLUX maps the flow versus concentration relationship developed from the sample record onto the entire flow record to calculate total mass, streamflow, and associated error statistics. It also provides an option to stratify the data into groups on the basis of flow to improve the fit of the individual models.

Data requirements for FLUX include

- Constituent concentrations, collected on a weekly to monthly frequency for at least a year
- Date collected
- Corresponding flow measurements (instantaneous or daily mean values)
- Complete flow record (daily mean streamflow) for the period of interest.

Regression of Pollutant Load and Flow

A very simple approach to estimating pollutant logs is to use available water quality and flow data to develop a regression equation representing the relationship between the pollutant load and flow magnitude. That equation is then used to estimate pollutant loads on days when flow is available but water quality data are not. For example, the approach can be applied to a flow gauging station that has sporadic water quality data but continuous flow data to estimate water quality and, therefore, pollutant loading on unmonitored days.

However, many pollutant loads, such as sediment, are storm-driven and observed values often span several orders of magnitude. For this reason, the instream sediment load versus flow relationship tends to be linear when examined on a logarithmic scale. This phenomenon can introduce a large amount of error when using a regression approach to estimate pollutant loads. To reduce this error and remove the bias from the regression analysis, a log transform regression approach can be used. The U.S. Geological Survey (USGS) recommends Minimum Variance Unbiased Estimator, or MVUE, (Cohn and Gilroy 1991) as one of the methods for bias correction. The objective of this method is to yield an unbiased estimate with the smallest possible variance. Go to **http://co.water.usgs.gov/sediment/bias.frame.html** for more information on MVUE.

8.2.2 Using Literature Values to Estimate Loads

One of the simplest techniques for estimating pollutant loads involves calculating loads on the basis of land use areas and representative loading rates (i.e., load per area of land). An example of this approach is shown in figure 8-1. In this case the load is a function of a single factor, “land use area,” based on a predefined loading rate. This simple presentation has the benefit of being very easy to apply and explain, but simplicity also results in several limitations. The loading rate is a static value and does not account for temporal or spatial variations in environmental conditions such as precipitation and soils.

The export coefficient model is the simplest type of pollutant runoff model because all factors that effect pollutant movement are combined into one term—the export coefficient. For example, the total pollutant load (in kilograms per year) is calculated by multiplying the land use areas (in hectares) by the export coefficients (in kilograms per hectare per year) for various activities, such as corn, pasture, and residential use and summing the products. Export coefficients for the various land uses can be obtained from literature searches. The table below presents an example of an export coefficient spreadsheet used to obtain a rough estimate of the effects of various land use activities on watershed nutrient loading.

Example of Pollutant Budget Estimation Using Export Coefficient Model

Land Use	Area (ha)	Nitrogen Export Coefficient (kg/ha/yr)	Total Nitrogen Load (kg/yr)	Percent of Nitrogen Load	Phosphorus Export Coefficient (kg/ha/yr)	Total Phosphorus Load (kg/yr)	Percent of Phosphorus Load
Forest	100	1.8	180	0.91	0.11	11	0.52
Corn	200	11.1	2220	11.24	2	400	18.95
Cotton	100	10	1000	5.6	4.3	430	20.37
Soybeans	20	12.5	250	1.27	4.6	92	4.36
Small Grain	50	5.3	285	1.34	1.5	75	3.55
Pasture	300	3.1	930	4.71	0.1	30	1.42
Feedlot or Dairy	5	2,900	14,500	73.39	220	1,100	52.11
Idle	30	3.4	102	0.52	0.1	3	0.14
Residential	20	7.5	150	0.76	1.2	24	1.14
Business	10	13.8	138	0.7	3	30	1.42
Industrial	5	4.4	22	0.11	3.8	19	0.9
Total	840	-	19,757	1	-	2,111	100

Note: Agricultural coefficients are from Reckhow et al. (1980), and urban coefficients are from Athayde et al. (1983).

Figure 8-1. Example of an Application of Export Coefficients to Calculate Pollutant Loads

Because the loading estimate is dependent on the loading rate used in the calculation, it's important to identify values that are realistic for your watershed. Loading rates for land uses can vary widely throughout the nation depending on precipitation, source activity, and soils, and in some areas estimates are not available. Regional loading rates might be available from scientific literature or watershed studies conducted in nearby watersheds. Otherwise, use national estimates with caution, recognizing that the values might not be representative of your watershed.

North Carolina State University's WATER, Soil, and Hydro-Environmental Decision Support System (WATERSHEDSS) provides a tool for land managers to evaluate pollutant budgets and agriculture management practices. ➯ To download the tool for calculating loads using export coefficients, go to **www.water.ncsu.edu/watershedss**. The system also includes a database of agricultural management practices, references on nonpoint source pollutants and sources, and an annotated bibliography of nonpoint source literature.

Empirical relationships documented in scientific literature are another option for estimating pollutant loads. Empirical relationships are those based on observed data, and they are represented by an empirical equation. An example of an empirical relationship relating watershed characteristics to pollutant loading is the Simple Method (Schueler 1987). The Simple Method is a lumped-parameter empirical model used to estimate stormwater pollutant loadings under conditions of limited data availability. Because it is a lumped approach, it assumes the physical characteristics for land units within a subwatershed are homogeneous, thereby simplifying the physical representation of the subwatershed. The approach calculates pollutant loading using drainage area, pollutant concentrations, a runoff coefficient, and precipitation data. In the Simple Method, the amount of rainfall runoff is assumed to be a function of the imperviousness of the contributing drainage area. More densely developed areas have more impervious surfaces, such as rooftops and pavement, causing more stormwater to run off rather than being absorbed into the soil. The Simple Method includes default and suggested values for the equation parameters, or values can be watershed-specific based on monitoring data or local information.

Where to Get Export Coefficients

Lin (2004) summarizes and reviews published export coefficient and event mean concentration (EMC) data for use in estimating pollutant loading into watersheds. Some references included in that review and commonly used for export coefficients are

Beaulac, M.N., and K.H. Reckhow. 1982. An examination of land use-nutrient export relationships. *Water Resources Bulletin* 18(6): 1013–1024.

Reckhow, K.H., M.N. Beaulac., and J.T. Simpson. 1980. M*odeling phosphorus loading and lake response under uncertainty: A manual and compilation of export coefficients*. EPA-440/5-80-011. U.S. Environmental Protection Agency, Office of Water Regulations, Criteria and Standards Division, Washington, DC.

8.3 Watershed Modeling

Models provide another approach for estimating loads, providing source load estimates, and evaluating various management alternatives. A model is a set of equations that can be used to describe the natural or man-made processes in a watershed system, such as runoff or stream transport. By building these cause-and-effect relationships, models can be used to forecast or estimate future conditions that might occur under various conditions. Models can be highly sophisticated, including many specific processes such as detailed descriptions of infiltration and evapotranspiration. Models can also be very generalized, such as a simple empirical relationship that estimates the amount of runoff based on precipitation. Some models are available as software packages, whereas simple models or equations can be applied with a calculator or spreadsheet. Compared to the simple approaches discussed in section 8.2, models add more detailed procedures that represent the separate processes of rainfall, erosion, loading, transport, and management practices. By separately addressing each process, models can be adapted to local conditions, and the simulation can be made more sensitive to land use activities and management changes.

Definitions

Model: A representation of an environmental system through the use of mathematical equations or relationships.

Modeling system: A computer program or software package that incorporates a model and input and output systems to facilitate application.

Model application: The use of a model or models to address defined questions at a specific location.

This section discusses the role of modeling in watershed planning, the types of models available, how to select appropriate models for your watershed study, and setting up and applying models for a watershed.

The Watershed Continuum

One way to represent the watershed is by following the flow of water from land areas to streams and rivers, through lakes, to estuaries, and ultimately to the ocean. When we evaluate water quality standards, the focus is typically on the waterbody of concern. For TMDLs, the dominant use of models is to evaluate the relationship between human actions (e.g., land use management or wastewater treatment) and the impaired downstream waterbody (e.g., river, lake, or estuary). Human actions, such as management practices, land use activities, direct withdrawals of drinking or cooling water, and discharges of wastewater, can all be considered factors that affect watersheds at the land, river, lake, or estuary level.

For TMDLs, modeling typically focuses on describing the linkage between human activities and impaired waters. This "linkage analysis" is necessary to demonstrate that the plan will achieve water quality standards (USEPA 1999a, 1999b, 2001a). For watershed management plans, analysis should focus in more detail on the management actions and land-based activities that will be used to meet water quality goals. In this case the analysis is focused on determining how best to address the management needs. Although modeling for watershed management planning is similar to TMDL modeling, the focus on management typically results in more detailed, localized modeling. This localized modeling and evaluation can be performed separately or in tandem with TMDL or other modeling efforts. The models described in this chapter emphasize the management and localized evaluations typically employed in watershed planning and provide references and links for other types of supporting models.

8.3.1 Factors to Consider When Selecting a Model

Before selecting the most appropriate model, you should define the approach for the specific study. An approach may include one or more models, multiple analysis procedures, and a variety of input data to address the project needs. Selecting the appropriate model application or approach requires an understanding of the range of complexity of the analytic techniques and a clear understanding of the questions to be answered by the analysis. Note that the model application might include the following:

- Various levels of detail for each component
- More than one model to address different waterbodies, pollutants, or stressors
- An available modeling system; a modification of an existing model; or a local, custom model
- A model documentation plan

Determining the model application also means defining the data needs and the accuracy of the modeling results. To select a model and associated application needs, first examine the questions that need to be answered. The following are questions that models are typically used to answer:

- Will the management actions result in meeting water quality standards?
- Which sources are the main contributors to the pollutant load targeted for reduction?
- What are the loads associated with the individual sources?
- Which combination of management actions will most effectively meet the identified loading targets?
- When does the impairment occur?
- Will the loading or impairment get worse under future land use conditions?
- How can future growth be managed to minimize adverse impacts?

Evaluating questions by using models requires looking at and comparing results in terms of load, concentration, flow, or another measurement. This comparison should consider the indicators identified to evaluate the watershed concerns (↳ section 4.6). For example,

- A lake eutrophication problem might focus on predicting the total nitrogen and phosphorus load.
- A river with an attached algae problem might need models that can predict concentrations of dissolved nitrogen and phosphorus during low-flow conditions.
- An area with beach closures due to pathogens might focus on predicting pathogen counts and the frequency of water quality standards violations.
- A concern over sediment in streams might focus on changes in hydrology, stream morphology, or sediment loading from erosion-prone areas.

In each case the predictions of the model should be evaluated on the basis of the indicators identified for meeting and tracking the goals of the watershed management plan. The indicators used often dictate the level of detail of the study. Predicting short-term concentrations, such as a concentration of aluminum, might require more detailed analysis of flow and pollutant transport. The model should support the development of source loads and estimates of their magnitude, and it should support the development of the appropriate pollutant load reduction estimates.

In defining a model application for your watershed, keep in mind four general considerations:

1. Is the approach appropriate to your specific situation, answering the questions needed to develop a watershed plan (relevance)?
2. Has the modeling system been shown to give valid results (credibility)?
3. Is the model easy enough to learn and use that you are likely to succeed at obtaining useful results (usability)? Are data available to support the model (usability)?
4. Is the model able to predict water quality changes based on the changes planned for your watershed management plan (utility)?

Each of these considerations is discussed below.

Additional Modeling Definitions

Field scale. Some applications are focused on small areas at the subbasin or smaller level. Field-scale modeling usually refers to geographic areas composed of one land use (e.g., a cornfield).

Physically based models. A physically based model includes a more detailed representation of fundamental processes such as infiltration. Applying physically based models requires extensive data and experience to set up and test the model. HSPF and SWAT both include physically based processes, although many simplifications are still used.

Lumped model. A model in which the physical characteristics for land units within a subwatershed unit are assumed to be homogeneous is referred to as a "lumped" model. Discrete land use areas within a subwatershed area are lumped into one group.

Mechanistic model. A mechanistic model attempts to quantitatively describe a phenomenon by its underlying causal mechanisms.

Numerical model. A numerical model approximates a solution of governing partial differential equations that describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process.

Steady state model. A steady state model is a mathematical model of fate and transport that uses constant values of input variables to predict constant values of receiving water quality concentrations. Steady state models are typically used to evaluate low-flow conditions.

Dynamic model. A dynamic model is a mathematical formulation describing the physical behavior of a system or a process and its temporal variability.

Relevance

Even if the model has been reviewed in the literature and has been applied in other watersheds, you need to make sure that it's relevant to the needs of your watershed. For example, a model developed and tested only in urban areas, or even in rural areas that are mostly forested, is not a good choice for a watershed that consists almost entirely of agricultural row crops or mixed uses. If flow-through tile drains are one of the main pathways through which

Relevance Considerations

- ✓ The model can represent the land uses and processes that are most important in your watershed.
- ✓ The model predicts the pollutants you're concerned about.

water reaches the stream in your watershed, a model that does not include artificial drainage is probably not a good choice. For specialized cases, such as tile drainage, a custom modeling application might be needed. Many models have been developed for specific pollutants. Some specialize in sediment only because reducing erosion was historically the mission of modeling conducted by the U.S. Department of Agriculture (USDA). Many models give results for sediment, nutrients, and perhaps pesticides, but not for microbial contaminants.

Credibility

Because it's not possible to know in advance how accurate the results of a specific model will be, you need to rely on what others have found. Scientists rely on peer review of journal articles written about the use of a model. A quick rule of thumb is to use only models whose validation has appeared in respected peer-reviewed journals. That way you benefit from the time other modelers and scientists have spent reviewing the model. All the models reviewed in this handbook have been validated, at least to some extent.

Credibility Considerations

- ✓ Model validations have been published in a peer-reviewed journal.
- ✓ The model is in the public domain, and the source code is available on request.

In addition to using only models whose validation has appeared in respected peer-reviewed journals, you could also develop an external peer review committee to review not only the development of a model but also the validity of the model application to the specific project at hand. The California Water and Environmental Modeling Forum (**www.cwemf.org**) has a procedure for such an approach.

Most models distributed in the public domain have been developed by government agencies (e.g., EPA or USDA) or universities and are freely available. However, some consultants use proprietary models, which are privately owned software. Such models cannot be checked because the code is not available to others. It is generally a good idea to use nonproprietary models if possible. Proprietary models normally require a purchase fee and have limited distribution rights. Limiting distribution and review might affect acceptance by the stakeholders.

Because models generate data, EPA has developed a manual for preparing quality assurance project plans for models entitled *Guidance for Quality Assurance Project Plans for Modeling* (EPA QA/G-5M). The guidance is available on EPA's Web site at **www.epa.gov/quality**. Also, it should be noted that most models have user support groups that discuss model use and utility through online forums. For more information, conduct a Web search for "user support groups" and the model under review.

Usability

Usability Considerations

- ✓ Documentation, training, and support are available.
- ✓ The model can be run with data that are generally available or data that can be obtained with reasonable effort.
- ✓ The model and user interface are reliable and thoroughly tested.

Accuracy of prediction is important, but if the model will not answer the questions you need to develop your watershed plan, it will not be useful.

Documentation that explains the parameters, how to get them, and reasonable values is essential to ensure that the model is usable. New users might need some sort of training to learn how to use the model. Finally, model users sometimes run into questions that are not addressed in the documentation. A model that will be widely used needs to have user support available. The support can be in the form of a person who provides technical assistance or a list server where other users can answer questions.

Obtaining input data is often the most time-consuming and difficult part of running a model. This often comes as a surprise to those who have not used models. Models generally require data on land cover, land management (such as agricultural practices), factors that affect the rate at which water can flow into the soil and recharge ground water (usually geology or soil type), and other information about the land in the watershed. In addition, daily or even hourly weather data, including precipitation and temperature, are usually required. Other weather data that are more difficult to obtain, such as relative humidity and wind speed, might be required. For models to be calibrated, accurate input data are needed. Some modeling systems, such as EPA BASINS, have compiled much of the basic data needed to run the model; however, this coarse, national-scale data will not always be accurate enough to give useful results, particularly in small watersheds. Other national, publicly available databases are available from USGS and other sources. Nevertheless, parameters like soil nutrient concentrations or fertilizer applications, particularly those associated with agricultural production and other management activities, are not available nationally and must be obtained locally.

Utility for Watershed Planning

Using a model to predict the impact of changes in a watershed requires that the model be able to represent those changes. Models represent changes in watershed management in very different ways. You'll need to consider what management practices are likely to be applied in your watershed and whether the model can be used to evaluate their benefits. In many cases other analyses are used to supplement a model; sometimes additional spreadsheet calculations can be used to check on the potential load reductions from various methods. In addition, you might want to consider how the model will be used in the future. Will it be used to check future changes in management or as a tool to track progress? If the model will be used as an ongoing planning tool, remember to consider the complexity of the model and the availability of trained staff to apply the model.

Utility Considerations

✓ The model or supplemental tools are able to predict the likely water quality impacts of the land use or management changes you are considering in your watershed plan.

8.3.2 Using Watershed Modeling Tools to Evaluate Loads

Watershed models use a set of equations or techniques to analyze the following key components of the watershed system.

- ***Rainfall/runoff:*** The description of precipitation, infiltration, evaporation, and runoff. This portion of a model is used to calculate the amount and timing of runoff from a land area. Runoff is also related to erosion and to sediment and pollutant transport. In cold-climate watersheds, it might be important to use a model that can represent snowmelt/runoff conditions.
- ***Erosion and sediment transport:*** The description of soil detachment, erosion, and sediment movement from a land area. In more detailed approaches this is linked to the runoff calculation and might include sediment deposition.
- ***Pollutant loading:*** The wash-off of pollutants from a land area. In generalized approaches this is a loading factor. More detailed techniques link pollutant wash-off to hydrology and sediment movement.

- ***Stream transport:*** The stream portion of watershed models, which is needed, at a minimum, to collect the runoff/sediment/pollutants from the various land areas. More detailed models include evaluation of instream behavior of sediment and pollutants. Processes may include deposition, resuspension, decay, and transformation.
- ***Management practices:*** A management practice can be land-based (e.g., tillage or fertilizer application), constructed (e.g., stormwater ponds), or input/output to a stream (e.g., wastewater treatment). Land-based management can be generalized (e.g., number of acres treated) or specific (e.g., field-specific practices). Some models include more detailed simulation techniques. For example, a pond analysis might include sediment settling and first-order decay of pollutants.

First, the land areas are described, typically in terms of land use, soils, and slope, which are the key features that affect runoff, erosion, and pollutant loadings. Second, the management practices present in the watershed are considered. Third, the stream and river transport is considered. Each component of this analysis can be considered at various levels of detail. For example, in describing runoff there are several distinct levels of analytical detail (table 8-2). Each level considers more specific factors and processes. The more detailed the equations used to build the modeling system, the more parameters need to be estimated and the more detailed the evaluation of the model performance needs to be. For each situation the analyst will need to select the type of model, along with the associated level of detail, that is consistent with the objectives of the analysis.

Table 8-2. Various Levels of Detail for Simulating Runoff

Level of Detail	Equation	Assumptions
Generalized	Percentage of rainfall that runs off the land into the water (rational method/ regression of rainfall and runoff observations)	Simple relationship between rainfall and runoff. One factor represents the loss associated with evaporation and plant uptake. No special consideration of slope or soil characteristics. No consideration of soil moisture.
Mid-level	Curve number	Simple relationship based on studies across the country. Varies depending on soil type, vegetation, and slope. Considers soil moisture (antecedent moisture condition). Does not consider variations in storm intensity; uses daily rainfall.
Detailed	Infiltration equation	Describes infiltration of water and evapotranspiration. Considers soil moisture and soil type, vegetation, and slope. Considers variations in storm intensity. Time step is typically hourly rainfall or less.

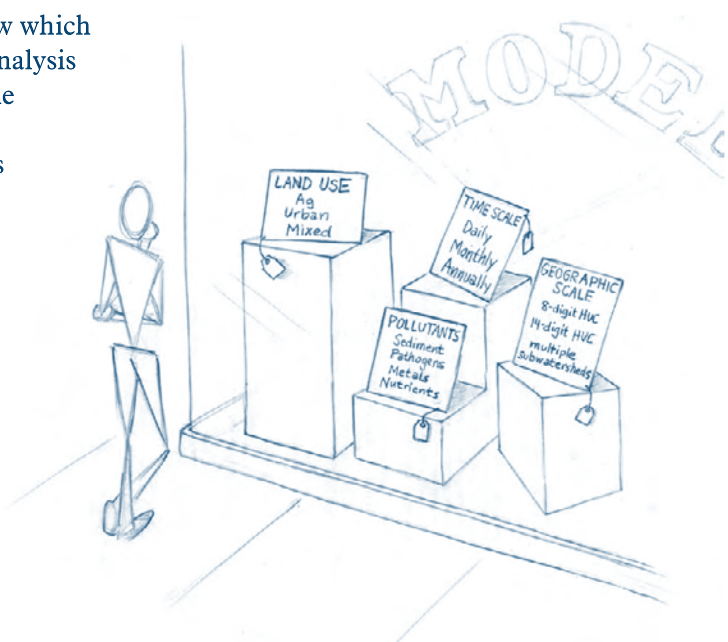
Model applications to specific watersheds often include a mixture of levels of detail depending on the problems being considered. For example, a modeling analysis supporting an agricultural nutrient management initiative might include very detailed descriptions of land behavior, such as nitrogen use by plants, and a very simplified analysis of stream transport. A study considering the upgrade of a wastewater treatment plant would include a detailed examination of the stream conditions in summer and a very simplified representation of land use activities. Table 8-3 describes some of the variations in the level of detail that might be considered in a watershed planning project.

Table 8-3. Levels of Detail in Watershed Models

Element	Generalized	Mid-level	Detailed
Land			
Land use	Category (Agriculture)	Subcategory (Cropland)	Specific (Corn, ridge-tilled)
Slope	N/A	Average for area	Average for area
Soil moisture	N/A	Antecedent moisture condition (3 levels)	Calculated
Hydrology	Percent runoff	Curve number	Infiltration equations
Pollutants	Single	Multiple	Chemical and biological interactions between pollutants
Load	lb/ac/year	lb/day; daily average concentration	lb/hr; hourly average concentration
Management Practices			
Management Practices	Percent removal	Percent removal and estimated volume captured	Hydrology Deposition/settling First order decay and transformation
Streams/Rivers			
Hydrology	Single flow, steady state	Single flow, steady state	Continuous or variable flow
Water quality	Regression, simple relationships	Eutrophication cycle	Eutrophication cycle, carbon/nutrient/BOD processes
Toxic substances	Regression, simple relationships	Settling, 1st-order decay	Transformation, biodegradation, other processes

8.3.3 Model Selection and Application Process

With so many models available, how do you know which one to choose? The development of a modeling analysis involves more than selecting a modeling tool. The application of a model for decisionmaking also involves designing and implementing an analysis that addresses the management questions. Typically, this involves a combination of data analysis techniques, as described in chapter 7, and compilation and organization of disparate data sources.



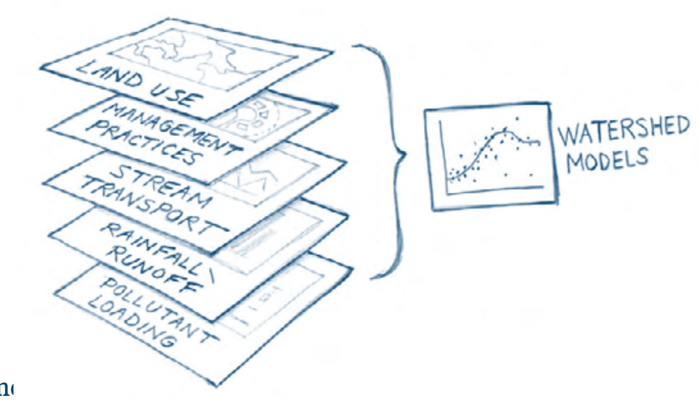
Described below are the key steps for selecting and designing a modeling application for watershed planning purposes. Throughout the watershed process you've built an understanding of the watershed—through scoping, stakeholder input, and data collection and analysis. The design of the modeling approach should build on this understanding and help you to better understand the watershed.

1. **Consider the objectives of the analysis.** During the scoping process the key objectives of the study, as well as the general modeling needs and watershed characteristics, are identified. The specific objectives and associated indicators will help to define the pollutants that the model might need to consider.

2. **Define the specific questions that the modeling will be used to answer.** As discussed earlier in the chapter, before selecting a model, the analyst should first carefully define the questions that the model will be used to answer. The questions should directly relate to the overarching objectives of the study. The following are examples of modeling questions:
   - What are the sources of the pollutant load?
   - Where can management practices be targeted to best meet load reduction requirements?
   - What combination of management practices will result in reducing the load to the desired level and meeting water quality goals?

3. **Select the modeling approach that will address the questions.** The modeling approach includes the model(s) to be used, the input data processing requirements and data sources, the model testing locations and data sources, and the output analysis. The modeling approach defines how the model will be applied, not just what the model is. The approach provides the entire plan or road map for analysis and is broader than the selection of a model.

4. **Set up the model.** As required by the modeling approach identified above, the input data are collected and processed for the model (or models). Typical data inputs include the following:
   - Land use
   - Soils
   - Slope
   - Activities, management locations, and types
   - Monitoring data—flow and water quality
   - Meteorologic data—precipitation and temperature



   Each dataset might require some preprocessing before input. For example, land use information might be selectively updated where new development has occurred. Sometimes multiple land use datasets are combined. For example, one data source might provide a more detailed breakdown of forest types and could be used to add detail to a broader land use coverage. Some models require developing categories of land use, soil, and slope characteristics. Resulting units could include corn fields with B soils (a hydrologic soil group defined by the USDA) and moderate slopes, pasture with C soils and steep slopes, and so on. User's guides and the selected modeling references provide some additional guidance on data preprocessing needs for individual models. Much of the data required for watershed models is discussed in chapter 5.

5. **Test the model's performance.** Regardless of the complexity or detail of the modeling approach, appropriate testing (calibration and validation) of model accuracy should be performed. Remember that modeling results need a reality check before they are used to support a loading analysis or evaluation of management scenarios. If data are available, the model should be calibrated and validated to ensure accurate representation of the watershed processes. When data are limited, you should also compare model results to literature values and data from surrounding watersheds to review the integrity of the results. Do the loads seem realistic given observed concentrations and flows or documented loads in nearby watersheds? Do the simulation results make sense given the watershed processes? For example, if a watershed model produces monthly loads, do the higher loads occur during the times of higher observed flows and concentrations? Or, if a model provides output from both ground water and surface water, do the relative contributions make sense given the topography and geology of the area? Watershed models are meant to represent the processes affecting runoff and pollutant transport and loading. Use your knowledge of the area to reality-check the model representations and output. More information on model calibration and validation is provided in section 8.4.5.

What's the Difference between Model Validation and Calibration?

Calibration and validation are two separate procedures in model development and testing. Available monitoring data are separated into two separate time periods for testing. Using one dataset, calibration parameters are adjusted, within reasonable ranges, until a best fit to observed data is generated. Using the second dataset, validation is performed by keeping the parameter set constant and testing the performance of the model. Time periods for calibration and validation are carefully selected to include a range of hydrologic conditions.

6. **Apply the model and interpret the results.** The model is applied to evaluate the range of conditions required for addressing the modeling questions. For example, a model might be used to evaluate the nutrient loading over a 10-year period. Output postprocessing might include developing annual and monthly loading summaries by source category and evaluating seasonal and annual variation. Multiple model applications might be used to consider changes in land use, installation of management practices, and alterations in cultivation techniques. Output can be processed to support development of essential elements of the watershed plan (source controls, magnitude of sources, and pollutant load reduction estimates).

7. **Update the model to include new information or refine assumptions.** Often after the initial management planning study is complete, additional data are collected or new information is discovered. The model can be updated periodically to further refine and test performance and update management recommendations, if appropriate.

Selecting and executing an appropriate modeling approach can support the development of a watershed management plan. Use caution in selecting an approach consistent with the available data, the specific questions to be addressed, and the type of management. Data analysis is an ongoing process in which modeling is only one potential tool. In many cases, simplified techniques or statistical analysis is adequate to evaluate watershed conditions and no formal modeling is required. Throughout the process, focus on using the most simple methods appropriate to answering the questions at hand.

8.3.4 What Models Are Available?

Various modeling systems have been developed and used to answer a wide range of environmental questions. This handbook focuses on selected models that are publicly available and have a track record of application and use. The models are commonly used in TMDLs and other watershed studies. They represent a range of complexity and are applicable to a variety of pollutants and pollutant sources.

Although these models are supported by EPA and included in this handbook, other similar watershed models might be appropriate for use in developing your watershed plan. An inventory of available models that evaluates the models across a set of key characteristics is provided in table 8-4. These characteristics were selected to help differentiate among available tools and to describe areas of emphasis, complexity, and types of pollutants considered. Key characterization factors include the following:

- **Type.** "Landscape only" indicates that the model simulates only land-based processes; "comprehensive" models include land and stream and conveyance routing.
- **Level of complexity.** Complexity in watershed models is classified as three levels. Export functions are simplified rates that estimate loading based on a very limited set of factors (e.g., land use). Loading functions are empirically based estimates of load based on generalized meteorologic factors (e.g., precipitation, temperature). Physically based models include physically based representations of runoff, pollutant accumulation and wash-off, and sediment detachment and transport. Most detailed models use a mixture of empirical and physically based algorithms.
- **Time step.** Time step is the unit of time (e.g., hourly, monthly) for which a model simulates processes and provides results. The table identifies the smallest time step supported by a model. If larger output time steps are needed, model output can be summarized from smaller time steps.
- **Hydrology.** This criterion identifies whether a model includes surface runoff only or surface and ground water inputs as well.
- **Water quality.** Water quality capabilities are evaluated based on the pollutants or parameters simulated by the model.
- **Types of best management practices.** The types of management practices simulated by the models are indicated in the table.

Even if you're not planning to run the model yourself, it's helpful to know the capabilities and requirements of the major types of watershed models so you can "talk the talk" and make informed decisions about how to proceed with your data analysis. Remember that typically it is not the model itself that causes problems but the matching of the model to local conditions, key assumptions, and interpretation of model outputs.

↳ Additional detailed information on available models is provided in EPA's *Compendium of Tools for Watershed Assessment and TMDL Development* (USEPA 1997c). Although updated versions of some models have been released since the compendium was published, it provides a good starting point for researching available models and understanding their capabilities. ↳ A more recent online database, provided by EPA's Council on Regulatory Environmental Modeling, provides links to model reviews and resources (**http://cfpub.epa.gov/crem/**).

Table 8-4. Overview of Several Available Watershed Models

		Type		Level of Complexity			Time step				Hydro-logy		Water Quality					Type of BMPs						
Model Acronym	**Source**	Landscape only	Comprehensive	Export coefficients	Loading functions	Physically based	Sub-daily	Daily	Monthly	Annual	Surface	Surface and ground water	User-defined	Sediment	Nutrients	Toxic/pesticides	Metals	BOD	Bacteria	Detention basin	Infiltration practices	Vegetative practices	Wetlands	Other structures
AGNPS (event-based)	USDA-ARS	●	●	—	—	●	●	—	—	—	●	—	—	●	●	●	—	—	—	●	—	●	—	—
AnnAGNPS	USDA-ARS	—	●	—	—	●	—	●	—	—	●	—	—	●	●	●	—	—	—	●	—	●	—	—
BASINS	EPA	—	●	●	●	●	●	●	—	—	●	●	●	●	●	●	●	●	●	●	—	●	—	●
DIAS/IIDLMAS	Argonne National Laboratory	—	—	—	—	—	—	—	—	●	—	—	—	●	—	—	—	—	—	—	—	—	—	—
DRAINMOD	North Carolina State University	—	—	—	—	●	●	—	—	—	—	●	—	—	●	—	—	—	—	—	—	—	●	—
DWSM (event-based)	Illinois State Water Survey	—	●	—	—	●	●	—	—	—	●	—	—	●	●	●	—	—	—	●	●	—	—	—
EPIC	Texas A&M University–Texas Agricultural Experiment Station	—	—	—	—	—	—	●	—	—	●	—	—	●	●	●	—	—	—	●	●	—	●	—
GISPLM	College of Charleston, Stone Environmental, and Dr. William Walker	—	●	—	●	—	—	●	—	—	●	—	—	—	●	—	—	—	—	—	—	—	—	—
GLEAMS	USDA-ARS	—	—	—	—	—	—	●	—	—	●	—	—	●	●	●	—	—	—	—	—	—	—	—
GSSHA	USACE	●	●	—	—	●	●	—	—	—	—	●	—	●	—	—	—	—	—	●	●		●	●
GWLF	Cornell University	—	●	—	●	—	—	—	●	—	—	●	—	●	●	—	—	—	—	—	—	●	—	—
HEC-HMS	USACE	—	●	—	—	●	●	—	—	—	●	—	—	—	—	—	—	—	—	—	—	—	—	—
HSPF	EPA	—	●	—	—	●	●	—	—	—	—	●	●	●	●	●	●	●	●	—	—	—	—	—
KINEROS2 (event-based)	USDA-ARS	—	●	—	—	●	●	—	—	—	●	—	—	●	—	—	—	—	—	●	—	●	—	●
LSPC	EPA and Tetra Tech, Inc.	—	●	—	—	●	●	—	—	—	—	●	●	●	●	●	●	●	●	●	—	●	—	●
Mercury Loading Mode	EPA	—	—	—	—	●	—	—	—	●	●	—	—	—	—	—	●	—	—	—	—	—	—	—
MIKE SHE	Danish Hydraulic Institute	—	●	—	—	●	●	—	—	—	—	●	—	—	—	—	—	—	—	—	—	—	—	—
MINTEQA2	EPA	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	●	—	—	—	—	—	—	—
MUSIC	Monash University, Cooperative Research Center for Catchment Hydrology	—	—	—	—	●	●	—	—	—	●	—	●	—	—	—	—	—	—	●	●	●	●	●

Table 8-4. Overview of Several Available Watershed Models (continued)

Model Acronym	Source	Type		Level of Complexity			Time step				Hydrology		Water Quality					Type of BMPs						
		Landscape only	Comprehensive	Export coefficients	Loading functions	Physically based	Sub-daily	Daily	Monthly	Annual	Surface	Surface and ground water	User-defined	Sediment	Nutrients	Toxic/pesticides	Metals	BOD	Bacteria	Detention basin	Infiltration practices	Vegetative practices	Wetlands	Other structures
P8-UCM	Dr. William Walker	—	—	●	●	—	●	—	—	—	●	—	●	●	●	—	●	—	—	●	●	●	—	●
PCSWMM	Computational Hydraulics Int.	—	●	—	●	●	●	—	—	—	—	●	●	●	●	●	●	—	●	●	●	—	—	●
PGC–BMP	Prince George's County, MD	—	—	—	●	—	●	—	—	—	—	—	—	●	●	—	●	—	—	●	●	●	●	●
REMM	USDA-ARS	—	—	—	—	—	—	—	—	—	—	—	—	●	●	●	●	—	—	—	—	●	—	—
SHETRAN	University of Newcastle (UK)	—	●	—	—	●	●	●	—	—	—	●	—	●	—	—	—	—	—	—	—	—	—	—
SLAMM	University of Alabama	—	—	—	—	—	●	—	—	—	●	—	—	●	●	—	●	—	—	●	●	●	●	●
SPARROW	USGS	—	●	—	—	—	—	—	—	●	●	—	—	●	●	●	—	—	—	—	—	—	—	—
STORM	USACE (mainframe version), Dodson & Associates, Inc. (PC version)	—	—	●	—	●	●	—	—	—	●	—	—	●	●	—	—	—	●	—	—	—	—	●
SWAT	USDA-ARS	—	●	—	—	●	—	●	—	—	—	●	—	●	●	●	●	—	—	●	●	●	—	●
SWMM	EPA	—	●	—	—	●	●	—	—	—	—	●	●	●	●	●	●	●	●	●	●	—	—	—
TMDL Toolbox	EPA	—	●	—	—	●	●	—	—	—	—	●	●	●	●	●	●	●	●	●	—	●	—	●
TOPMODEL	Lancaster University (UK), Institute of Environmental and Natural Sciences	—	—	—	—	●	●	●	—	—	—	●	—	—	—	—	—	—	—	—	—	—	—	—
WAMView	Soil and Water Engineering Technology, Inc. (SWET) and EPA	●	●	—	—	●	●	—	—	—	—	●	—	●	●	●	●	—	●	●	●	●	●	●
WARMF	Systech Engineering, Inc.	—	●	—	—	●	—	●	—	—	—	●	—	●	●	●	●	●	●	—	—	—	●	●
WEPP	USDA-ARS	—	—	—	—	●	—	●	●	●	—	●	—	●	—	—	—	—	—	—	●	—	—	—
WinHSPF	EPA	—	●	—	—	●	●	—	—	—	—	●	●	●	●	●	●	●	●	—	—	—	—	—
WMS	Environmental Modeling Systems, Inc.	—	●	—	—	●	●	—	—	—	—	●	●	●	●	●	●	●	●	●	●	—	●	●
XP-SWMM	XP Software, Inc.	—	●	—	—	●	●	—	—	—	—	●	●	●	●	●	●	●	●	●	●	—	—	●

Notes: BMPs = best management practices. — Not supported ● Supported

Source: USEPA. 2005. *TMDL Model Evaluation and Research Needs*. EPA/600/R-05/149. U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Cincinnati, OH. *www.epa.gov/nrmrl/pubs/600r05149/600r05149.htm*

Seven watershed models are presented here for more detailed discussion: AGNPS, STEPL, GWLF, HSPF, SWMM, P8-UCM, and SWAT. The models represent a cross section of simple to more detailed approaches, provide simulation of rural and more urbanized areas, and include a diversity of approaches. These models are used to describe key differentiators and considerations in selecting and applying models.

Other models that have specialized capabilities to support watershed management planning or TMDL development are available. The additional models include

- WAMVIEW for areas where there are high water tables that affect infiltration and runoff
- Models that specialize in detailed sediment detachment and wash-off, such as KINEROS and the Sediment Tool (TMDL Toolbox found at **www.epa.gov/athens/wwqtsc**)
- Specialty models for simulating mercury, such as the TMDL Toolbox Mercury Tool, which provides watershed-scale assessment of mercury loading

The key features of the selected models are presented below. In section 8.4 the model application process for the selected models is described. Appendix A provides resources for more detailed discussion on available models and their application.

AGNPS

The Agricultural Non-Point Source (AGNPS) model was developed by USDA's Agricultural Research Service for use in evaluating the effect of management decisions on a watershed system. The term "AGNPS" now refers to the system of modeling components, including Annualized AGNPS (Ann AGNPS), rather than the single-event AGNPS, which was discontinued in the mid-1990s. AGNPS has the advantage of providing spatially explicit modeling results, which is not true of most of the other models described here. However, the annualized version has not yet had extensive validation, and the user base is not yet broad. One training opportunity per year is typically offered. The model, documentation, and information about training are available at **www.ars.usda.gov/research/docs.htm?docid=5199**.

AnnAGNPS is a continuous-simulation, watershed-scale program developed based on the single-event model AGNPS. AnnAGNPS simulates quantities of surface water, sediment, nutrients, and pesticides leaving the land areas and their subsequent travel through the watershed. Runoff quantities are based on a runoff curve number (CN), while sediment is determined using the Revised Universal Soil Loss Equation (RUSLE; USDA 1996). Special components are included to handle concentrated sources

> **Where to Find the Selected Models**
>
> ***AGNPS***
> **www.ars.usda.gov/research/docs.htm?docid=5199**
>
> ***STEPL***
> Temporary URL **http://it.tetratech-ffx.com/stepl**
>
> ***GWLF***
> The original version of the model has been used for 15 years and can be obtained from Dr. Douglas Haith at Cornell University. A Windows interface (Dai et al. 2000) is available at **www.vims.edu/bio/vimsida/basinsim.html**. Penn State University developed an ArcView interface for GWLF (**www.avgwlf.psu.edu**) and compiled data for the entire state of Pennsylvania (Evans et al. 2002).
>
> ***HSPF***
> HSPF is available through EPA's Center for Exposure Assessment Modeling (**www.epa.gov/ceampubl/swater/hspf**) and also as part of EPA's BASINS system (**www.epa.gov/ost/basins/**). Another formulation of HSPF is EPA's Loading Simulation Program in C++ (LSPC), which can be downloaded at **www.epa.gov/athens/wwqtsc/html/lspc.html**.
>
> ***P8-UCM***
> **www.wwwalker.net/p8/p8v24.zip**
>
> ***SWAT***
> **www.brc.tamus.edu/swat**
> SWAT is also included in EPA's BASINS system **www.epa.gov/waterscience/basins/basinsv3.htm**.
>
> ***SWMM***
> **www.epa.gov/ednnrmrl/models/swmm/index.htm**

> **Physically Based Models**
>
> A physically based model includes a more detailed representation of processes based on physical features. Applying physically based models requires extensive data to set up and test the model and substantial modeling experience. HSPF and SWAT both include physically based processes, although many simplifications are used.

of nutrients (feedlots and point sources), concentrated sediment sources (gullies), and added water (irrigation). Output is expressed on an event basis for selected stream reaches and as source accounting (contribution to outlet) from land or reach components over the simulation period. The model can be used to evaluate the effect of management practices such as agricultural practices, ponds, grassed waterways, irrigation, tile drainage, vegetative filter strips, and riparian buffers. All runoff and associated sediment, nutrient, and pesticide loads for a single day are routed to the watershed outlet before the next day's simulation. There is no tracking of nutrients and pesticides attached to sediment deposited in stream reaches from one day to the next. Point sources are limited to constant loading rates (water and nutrients) for the entire simulation period, and spatially variable rainfall is not allowed. ↳ The model is available at **www.ars.usda.gov/Research/docs.htm?docid=5199**.

AGNPS was developed for agricultural or mixed-land-use watersheds. It predicts nitrogen, phosphorus, and organic carbon. It is appropriate for use on watersheds of up to 500 square kilometers. It provides information on the impact on various locations in the watershed, rather than simply on various land uses.

STEPL

STEPL is a simplified spreadsheet tool for estimating the load reductions that result from implementing management practices. It is designed as a customized Excel spreadsheet model that is easy to use. Users can modify the formulas and default parameter values without any specialized programming skills. STEPL includes a management practice calculator that computes the combined effectiveness of multiple management practices implemented in serial or parallel configurations (or both) in a watershed. Management measures that affect hydrology or sediment can be estimated with empirical factors, such as the Soil Conservation Service (SCS; now the Natural Resources Conservation Service [NRCS]) CN for estimating runoff and USLE C and P factors representing vegetative cover and conservation practices, respectively. (↳ More detail on selecting CNs and USLE parameters is included in section 8.4.3.) Pollutant load reductions attributable to the management practices are estimated with reduction factors (or management practice effectiveness) applied to the pre-management practice loads from the various land uses. ↳ The user's guide, model, default database, and other supporting information are available on the STEPL Web site (temporary URL **http://it.tetratech-ffx.com/stepl**). Application of the STEPL tool requires users to have a basic knowledge of hydrology, erosion, and pollutant loading processes. Familiarity with the use and limitations of environmental data is also helpful. Computer skills in Microsoft Excel and the use of Excel formulas are needed.

GWLF

The Generalized Watershed Loading Function (GWLF) model simulates runoff and sediment delivery using the SCS curve number equation (CNE) and the USLE, combined with average nutrient concentration based on land use. GWLF is a good choice for watershed planning where nutrients and sediment are primary concerns. Because of the lack of detail in predictions and stream routing (transport of flow and loads through the stream system), the outputs are given only monthly, although they are calculated daily.

The model is simple enough that most people should be able to learn it without attending training sessions. The original version of the model has been used for 15 years. Data requirements are low: information on land use, land cover, soil, and the parameters that govern runoff, erosion, and nutrient load generation is all that is required. Pennsylvania State University developed an ArcView interface for GWLF (**www.avgwlf.psu.edu**) and compiled data for the entire state of Pennsylvania (Evans et al. 2002). A Windows interface (Dai et al. 2000) is also available at **www.vims.edu/bio/vimsida/basinsim.html**. Calibration requirements for GWLF are very low. GWLF is a good choice for watershed planning in many situations. The interfaces and documentation are excellent, and the model is quite easy to use. The management practice tool (PRedICT or Pollution Reduction Impact Comparison Tool) is a good, simple way to estimate the impact of management practices. However, GWLF is limited to nutrient and sediment load prediction and does not include instream processes like flow and transport of loads.

HSPF

The Hydrologic Simulation Program–Fortran (HSPF) is a comprehensive package for simulating watershed hydrology and water quality for a wide range of conventional and toxic organic pollutants. HSPF simulates watershed hydrology, land and soil contaminant runoff, and sediment-chemical interactions. The model can generate time series results of any of the simulated processes. Overland sediment can be divided into three types of sediment (sand, silt, and clay) for instream fate and transport. Pollutants interact with suspended and bed sediment through soil-water partitioning. HSPF is one the few watershed models capable of simulating land processes and receiving water processes simultaneously. It is also capable of simulating both peak flow and low flows and simulates at a variety of time steps, from subhourly to one minute, hourly, or daily. The model can be set up as simple or complex, depending on application, requirements, and data availability. For land simulation, processes are lumped for each land use type at the subwatershed level; therefore, the model does not consider the spatial location of one land parcel relative to another in the watershed. For instream simulation, the model is limited to well-mixed rivers and reservoirs and one-directional flow. HSPF requires extensive calibration and generally requires a high level of expertise for application.

The most recent release is HSPF Version 12, which is distributed as part of the EPA BASINS system. Another formulation of HSPF is EPAs Loading Simulation Program in C++ (LSPC), a watershed modeling system that includes algorithms for simulating hydrology, sediment, and general water quality on land, as well as a simplified stream transport model (**www.epa.gov/athens/wwqtsc/html/lspc.html**). A key advantage of LSPC is that it has no inherent limitations in terms of modeling size or model operations and has been applied to large, complex watersheds. In addition, the Microsoft Visual C++ programming architecture allows for seamless integration with modern-day, widely available software such as Microsoft Access and Excel. Data management tools support the evaluation of loading and management within multiple watersheds simultaneously.

P8-UCM

The P8-UCM program predicts the generation and transport of stormwater runoff pollutants in small urban catchments. It consists mainly of methods derived from other tested urban runoff models (SWMM, HSPF, D3RM, TR-20). Model components include stormwater runoff assessment, surface water quality analysis, and routing through structural controls. The model applications include development and comparison of stormwater management plans, watershed-scale land use planning, site planning and evaluation for compliance, effectiveness of sedimentation ponds and constructed wetlands, and selection and sizing of management practices.

Simulations are driven by continuous hourly rainfall and daily air temperature time series data. The model simulates pollutant transport and removal in a variety of urban stormwater management practices, including swales, buffer strips, detention ponds (dry, wet, and extended), flow splitters, and infiltration basins (offline and online); pipes; and aquifers. The model assumes that a watershed is divided into a lumped pervious area and a lumped impervious area and does not evaluate the spatial distribution of pervious and impervious land uses. The model also assumes that pollutants entering the waterbodies are sediment-adsorbed. P8-UCM is a simple model that requires moderate effort to set up, calibrate, and validate. Limitations of the model include limited capability in flow and pollutant routing and limited capability in ground water processes and ground water and surface water interaction.

SWAT

The Soil and Water Assessment Tool (SWAT) was developed by the USDA's Agricultural Research Service (ARS) and is one of the models in the EPA BASINS modeling system. SWAT is included in EPA's BASINS v3.1—**www.epa.gov/waterscience/basins/basinsv3.htm**. SWAT is strongest in agricultural areas; the urban component was added more recently. Pollutants modeled are pesticides, nutrients, sediment based on agricultural inputs, and management practices. The bacteria component has been developed but is still being tested. SWAT has been validated in many watersheds. It is more comprehensive than GWLF and can better estimate the water quality impacts of some management changes; however, the added accuracy gained by running SWAT will be worth the extra effort only in watersheds where high-resolution agricultural management analyses are warranted and where information on agricultural land use practices can be obtained.

SWMM

SWMM is a dynamic rainfall-runoff simulation model developed by EPA. It is applied primarily to urban areas and for single-event or long-term (continuous) simulation using various time steps (Huber and Dickinson 1988). It was developed for analyzing surface runoff and flow routing through complex urban sewer systems. First developed in 1971, SWMM has undergone several major upgrades. The current edition, Version 5, is a complete rewrite of the previous release and was produced by EPA's National Risk Management Research Laboratory. For more information on SWMM and to download the current version, go to **www.epa.gov/ednnrmrl/models/swmm/index.htm**.

The model performs best in urbanized areas with impervious drainage, although it has been widely used elsewhere. SWMM has been applied to urban hydrologic quantity and quality problems in a number of U.S. cities, as well as extensively in Canada, Europe, and Australia (Donigian and Huber 1991; Huber 1992). In addition to its use in comprehensive watershed-scale planning, typical uses of SWMM include predicting combined sewer overflows, assessing the effectiveness of management practices, providing input to short-time-increment dynamic receiving water quality models, and interpreting receiving water quality monitoring data (Donigian and Huber 1991).

In SWMM, flow routing is performed for surface and sub-surface conveyance and ground water systems, including the options of non-linear reservoir channel routing and fully dynamic hydraulic flow routing. In the fully dynamic hydraulic flow routing option, SWMM simulates backwater, surcharging, pressure flow, and looped connections. SWMM has a variety of options for water quality simulation, including traditional buildup and wash-off formulation, as well as rating curves and regression techniques. USLE is included to simulate soil erosion. SWMM incorporates first-order decay and a particle settling mechanism in pollutant transport simulations and includes an optional simple scour-deposition routine. The latest version of SWMM simulates overland flow routing between pervious and impervious areas within a subcatchment. Storage, treatment, and other management practices can also be simulated. The model typically requires calibration of its parameters for water quantity and quality simulations. The model also assumes that all pollutants entering the waterbodies are adsorbed to sediment.

8.3.5 Capabilities of the Selected Models

Major factors in selecting a watershed model include

- Water quality indicators simulated
- Simulation of land and water features (e.g., land use and waterbody types)
- Application considerations (e.g., training required)

The following sections discuss the capabilities and characteristics of the selected models for each of these considerations.

Water Quality Targets or Endpoints for the Selected Models

The selection of the appropriate model for your watershed and your goals depends on the types of processes you need to simulate. The initial criteria for determining which model is right for your watershed analysis include the water quality targets or goals. Water quality targets are based on specific parameters (e.g., phosphorus, sediment) and typically have an associated magnitude, duration, and frequency. For example, a target might be established for a monthly sediment load of 20 tons, or a bacteria target might be set as a daily maximum of 400 counts/100 mL. To better summarize the selected watershed models' applicability to typical water quality targets and to aid in identifying appropriate models for your watershed, table 8-5 summarizes the models' abilities to simulate typical target pollutants and expressions (e.g., load versus concentration). The table scores the models depending on the time step of the simulation for the target—annual, daily, or hourly.

Simulation of Land and Water Features

After you've initially identified models based on the necessary parameters, it's important to identify the major land and water features or processes that you want to simulate. For example, what types of land uses are in your watershed? Is ground water an important influence on instream water quality? Are there certain types of management measures you want to evaluate in your watershed? The available models simulate different land and water features, and they do so at different levels of detail. Table 8-6 provides a summary of the selected key models' capabilities for simulating a variety of land and water features. The table identifies the following categories:

- **General Land and Water Features:** Rates models according to their ability to simulate general land uses and waterbody types.
- **Detailed Features:** Rates models on the basis of their ability to simulate special processes such as wetlands, hydrologic modification, urban management practices, and rural management practices.

Application Considerations

Another issue to consider when selecting your model is what it takes to apply the model—considerations like how long it will take to set up and apply the model, how much training you'll need, and how much the model will cost. Table 8-7 rates the selected models based on

Table 8-5. Water Quality Endpoints Supported by the Selected Watershed Models

Parameter/Endpoint	AGNPS	STEPL	GWLF[a]	HSPF	P8-UCM	SWAT	SWMM
Total phosphorus (TP) load	◗	○	◗	●	●	◗	●
TP concentration	◗	—	◗	●	●	◗	●
Total nitrogen (TN) load	◗	○	◗	●	●	◗	●
TN concentration	◗	—	◗	●	●	◗	●
Nitrate concentration	—	—	—	●	—	◗	●
Ammonia concentration	—	—	—	●	—	◗	●
TN:TP mass ratio	—	—	◗	●	—	◗	●
Dissolved oxygen	◗	—	—	●	—	◗	●
Chlorophyll *a*	—	—	—	●	—	◗	—
Algal density (mg/m^2)	—	—	—	—	—	—	—
Net total suspended solids load	—	○	—	●	●	—	●
Total suspended solids concentration	◗	—	—	●	●	◗	●
Sediment concentration	◗	—	◗	●	●	◗	●
Sediment load	◗	○	◗	●	—	◗	●
Metals concentrations	—	—	—	●	—	◗	●
Conductivity	—	—	—	●	—	—	—
Pesticide concentrations	◗	—	—	●	—	◗	—
Herbicide concentrations	◗	—	—	●	—	◗	—
Toxics concentrations	—	—	—	●	—	—	—
Pathogen count (*E. coli*, fecal coliform bacteria)	—	—	—	●	—	◗	●
Temperature	—	—	—	●	—	◗	—

Key: — Not supported ○ Annual ◗ Daily ● Hourly

[a]GWLF calculations are performed on a daily basis, but the results are presented on a monthly basis.

Source: USEPA. 2005. *TMDL Model Evaluation and Research Needs*. EPA/600/R-05/149. U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Cincinnati, OH. *www.epa.gov/nrmrl/pubs/600r05149/600r05149.htm*

Table 8-6. Land and Water Features Supported by the Selected Watershed Models

Land and Water Feature	AGNPS	STEPL	GWLF	HSPF	P8-UCM	SWAT	SWMM
General Land and Water Features							
Urban	—	○	◗	◗	◗	◗	●
Rural	●	○	◗	●	○	●	◗
Agriculture	●	○	◗	●	○	●	○
Forest	—	○	◗	●	○	●	○
River	—	—	○	●	○	○	○
Lake	—	—	—	◗	—	○	○
Reservoir/impoundment	—	—	—	◗	◗	○	◗
Estuary (tidal)	—	—	—	—	—	—	—
Coastal (tidal/shoreline)	—	—	—	—	—	—	—
Detailed Land Features							
Air deposition	—	—	—	○	—	—	—
Wetlands	—	—	—	◗	○	○	○
Land-to-land simulation	○	—	—	○	—	—	—
Hydrologic modification	—	—	—	◗	—	—	◗
BMP siting/placement	●	—	—	○	◗	—	◗
Urban Land Management							
Street sweeping and vacuuming	—	—	○	—	◗	○	◗
Nutrient control practices (fertilizer, pet waste management)	◗	—	—	○	○	○	○
Stormwater structures (manhole, splitter)	—	—	—	—	○	—	◗
Detention/retention ponds	◗	—	—	○	◗	○	◗
Constructed wetland processes	—	—	—	—	○	○	○
Vegetative practices	◗	—	○	○	○	○	○
Infiltration practices	—	—	—	○	○	—	—
Rural Land Management							
Nutrient control practices (fertilizer, manure management)	●	○	○	●	—	●	○
Agricultural conservation practices (contouring, terracing, row cropping)	●	○	○	●	—	●	○
Irrigation practices/tile drains	○	—	—	—	—	●	—
Ponds	◗	—	—	◗	◗	◗	◗
Vegetative practices	◗	○	○	○	—	◗	—

Key: — Not supported
○ Low: Simplified representation of features, significant limitations
◗ Medium: Moderate level of analysis, some limitations
● High: Detailed simulation of processes associated with land or water feature

Source: USEPA. 2005. *TMDL Model Evaluation and Research Needs*. EPA/600/R-05/149. U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Cincinnati, OH. *www.epa.gov/nrmrl/pubs/600r05149/600r05149.htm*

the practical considerations affecting their application. Models with filled circles are generally easier to use and require less data and time for application.

Table 8-7. Application Considerations of the Selected Watershed Models

Application Considerations	AGNPS	STEPL	GWLF	HSPF	P8-UCM	SWAT	SWMM
Experience required	◗	●	●	—	●	○	—
Time needed for application	◗	●	●	—	●	◗	○
Data needs	◗	●	●	○	●	◗	○
Support available Support available	◗	○	○	●	○	◗	◗
Software tools	◗	●	●	●	○	●	○
Cost to purchase	●	●	●	●	●	●	●

Key:

Experience:

— Substantial training or modeling expertise required (generally requires professional experience with advanced watershed and/or hydrodynamic and water quality models)

○ Moderate training required (assuming some experience with basic watershed and/or water quality models)

◗ Limited training required (assuming some familiarity with basic environmental models)

● Little or no training required

Support Available:
- — None
- ○ Low
- ◗ Medium
- ● High

Time Needed for Application:
- — > 6 months
- ○ > 3 months
- ◗ > 1 month
- ● < 1 month

Software Tools:
- — None
- ○ Low
- ◗ Medium
- ● High

Data Needs:
- ○ High
- ◗ Medium
- ● Low

Cost to Purchase:
- — Significant cost (> $500)
- ○ Nominal cost (< $500)
- ◗ Limited distribution
- ● Public domain

Source: USEPA. 2005. *TMDL Model Evaluation and Research Needs*. EPA/600/R-05/149. U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Cincinnati, OH. *www.epa.gov/nrmrl/pubs/600r05149/600r05149.htm*

8.4 Model Application Process for the Selected Models

Previous sections discussed the basic features of models, how to select appropriate models for your project, and general steps in applying models. This section discusses the decisions made during model application. Although the models have different features and capabilities, some basic decisions regarding data and data processing are required for every model application. The major data needs for the selected models reviewed here are summarized in table 8-8. These are the decisions that result in tailoring the model to your specific site. Each major decision point is discussed, along with some suggestions for how to decide the appropriate level of detail.

For loading analysis you need to think carefully about the area being modeled. A watershed is usually composed of areas with diverse land uses and activities. Some watersheds have regional differences, such as a densely populated areas surrounded by countryside. When applying a model to a watershed, the diversity within the watershed is simplified into major categories so that the loads can be estimated. If the analysis is too detailed, the modeling becomes very difficult to apply and test. If the analysis is too simplified, some important information might be lost. Modeling should build on the detailed understanding of the watershed developed during planning and data analysis.

Table 8-8. Typical Data Needs for Example Models

Model	Number of Watersheds	Land Use and Soil Parameters	Stream Channel Characteristics	Nutrient Applications	Management Practices
AGNPS	> 1	CN/USLE	N/A	Application rate	Location and type associated with land use
STEPL	1	CN/USLE	N/A	N/A	General type
GWLF	1	CN/USLE	N/A	Manure/nutrient applications, date	General/agricultural
HSPF	> 1	HSPF-specific	Flow/discharge relationships, length	Application rate	Location and type
P8-UCM	1	CN/USLE	N/A	N/A	General type
SWAT	> 1	CN/USLE	Dimensions of stream channel	Application rate	Location and type associated with land use
SWMM	> 1	Green-Ampt/USLE	Dimensions of stream channel, conduits, and pipes	Buildup and wash-off rates	Location and type associated with land use

Note: CN = curve number; USLE = Universal Soil Loss Equation.

8.4.1 Watershed Delineation

Although you've already delineated your watershed (↳ section 5.4.1), you'll likely further divide the watershed into small subwatersheds for modeling and evaluation. Dividing the watershed into subwatersheds is usually the very first step in watershed modeling. A watershed of 10 square miles might be subdivided into 20 subwatersheds about 0.5 square mile each. How do you decide how small to go? That depends on the watershed characteristics, the type of model you're using, and the management actions that might be considered. Some watershed characteristics to consider when subdividing the watershed include

- Land use distribution and diversity
- Location of critical areas
- Stream gauging stations and water quality monitoring locations (subwatersheds should match key monitoring locations for testing)
- Location of physical features like lakes, dams, and point source discharges
- Changes in topography
- Soil distribution
- Areas where management might change

Table 8-9 provides examples of the number of subwatersheds and average size of subwatersheds for some very large watershed modeling applications using HSPF or LSPC. Why do they vary significantly? The watershed with the most uniform land uses and a large area was evaluated using large subwatersheds (e.g., Tongue River watershed in Montana). The watershed with the smallest subwatersheds is in an area that ranges from highly urbanized to rural and has a dense network of monitoring data available for testing. In this application the local conditions are represented by using smaller watersheds. Each application is unique, and watersheds are defined accordingly.

Table 8-9. Examples of Number and Size of Subwatersheds in Modeling Applications

Watershed	Location	Watershed Size (mi²)	Number of Subwatersheds	Average Subwatershed Size (mi²)
Mobile River Basin	AL/GA/MS/TN	43,605	152	286.88
French Gulch Creek	AZ	16	26	0.62
Boulder Creek	AZ	138	9	15.33
Clear Lake Watershed	CA	441	49	9.00
San Gabriel River	CA	689	139	4.96
San Jacinto River	CA	770	32	24.06
Los Angeles River	CA	834	35	23.83
Sacramento River	CA	9,147	249	36.73
Lake Tahoe Watershed	CA/NV	314	184	1.71
Christina River	DE/MD/PA	564	70	8.06
Tug Fork River	KY/VA/WV	1,500	455	3.30
Upper Patuxent River	MD	130	50	2.60
Lower Tongue River	MT	3,609	30	120.30
Lake Helena Watershed	MT	616	49	12.57
Wissahickon Creek	PA	64	5	12.80
Tyger River	SC	750	75	10.00
Salt River	USVI	5	13	0.38
Tygart Valley River	WV	1,362	1,007	1.35
West Fork River	WV	880	645	1.36

The number and size of subwatersheds can affect the model selection process. Some watershed models have limitations on the number of subwatersheds or the size of the area the model can simulate. HSPF, SWMM, and SWAT are typically used for multiple subwatersheds, allowing for the evaluation of geographic distributions of loads. Models like GWLF and STEPL do not inherently handle multiple watersheds and therefore are applied to one watershed at a time.

How are subwatersheds delineated? Most applications today use a geographic information system (GIS) to delineate watersheds based on Digital Elevation Models (DEMs) and topographic maps. Some software packages provide autodelineation tools or other aids to help define hydrologic boundaries. Predefined watershed boundaries such as 14-digit hydrologic units can be used. See section 5.4.1 for more details on delineating watersheds.

8.4.2 Land Use Assignment

Land use information is typically provided as a GIS coverage or map with many individual codes that describe detailed land use types. For modeling purposes, these individual codes should be grouped into a more manageable set of dominant land use types. How much combining is done depends on the watershed characteristics. Factors to consider in deciding on land use grouping include the following:

- Dominant land use types
- Land uses subject to change or conversion
- Land use types where management changes are expected
- Spatial diversity within the watershed
- Availability of information on individual land use types

When grouping land uses, recognize that the summary of pollutant loading will be presented by land use category. Too many categories of land uses can be difficult to model, test, and report. Too few categories can result in oversimplification and generalization of the watershed conditions. Like so many aspects of watershed analysis, this decision depends on the local conditions and the management concerns being evaluated. When selecting your land use grouping, think about the dominant features of your watershed and how they might change in the future (table 8-10). For example, in a watershed that is predominantly forested, the key land use categories might include various ages of trees (newly established, mature), logging roads, and small residential areas. Changes under consideration might be forest practices/harvesting techniques, road removal, and road management. For this watershed most of the detailed land use categories would relate to forest type and practice. In an urban watershed, forest might be grouped into a single category while numerous densities of urban land uses (e.g., commercial, industrial, high-density urban) are represented in more detail.

Table 8-10. Example Land Use Categories for Watershed Models

Forested Watershed	Urban Watershed
• Mature forest • Scrub/brush • Newly established forest (1–5 years) • Harvested areas (0–1 years) • Dirt roads • Camp areas • Residential	• Low-density residential • Medium-density residential • High-density residential • Commercial • Industrial • Open space

8.4.3 Parameter Selection

Once subwatersheds and land uses are defined, the next decisions involve summarizing other spatial information within each subwatershed. For most models, this involves combining information on soils, topography, and land use. For example, models that use the CNE (STEPL, GWLF, SWAT, AGNPS, and P8-UCM) have look-up tables that relate soil, crop type, and management to a CN factor (USDA-NRCS 1986). The CN is used in the model to calculate runoff based

> **Tip** The decisions made regarding data processing for model input are part of the assumptions and potential limitations of the modeling approach. During the application, keep a log of all data-processing steps for later use in documenting and identifying assumptions and limitations.

on rainfall for specific land areas. For HSPF, an infiltration factor that relates to the soil type associated with each land use is selected. For example, CN options for cornfields (row crops without conservation treatment) include the following (USDA-NRCS 1986):

Corn	A soil	Good Condition	67
Corn	B soil	Fair Condition	79.5 (Average of the CNs for poor and good conditions)
Corn	B soil	Good Condition	78
Corn	C soil	Poor Condition	88

"Condition" applies to the soil conditions for the area. An area with good-condition soils likely has a better soil structure, resulting in good infiltration and less runoff. Poor-condition soils are typically more compacted, resulting in less infiltration and more runoff. When setting up the model, you would select the appropriate CN that represents a subwatershed/land use unit.

Similarly, key parameters for sediment predictions in STEPL, GWLF, SWAT, AGNPS, and P8-UCM are based on the USLE and are selected for each subwatershed/land use unit. The USLE includes parameters that relate to slope, length, erosion potential, and cropping practice.

The USLE can be written as follows (Wischmeier and Smith 1965, 1978):

$$A = R \times K \times LS \times C \times P$$

Where A represents the potential long-term average annual soil loss in tons per acre per year, R is the rainfall and runoff factor by geographic location, K is the soil erodibility factor, LS is the slope length-gradient factor, C is the crop/vegetation and management factor, and P is the support practice factor. For example, USLE parameters for a cornfield with 2-percent slope, erodible soils, and conventional tillage could be selected as follows:

R = 275 (Clarke County, Georgia)

K = 0.3 (soil textural class = loam)

LS = 0.2008 (2 percent slope and 100 feet of slope length)

C = 0.54 (residue removed, conventional tillage, fall plow)

P = 1 (no supporting practice)

Therefore, average annual soil loss is calculated as

$$A = 275 \times 0.3 \times 0.2008 \times 0.54 \times 1 = 8.9 \text{ ton/acre/year}$$

If no-till is practiced and the soil surface is covered with residues, the C factor is 0.11 and the average annual soil loss will be

$$A = 275 \times 0.3 \times 0.2008 \times 0.11 \times 1 = 1.8 \text{ ton/acre/year}$$

The convenience and consistency of the CNE and USLE approaches are one of the reasons that use of models based on them is prevalent. In many areas the CNE, as applied in the NRCS runoff model TR-20, is also used for predicting flow when designing stormwater ponds and road culverts. Engineers and analysts throughout the country are familiar with these fundamental equations.

There are, however, some limitations that you should consider when applying models based on these equations. Like any analytic tool, they are generalizations of natural physical processes of runoff and erosion. The CNE is based on a standard storm and uses daily rainfall. That means a very intense storm in which the rainfall falls very quickly is treated in the same way as a slow rainfall that continues throughout the day. This can result in some overprediction or underprediction of rainfall on a specific day. Similarly, the USLE simplifies the erosion processes of detachment (loosening of surface soils due to rainfall) and wash-off. These processes are also very sensitive to rainfall intensity and localized conditions. HSPF and SWMM are more sensitive to rainfall intensity because they use an hourly or shorter rainfall record. However, this additional detail requires more information and model testing to verify model performance.

Simulation of Management Practices

The selected models reviewed here have various capabilities for the representation of management practices, and they tend to specialize in agricultural and urban practices as listed below:

- Agricultural practices—SWAT, AGNPS, GWLF, STEPL
- Urban practices—P8-UCM, STEPL, SWMM
- Mixed land use—STEPL, HSPF

More information on how the selected models simulate management practices and how they can support selection of management strategies is included in section 11.3.

8.4.4 Model Testing

How do you know if the model is working appropriately? What kinds of tests can you perform to prove that the model is working? Before embarking on detailed evaluation and statistical testing of a model, you must first check the fundamental performance of the model. Check whether the model is working, evaluate the basic performance, and adjust or verify inputs if necessary. Then test for accuracy. In the early testing process, most modelers look at graphs of observed and simulated data and generalized summaries of flow and loading predictions. Initially, you're looking for ways to improve the model and identify features that might have been missed during setup. In the later part of model testing, you're looking for proof that the model is working well and providing reasonable results.

Tip Use common sense in testing modeling results. Ask a few key questions: Do the results appear consistent with other studies or literature values? Is the water balance correct? Are the predictions consistent with the types of sources or land uses in the watershed? Are there any missing sources?

Testing involves comparing modeling results with observed data. It should focus on the questions the model is designed to answer. If a model is designed to evaluate annual nutrient loads, for example, comparisons are made with flow and nutrient monitoring information. Sometimes, when data are highly limited, model testing is based primarily on comparison with literature values, similar studies in nearby regions, and evaluation using alternative calculation techniques. Figure 8-2 shows idealized model testing points: an upstream small watershed (1), a small watershed dominated by a single land use (2), and a downstream point at a USGS flow gauging station (3). In cases where additional data gathering is not possible and historical records are limited, testing might be based on a single downstream location. Testing is best performed at locations where flow gauging and water quality sampling are available, typically at USGS gauging stations. When selecting the subwatershed delineation in the initial model setup, consider the locations of available monitoring and testing points. Then the model output can be compared at the locations where flow and water quality measurements are available.

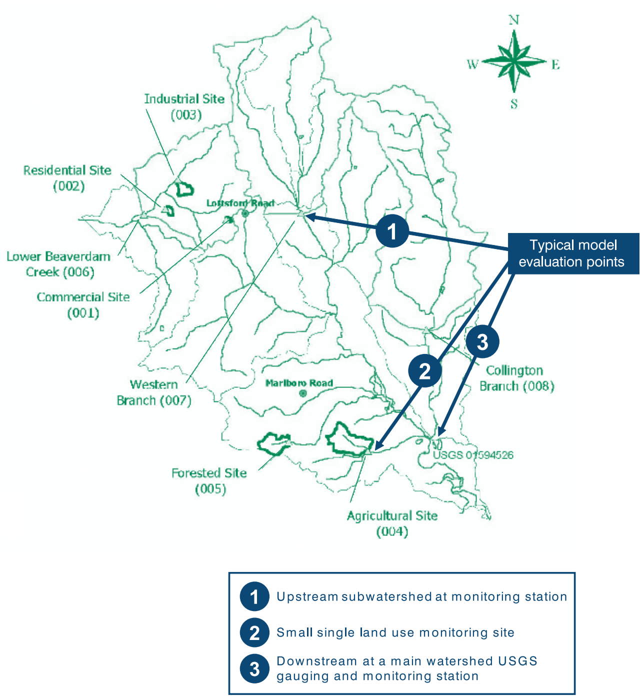


Figure 8-2. Typical Model Evaluation Points

Example Calibration Tests

Regression: Model output is plotted against observed data, and a regression equation can identify the relationship between modeled and observed values and the goodness of fit. (See figures 8-3 and 8-4 for examples.)

Relative error: Modeled errors are measured by comparing simulated flow values with observed flow values for various periods (e.g., for the summer) using the following equation:

(Simulated value − observed value)/observed value

A small relative error indicates a better goodness of fit for calibration.

Model coefficient of efficiency: This value measures the ratio of the mean square error in model predictions to the variance in the observed data. Values range from minus infinity to 1.0; higher values indicate better agreement.

Student's t-test: This test measures the equality of average modeled concentrations compared to average observed concentrations over various periods (e.g., the entire calibration period).

Some modeling studies require adjusting or estimating parameters through a calibration process. For this process the monitoring data are split into two independent periods—calibration and validation. Ideally, these periods are two typical time periods (not extreme conditions) with a range of flow conditions. During the calibration period key parameters are adjusted within reasonable ranges until the best fit with the observed data is determined. The performance of the "calibrated" model is then tested for a separate validation period.

The various model adjustment capabilities for the selected models depend on the techniques used for simulating runoff and pollutant transport (table 8-11). All models based on the CNE have limited ability for calibration of flow. Because the CN is selected based on defined look-up tables, only some slight adjustment of a CN for local conditions can be justified. GWLF and SWAT provide for ground water discharges to stream systems, offering an opportunity for calibrating instream flow volume. In this group of models, HSPF provides the most flexibility for adjusting parameters to match local conditions. HPSF includes calibration variables for infiltration, upper and lower zones of soil storage, ground water inputs to streams, and pollutant buildup and wash-off. Although this flexibility can help tailor the model to local conditions, the number of parameters involved can introduce errors and bias to the analysis as well. Adjustment of parameters must carefully consider the physical processes being represented and the reasonable ranges for the parameters. SWMM has many of the same infiltration and pollutant wash-off features as HSPF. SWMM has a more simplified approach for erosion simulation using the USLE, and it does not have the ability to simulate detailed land management activities (e.g., manure applications, tillage practices). However, SWMM does include techniques for evaluating structural management practices and pipes typical of urban areas.

Table 8-11. Typical Calibration Options for Selected Example Models

	Flow Calibration	Pollutant Calibration
AGNPS	Limited CN	Nutrient concentrations in water and sediment
STEPL	Limited/CN only	Loading rate
GWLF	Ground water recession	Nutrient concentrations in water (runoff, ground water) and sediment
HSPF	Multiple, infiltration, soil storage, ground water	Pollutant buildup and wash-off, instream transport/decay
P8-UCM	Limited/CN only	Loading rate or more detailed buildup and wash-off of dust and pollutants
SWAT	Ground water	Nutrient concentrations in water and sediment
SWMM	Multiple, infiltration, soil storage, ground water	Pollutant buildup and wash-off, instream transport/decay

There are two major sequences or hierarchies of testing—parameters and time scales. Of all the parameters predicted by the model, flow is always checked first, followed by sediment, and then the various pollutants being simulated (e.g., nutrients, metals). Multiple time scales are also evaluated, including annual, monthly, and daily summaries (figure 8-3). Time periods can also be grouped by season to evaluate performance that relates to wet and dry periods reflective of local weather patterns. In addition, for models sensitive to rainfall intensity, such as HSPF, predictions can be evaluated on the basis of storm size. For example, how well does the model predict the smallest 25 percent of all storms?

The typical factors used in evaluating model performance include the following:

- Water balance (general assessment of precipitation, evaporation, infiltration, and runoff)
- Observed versus measured flow (daily average, monthly, annual, and flow duration curves) (figure 8-3)
- Observed versus measured load (annual loads, seasonal variation, source loads)
- Observed versus modeled pollutant concentrations (figure 8-4) or pollutant loads

Figure 8-3. Sample Calibration Tests for Hydrologic Simulation

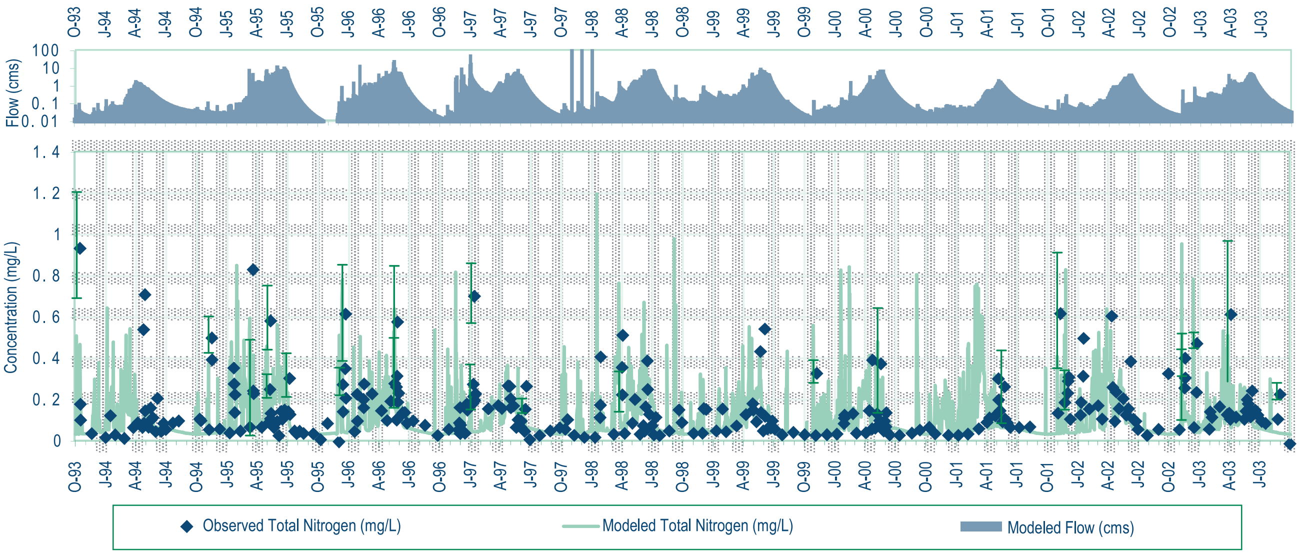


Figure 8-4. Sample Model Testing Graphic

These factors can all be "tested" through graphical evaluation or by applying statistical tests to observed data and modeled output (see sidebar for examples). Each test can examine different aspects of performance consistent with the type of model selected and the questions being evaluated. Testing is a process that can be used to diagnose problems with the model setup, improve model simulation, and ultimately confirm that the model is working correctly.

You should not rely too heavily on a single test, but use a combination of approaches to get a multifaceted evaluation of model performance. When you start testing the model, watch out for indications that something has been missed during model setup. Sometimes models appear not to work because a source is missing or was incorrectly entered into the model. For example, the model might appear to underpredict flow during low-flow periods. This could be an indication that a point source discharge is missing or that ground water recharge into the stream system is too low. Looking carefully at this low-flow period, when point sources and ground water are the dominant sources, and reviewing local records can help you to diagnose this problem. Always check carefully for missing information before you adjust model parameters to compensate for something you observe. Be careful to keep track of changes and modeling versions so that updates are consistently incorporated into subsequent analyses.

Sometimes local anomalies in geology and hydromodification can significantly affect flow and loading predictions. These local conditions should be considered during the model selection process. Setup and application of models need to specifically account for local geology and hydrologic conditions. Some examples of specialized conditions follow:

- *Unusual hydrology due to local geologic conditions (e.g., karst features).* Some areas have unusual conditions. Streams might disappear or have unusual flow patterns. If these conditions are not well understood or monitored, modeling will be difficult.
- *High water table.* If the water table is very high, rainfall might not infiltrate, or interactions between surface water and ground water might occur.
- *Undiagnosed or undiscovered sources.* If a source is unknown, it won't be in the model. When testing a model, you might realize that a source is missing. Additional field reconnaissance or monitoring might be needed to check.

8.4.5 Estimation of Existing Conditions and Baseline Scenarios

The modeling approaches developed are ultimately designed to support decisionmaking. Essential to decisionmaking is the application of the model to various alternatives. How you use the model to support decisionmaking is as important as the various steps that go into building and testing the model. Typically, models are applied to an existing condition to set a baseline for comparison. Existing conditions can be compared with management alternatives and future conditions. Remember that "existing" is really a reflection of the data used to build the model. If the land use data you're using are 10 years old and were not updated for the study, "existing" really represents 10 years ago. If residential development includes management practices and you have not included management practices in the model, "existing" conditions might overestimate loads.

Documenting Model Selection and Application

When using a model as part of a watershed management effort, it's important to document the modeling process. The purpose of documentation is to provide a firm understanding of what the modeling effort represents to the public and planning committee. At a minimum, the model documentation should include the following:

- Model name and version
- Source of model
- Purpose of model application
- Model assumptions (list or summarize); any of the assumptions could limit the usability of the results of the application, and that must be explained
- Data requirements and source of datasets

To estimate existing conditions, you apply the calibrated model to some typical time period and then calculate the loads based on model results. To help understand the watershed loads and their sensitivity to different watershed conditions, it's useful to apply the model to various scenarios that represent some variation of the baseline. Some of the model applications you might want to consider are

- Future land use under various growth or land use conversion scenarios
- Management practice or point source implementation alternatives
- Historical or predevelopment conditions

Ultimately, in designing and selecting management alternatives (discussed in chapters 10 and 11), you can use the model to support selection of the preferred alternative and to estimate the benefits of management implementation.

8.5 Presenting Pollutant Loads

You'll use the information gained from your loading analysis to quantify the watershed pollutant loads. Your loading analysis essentially quantified the loads, but now you have to decide how to present them for use in your watershed plan. Two factors will affect this decision—space and time. You need to decide the spatial resolution for your loads, as well as the time scale for their calculation. You initially made these decisions when you identified your sources (chapter 7), but now you'll refine the spatial and time scales for evaluating and calculating source loads based on your loading analysis.

Tip Keep a log of all scenarios considered and the input assumptions used for each.

Table 8-12 summarizes typical scales for calculating and presenting loading results from watershed models. Presentations can use a combination of tables and graphical displays. (Storing information in spreadsheets or databases can facilitate comparisons and preparation of graphics.) Developing maps, graphs, bar charts, and piecharts can help to summarize information and facilitate interpretation of results.

Table 8-12. Typical Loading Presentation Categories and Types

Spatial Scale	Land Use	Time Scale
• Watershed • Tributary (multiple-subwatershed) • Region (political or other boundaries) • Subwatershed • Critical areas	• Watershed general land use category (agriculture, urban) • Land use subcategory (cropland, pasture, residential)	• Average annual • Annual • Seasonal • Monthly • Storm • Design storm

8.5.1 Consider Spatial Scales

There are various options for assigning the spatial extent for your load calculations. You can quantify a gross load for the overall watershed or for each land use or even for each land use in each subwatershed. The detail to which you calculate the loads in the watershed will depend primarily on the types and locations of the watershed sources identified during the data analysis. If a spatial analysis of water quality data identified critical areas in the watershed—areas experiencing the most or worst problems and impairments—those areas should be isolated and the loadings presented separately. If the watershed is large and has a variety of pollutant sources, it is recommended that you present the loadings by subwatersheds or groupings of subwatersheds, such as larger tributaries (figure 8-5). Calculating loads by land use is also useful because many pollutants are associated more with some land uses than with others. For example, cropland runoff is often a source of nutrients, whereas forested areas are typically less significant sources of nutrients.

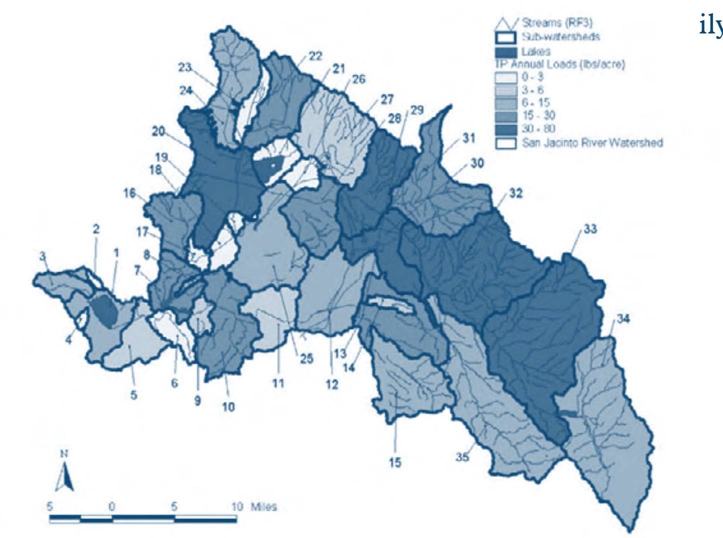


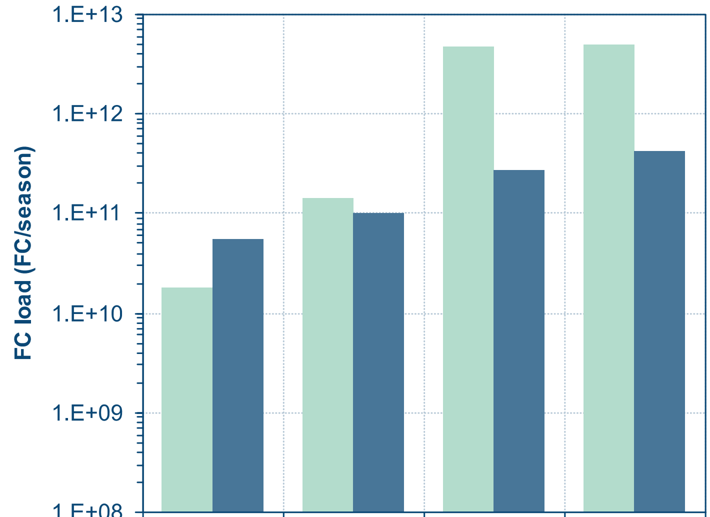
Figure 8-5. Presentation of Annual Sediment Loads (lb/ac) by Subwatershed, San Jacinto, California

8.5.2 Consider Time Scales

The other issue affecting how you present the watershed loads in your watershed plan is the associated time scale. Loads can be calculated for a number of time scales—daily, monthly, seasonal, annual. Like the spatial resolution, the appropriate time scale depends on the sources and problems in your watershed. The results of the data analyses provide a guide for selecting the appropriate time scale for the loading analysis and ultimate presentation of the loads. For example, analysis of monthly or seasonal water quality conditions identifies the critical times of year in the watershed. If there is considerable variation in water quality throughout the year, given source loading characteristics and weather patterns, it might be necessary to calculate seasonal loads (figure 8-6).

The impairment characteristics and water quality or watershed targets can also affect the loading time scale. Some pollutants, such as bacteria, have more immediate impacts, and associated targets are often based on daily maximums or a geometric mean of instantaneous concentrations. For bacteria, it might be appropriate to use an approach that is capable of calculating daily loads for comparison to water quality targets. Sediment loading, on the other hand, is a chronic problem that has long-term impacts (figure 8-7). Occasional high sediment concentrations might not cause problems, but frequent high sediment loading could result in long-term impacts on aquatic habitat. Therefore, it is usually appropriate to evaluate sediment loading on a monthly or annual basis.

Keep in mind that how you establish the pollutant loads will affect your ability to evaluate management options. When quantifying the pollutant loads, you're essentially establishing the baseline load that will be reduced to meet your watershed goals. If you establish an overall load for the entire watershed, it will be difficult to assess changes in loads and improvements throughout the watershed. If you establish loads at critical areas (e.g., downstream of a major source, for specific land uses), you can more readily evaluate the direct impact of the surrounding sources and also future management efforts targeted at those sources.



	Winter	Spring	Summer	Total
Existing	1.77E+10	1.43E+11	4.75E+12	4.91E+12
Allocation	5.61E+10	1.01E+11	2.76E+11	4.34E+11

Figure 8-6. Seasonal Fecal Coliform Bacteria Loads

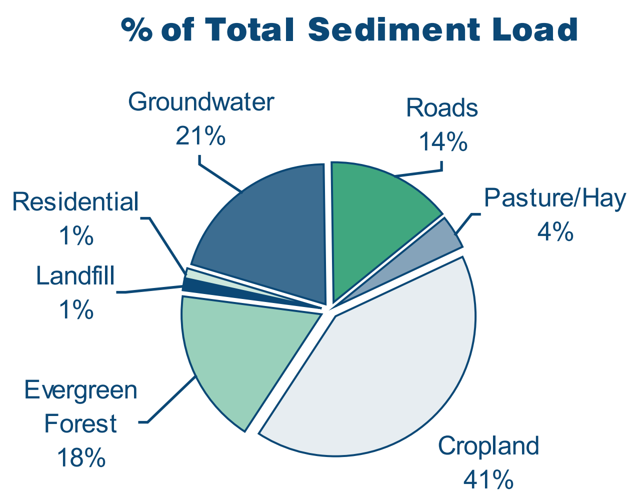


Figure 8-7. Total Sediment Load and Percentages Associated with Each Source

8.5.3 Next Steps in Developing the Watershed Plan

Now that you've calculated source loads for your watershed, you can move on to the next step of the watershed plan development process—identifying watershed targets and necessary load reductions. The loads you've calculated will provide the basis for identifying the load reductions needed to meet watershed goals and eventually for selecting appropriate management practices.

9. Set Goals and Identify Load Reductions

Chapter Highlights

- Setting goals
- Identifying management objectives
- Selecting indicators
- Developing targets
- Determining load reductions needed
- Focusing on load reductions

Read this chapter if...

- You want to select indicators to measure attainment of your watershed goals
- You want to use your watershed goals to identify numeric water quality targets
- You need an approach to determine how much of a load reduction you need to meet your watershed goals
- You want information on how to focus load reductions appropriately

9.1 How Do I Link the Watershed Analysis to Management Solutions?

Once you have analyzed the data, identified the problem(s) in the watershed, and identified and quantified the sources that need to be managed, you'll develop management goals and associated targets. During the scoping phase of planning (chapter 4), you established broad watershed goals (e.g., meet water quality standards, restore degraded wetlands) as a preliminary guide. Now that you have characterized and quantified the problems in the watershed (chapters 7 and 8), you're ready to refine the goals and establish more detailed objectives and targets that will guide developing and implementing a management strategy.

The process of developing specific objectives and targets is an evolution of the watershed goals you identified with your stakeholders. As you proceed through the watershed plan development, you'll gain more information on the watershed problems, waterbody conditions, causes of impairment, and pollutant sources. With each step of the process, you can focus and better define your watershed goals, until eventually you have specific objectives with measurable targets. Figure 9-1 illustrates this evolution. The first step is identifying the broad watershed goals with your stakeholders, answering "What do I want to happen as a result of my watershed plan?" As you do this, you'll also identify environmental indicators that can be used to measure progress toward meeting those goals. Once you have identified the sources contributing to watershed problems, you can refine your watershed goals and develop management objectives targeted at specific pollutants or sources. The management objectives identify how you will achieve your goals. It's important to have indicators that can be measured (e.g., load or concentration) to track progress toward meeting those objectives. You should link some of these indicators to pollutant sources based on their cause-and-effect relationship to then identify the load reductions needed to meet the target. For example, instream levels of dissolved oxygen can be linked to nutrient loads, and you can use various methods to determine what reductions in nutrients will result in the dissolved oxygen target.

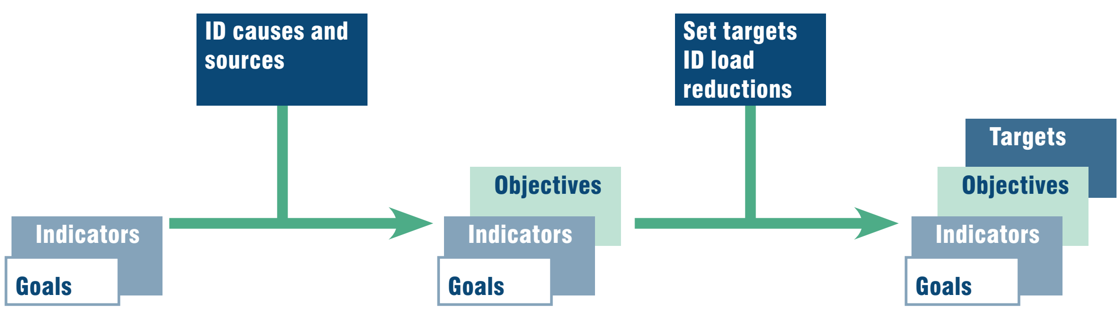


Figure 9-1. Process for Identifying Final Watershed Goals and Targets

Once you have identified your indicators, numeric targets, and associated load reductions, they can be incorporated into the management objectives for the final goals for your watershed plan. These goals will guide the identification and selection of management practices to meet the numeric targets and, therefore, the overall watershed goals, as discussed in chapters 10 and 11.

9.2 Translate Watershed Goals into Management Objectives

You've probably already identified preliminary goals and associated environmental indicators with your stakeholders, as outlined in chapter 4, but now you'll refine the goals on the basis of your data analysis. The data analysis identified the likely causes and sources affecting specific indicators (e.g., temperature, dissolved oxygen, pebble counts). Therefore, you have an idea of what sources need to be controlled to meet your overall watershed goals and can use this information to translate your watershed goals into management objectives. Management objectives incorporate the watershed goals but focus on specific processes that can be managed, such as pollutant loading and riparian conditions.

For example, perhaps during the scoping phase you knew that there was a problem with aquatic habitat so you established the preliminary goal "restore aquatic habitat." Now, after the data analysis, you can refine the goal to include a specific management objective, such as "restore aquatic habitat in the upper main stem of White Oak Creek by controlling agricultural sources of sediment." Table 9-1 provides some examples of translating watershed goals into management objectives.

Table 9-1. Sample Goals Linked to the Sources and Impacts to Define Management Objectives

Preliminary Goal	Indicators	Cause or Source of Impact	Management Objective
Support designated uses for aquatic life; reduce fish kills	Dissolved oxygen Phosphorus Temperature	Elevated phosphorus causing increased algal growth and decreased dissolved oxygen Cropland runoff	Reduce phosphorus loads from cropland runoff and fertilizer application
Reduce flood levels	Peak flow volume and velocity	Inadequate stormwater controls, inadequate road culverts	Minimize flooding impacts by improving peak and volume controls on urban sources and retrofitting inadequate road culverts
Restore aquatic habitat	Riffle-to-pool ratio, percent fine sediment	Upland sediment erosion and delivery, streambank erosion, near-stream land disturbance (e.g., livestock, construction)	Reduce sediment loads from upland sources; improve riparian vegetation and limit livestock access to stabilize streambanks
Meet water quality standards for bacteria to reduce beach closures	Fecal coliform bacteria	Runoff from livestock operations, waterfowl	Reduce bacteria loads from livestock operations
Improve aesthetics of lake to restore recreational use	Algal growth, chlorophyll a	Elevated nitrogen causing increased algal growth	Reduce nitrogen loads to limit algal growth
Meet water quality standards for metals	Zinc, copper	Urban runoff, industrial discharges	Improve stormwater controls to reduce metal loads from runoff
Restore wetland	Populations of wetland-dependant plant and animal species; nitrogen and phosphorus	Degradation of wetland causing reduced wildlife and plant diversity and increases in nitrogen and phosphorus runoff because of a lack of wetland filtration	Restore wetland to predevelopment function to improve habitat and increase filtration of runoff
Conserve and protect critical habitat	Connectivity, aerial extent, patch size, population health	Potential impacts could include loss of habitat, changes in diversity, etc.	Maintain or improve critical habitat through conservation easements and other land protection measures

9.3 Select Environmental Indicators and Targets to Evaluate Management Objectives

Once you have established specific management objectives, you'll develop environmental indicators and numeric targets to quantitatively evaluate whether you are meeting your objectives. You identified indicators with the stakeholders when you developed your conceptual model (➥ chapter 4), and the indicators should be refined in this step. The indicators are measurable parameters that will be used to link pollutant sources to environmental conditions. The specific indicators will vary depending on the designated use of the waterbody (e.g., warm-water fishery, cold-water fishery, recreation) and the water quality impairment or problem of concern. For example, multiple factors might cause degradation of a warm-water fishery. Some potential causes include changes in hydrology, elevated nutrient concentrations, elevated sediment, and higher summer temperatures. Each of these stressors can be measured using indicators like peak flow, flow volume, nutrient concentration or load, sediment concentration or load, and temperature.

Don't Forget About Programmatic and Social Indicators

➥ Chapters 4 and 12 discuss the development of a variety of indicators to measure progress in implementing your watershed plan and meeting your goals. Indicators can be environmental, social, or programmatic. This chapter discusses only environmental indicators and how they are used to represent watershed goals and evaluate pollutant load reductions. Social and programmatic indicators are identified as part of the implementation program, ➥ discussed in chapter 12.

A specific value can be set as a target for each indicator to represent the desired conditions that will meet the watershed goals and management objectives. Targets can be based on water quality criteria or, where numeric water quality criteria do not exist, on data analysis, reference conditions, literature values, or expert examination of water quality conditions to identify values representative of conditions that support designated uses. If a Total Maximum Daily Load (TMDL) already exists for pollutants of concern in your watershed, you should review the TMDL to identify appropriate numeric targets. TMDLs are developed to meet water quality standards, and when numeric criteria are not available, narrative criteria (e.g., prohibiting excess nutrients) must be used to develop numeric targets.

It might be necessary to identify several related indicators and target values to facilitate evaluation of pollutant loads and measure progress. For example, dissolved oxygen is an indicator of the suitability of a waterbody to support fisheries. However, dissolved oxygen is not a specific pollutant and is not typically estimated as a load. Because dissolved oxygen is a waterbody measure that is affected by several parameters, including nutrients, it's appropriate to select other indicators that can be linked to dissolved oxygen and quantified as loads (e.g., phosphorus loading).

Not All Indicators Will Have Associated Load Reductions

It will be difficult or impossible to develop quantifiable indicators for all watershed issues of concern. For example, some goals and associated indicators (e.g., "make the lake more appealing for swimming," or "reduce the prevalence of exotic species") are indirectly related to other indicators that are more easily linked to source loads (e.g., dissolved oxygen, nutrient loads), and trying to link them to one or even a few specific pollutants and source loads is often too difficult or inappropriate. Therefore, these indicators are expected to improve based on identified load reductions for other indicators. They will be directly measured to track overall watershed goals, but they will not have an associated load reduction target.

Table 9-2 provides some examples of indicators and target values associated with management objectives.

9.4 Determine Load Reductions to Meet Environmental Targets

At this point in the watershed planning process, you have already quantified the pollutant loads from sources in your watershed (➥ chapter 8) and identified appropriate environmental indicators and associated targets to meet your watershed goals. The next step is to determine the load reductions needed to meet your targets—how to control watershed sources to meet your goals.

Table 9-2. Examples of Indicators and Targets to Meet Management Objectives

Management Objective	Indicator and Target Value
Reduce phosphorus loads from cropland runoff and fertilizer application	*Dissolved oxygen*: Daily average of 7 mg/L (from water quality standards) *Phosphorus*: Daily average of 25 μg/L (based on literature values)
Minimize flooding impacts by improving peak and volume controls on urban sources and retrofitting inadequate road culverts	*Peak flow volume and velocity*: Peak velocity for 1-yr, 24-hr storm of 400 cfs
Reduce sediment loads from upland sources; improve riparian vegetation and limit livestock access to stabilize streambanks	*Riffle-to-pool ratio*: 1:1 ratio (based on literature values) *Percent fine sediment*: <10 percent of particles <4 mm (based on reference conditions)
Reduce bacteria loads from livestock operations	*Fecal coliform bacteria*: Geometric mean of 200 cfu/100 mL (based on water quality standards)
Reduce nitrogen loads to limit algal growth	*Algal growth*: <10 percent coverage of algal growth (based on reference conditions) *Chlorophyll a*: <1 μg/L (based on literature values)
Improve stormwater controls to reduce metal loads from runoff	*Zinc*: Maximum of 120 μg/L (based on water quality standards) *Copper*: Maximum of 13 μg/L (based on water quality standards)

This phase of the watershed planning process should result in element *b* of the nine elements for awarding section 319 grants. Element *b* is "*An estimate of the load reductions expected from management measures.*"

To estimate the load reductions expected from the management measures, you need to understand the cause-and-effect relationship between pollutant loads and the waterbody response. Establishing this link allows you to evaluate how much of a load reduction from watershed sources is needed to meet waterbody targets. The options for establishing such links range from qualitative evaluations to detailed receiving water computer modeling. As with your approach for quantifying pollutant loads, selecting the appropriate approach will depend on several factors, including data availability, pollutants, waterbody type, source types, time frame, and spatial scale. Most important, the approach must be compatible with the method used to quantify loads and must be able to predict the necessary load reductions to meet targets.

A number of techniques—some more rigorous and detailed than others—can be used. Sometimes models or analytic techniques that allow for careful calculation of appropriate loading are used, but at other times you might have only limited data to estimate loadings. This section includes a range of approaches you can use to identify the load reductions needed to meet targets. Remember that the load estimates can be updated over time as more information and data are collected. The options discussed in this section include

- Qualitative linkages
- Mass balance approach
- Empirical relationships
- Statistical or mathematical relationships
- Reference watershed approach
- Receiving water models

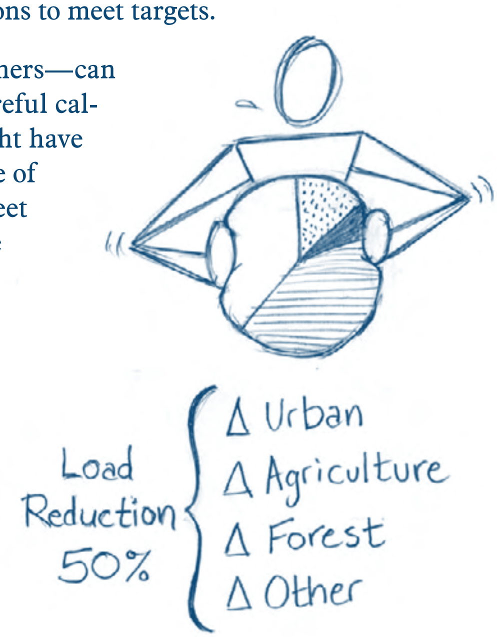


Table 9-3 presents some example approaches for the linkage analysis for typical waterbody-pollutant combinations. Many of these approaches are discussed in the following sections.

Table 9-3. Example Approaches for Linking Indicators and Sources

Waterbody–Pollutant Combination	Example Linkage Approach
River–Pathogens	Instream response using HSPF (data collection consideration)
Lake–Nutrients	Lake response using BATHTUB More detailed option using CEQUAL-W2 or EFDC
River–Nutrients	Stream response using mass balance, QUAL2E low-flow model, or WASP
River–Pesticides/Urban	Allowable loading determination based on calculation from identified target at design flow or a range of flows
River/Estuary–Toxic Substances	Allowable loading determination based on calculation from identified target at design flow or a range of flows
River–Sediment	Load target determined from comparison with desired reference watershed Geomorphic/habitat targets derived from literature
River–Temperature	SSTEMP or SNTEMP stream flow and temperature analysis QUAL2E stream flow and temperature analysis
River–Biological Impairment	Comparison of estimated watershed/source loads with loads in reference watershed
Estuary–Nutrients	Estuary response using Tidal Prism, WASP, EFDC, or similar model
Coastal Pathogen	Response using WASP, EFDC, or similar model Alternatively, determine correlation of coastal impairment with tributary loading

9.4.1 Qualitative Linkages Based on Local Knowledge or Historical Conditions

If you have only limited data for your watershed and the sources and causes are not well documented or characterized, it might be appropriate to use a theoretical linkage to explain the cause-effect relationship between sources and waterbody conditions. You might have to rely on expert or local knowledge of the area and sources to identify coarse load reduction

What if Load Reductions for My Watershed Have Already Been Established by a TMDL?

An existing study (e.g., TMDL) might already have identified the allowable loading for one or more pollutants in your watershed. You might be able to use these studies for your targets or at least incorporate them into your analysis.

Keep the following in mind when incorporating TMDL results:

- Pollutants: What pollutants were considered? How do they relate to your goals?
- Time frame: Have conditions changed from the time of TMDL development?
- Data availability: Are more data available now to update the analysis?
- Management efforts: Have any management activities been implemented since the TMDL was developed that should be taken into account?
- Source level: At what level did the TMDL assign load allocations and reductions? Do you want more detailed or more gross distributions?

targets. If you do this, remember to incorporate a schedule for updating your watershed plan and load reductions as more information and data are collected.

An example of a qualitative linkage is an assumed linkage between instream sediment deposition and watershed sediment loading. The expected problem is fine sediment filling in pools used by fish and cementing the streambed, prohibiting the fish from laying eggs. Although it is known that sediment loading increases the deposition of fine sediment, you have no documented or quantified link between the two. You can estimate a conservative load reduction, accompanied by plans for additional monitoring to evaluate instream conditions.

Another example of a qualitative linkage is the assumption that loading is directly proportional to the instream response. That is, a percent increase in loading will result in an equal percent increase in instream concentrations. Assuming this, you can use observed data to calculate the needed reduction in waterbody concentration to meet your target and assume that it is equal to the necessary percent reduction in loading. Although a 1-to-1 relationship between loading and concentration likely does not exist, you might not have the data needed to support identification of a more accurate linkage.

9.4.2 Mass Balance Approach

A mass balance analysis represents an aquatic system through an accounting of mass entering and exiting the system. This analysis simplifies the representation of the waterbody and does not estimate or simulate detailed biological, chemical, or physical processes. It can, however, be a useful and simple way to estimate the allowable loading for a waterbody to meet water quality standards or other targets. The approach includes tallying all inputs and outputs of a waterbody to evaluate the resulting conditions. To successfully apply a mass balance, it's important to understand the major instream processes affecting water quality, such as decay, background concentrations, settling, and resuspension. Many of these factors can be estimated based on literature values if site-specific information is not available.

The mass balance approach is versatile in its application, allowing for varying levels of detail. In addition, it requires loading inputs but does not require that the loads be calculated by particular methods. Because of this, you can use a mass balance in conjunction with a variety of approaches for calculating watershed loads. You can use loads calculated from a watershed model, as well as those from a simple analysis using loading rates and land use distribution. You can apply mass balance equations at various places in the watershed, depending on the resolution of your loading analysis.

Using a Mass Balance Equation to Evaluate Phosphorus Loading in Pend Oreille Lake, Idaho

The Pend Oreille Lake TMDL uses a mass balance approach for identifying existing loading and allowable loading for nutrients in the nearshore area of the lake. The nearshore area was identified as impaired on the basis of stakeholder concerns over algae and "slimy rocks" in the area. A mass balance approach was used to identify current watershed phosphorus loading based on observed lake concentrations and allowable loading based on an in-lake phosphorus target concentration. Several of the mass balance factors were based on site-specific data (e.g., lake "cell" volume calculated using Secchi depths) and literature values (e.g., settling velocity of phosphorus, first-order loss coefficients).

For more details on how this TMDL used mass balance, go to **www.tristatecouncil.org/documents/02nearshore_tmdl.PDF**.

9.4.3 Empirical Relationships

In some cases, depending on the indicators and pollutants of concern, you can use documented empirical relationships to evaluate allowable loading and load reductions to meet watershed targets. Empirical relationships are relationships based on observed data, and an empirical equation is a mathematical expression of one or more empirical relationships.

One example of an empirical relationship that can be used in evaluating allowable loading is the Vollenweider empirical relationship between phosphorus loading and trophic status. The Vollenweider relationship predicts the degree of a lake's trophic status as a function of the areal phosphorus loading and is based on the lake's mean depth and hydraulic residence time. For example, the Lake Linganore, Maryland, TMDL for nutrients used the Vollenweider relationship to identify the allowable loading and necessary loading reductions to return the lake to mesotrophic conditions, represented by Carlson's Trophic Status Index (TSI of 53 and chlorophyll a of 10 μg/L). The existing nutrient loading to the lake was calculated using land use areas and phosphorus loading rates obtained from the Chesapeake Bay Program. The Vollenweider relationship was then used to identify the allowable annual phosphorus loading rate to meet the trophic status targets. The existing loading and allowable loading were compared to identify the necessary load reductions.

Tip Check the assumptions used in developing empirical equations. They usually predict an "average" condition or are based on conditions specific to certain regions. Is your waterbody unusual (e.g., narrow and deep)? Sometimes the unique features of your waterbody or watershed make a difference and require more sensitive analyses or models.

Another example of an empirical relationship is the Simple Method (Schueler 1987), discussed in section 8.2.2. The Simple Method calculates pollutant loading using drainage area, pollutant concentrations, a runoff coefficient, and precipitation data. If your watershed target is a pollutant concentration, you can apply the Simple Method using your concentration target to estimate the allowable loading to meet that target.

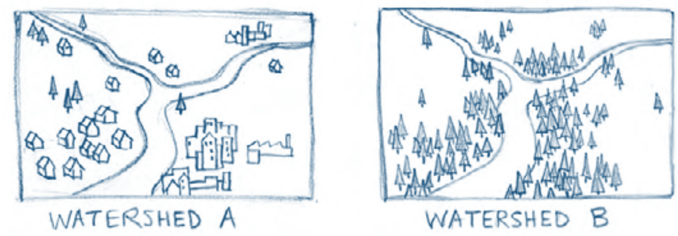
Use care when applying empirical relationships because although they are based on observed data, they might not be representative of your watershed or be applicable to your purposes. When using empirical relationships, it's important to review the documentation and literature to understand on what data the relationship is based and any related assumptions or caveats for applying the relationship or equation.

9.4.4 Statistical or Mathematical Relationships

You can use statistical or mathematical analyses to estimate allowable loadings and subsequent load reductions based on available data for your watershed. This approach assumes some relationship between key factors in the watershed (e.g., loading, percent land use) and instream conditions (e.g., concentration) based on observed data. A load duration curve, discussed in detail in section 7.2.4, is one of the most common of these types of linkages. This approach can be applied to diagnose and evaluate waters (e.g., dominant types of sources, critical conditions) and can help to determine specific load reductions. A limitation of this approach is that it does not explicitly describe where the loads are coming from or how they are delivered. The technique is well suited to areas where robust monitoring records are available but data are too limited to use more detailed watershed loading models. The analysis does not identify load reductions by source type, but it can be applied at any location in the watershed with sufficient data.

9.4.5 Reference Watershed Approach

If you don't have an appropriate water quality or loading target, another technique for linking your indicators to source loads is to compare your watershed with another one that is considered "healthy." The reference watershed approach is based on using an unimpaired watershed that shares similar ecoregion and geomorphological characteristics with the impaired watershed to identify loading rate targets. Stream conditions in the reference watershed are



assumed to be representative of the conditions needed for the impaired stream to support its designated uses and meet the watershed goals.

You should select a reference watershed on the basis of conditions that are comparable with the watershed requiring management. The reference watershed should be similar to your watershed in size, land use distribution, soils, topography, and geology. To set the loading rate target, predict the loading for each watershed through modeling or another method and then determine the allowable loading rate based on the reference watershed loads and areas. The loading rate from the reference watershed can be calculated at a level comparable to the sources you identified in your watershed. For example, you can model specific land uses or crop types in the reference watershed to identify loading rates or identify a gross rate based on the loading from the entire watershed. The reference loading rates are then multiplied by the appropriate areas of the watershed to identify allowable loads for the impaired watershed. The load reduction requirement is the difference between this allowable loading and the existing load (estimated in chapter 8).

This approach is best suited to waters not meeting biological or narrative criteria (e.g., criteria for nutrients and sediment), where instream targets are difficult to identify. Selecting a reference watershed can be extremely difficult, and not all areas have appropriate watershed data or sufficient monitoring data to support selection.

9.4.6 Receiving Water Models

Sometimes it will be appropriate or even necessary to use detailed receiving water modeling to relate watershed source loads to your watershed indicators. The following are typical situations in which you should use a model instead of a simpler approach:

- Locally significant features or conditions (e.g., groundwater interaction) affect the waterbody's response.
- Chemical and biological features are complicated and affect the waterbody's response to pollutant loads (e.g., nutrient loads affecting algal growth and subsequent dissolved oxygen).
- Unique physical characteristics of the waterbody must be considered (e.g., long and narrow lake).
- There are localized impairments and impacts due to the location of sources (e.g., discharge from a feedlot affects a small segment of stream).
- Cumulative impacts occur from pollutants (e.g., metals) that can accumulate in sediment and organisms.

Table 9-4 provides a summary of many of the receiving water models available to support linkage of sources and indicators for watershed planning. For more details on the models, go to EPA's Council for Regulatory Environmental Modeling (CREM) Web site at **http://cfpub.epa.gov/crem/**.

Table 9-4. Overview of Various Receiving Water Models

Model	Source	Type			Level of Complexity			Water Quality Parameter							
		Steady-state	Quasi-dynamic	Dynamic	1-dimensional	2-dimensional	3-dimensional	User-defined	Sediment	Nutrients	Toxic substances	Metals	BOD	Dissolved oxygen	Bacteria
AQUATOX	USEPA	—	—	●	●	—	—	—	●	●	●	—	●	●	—
BASINS	USEPA	—	●	●	●	—	—	●	●	●	●	●	●	●	●
CAEDYM	University of Western Australia	—	—	●	●	●	●	●	●	●	—	●	●	●	●
CCHE1D	University of Mississippi	—	—	●	●	—	—	—	●	—	—	—	—	—	—
CE-QUAL-ICM/ TOXI	USACE	—	—	●	●	●	●	●	—	●	—	●	●	●	—
CE-QUAL-R1	USACE	—	—	●	●	—	—	—	●	●	—	●	●	●	●
CE-QUAL-RIV1	USACE	—	—	●	●	—	—	—	—	●	—	●	●	●	●
CE-QUAL-W2	USACE	—	—	●	—	●	—	—	—	●	—	—	●	●	●
CH3D-IMS	University of Florida, Dept. of Civil and Coastal Engineering	—	—	●	●	●	●	—	●	●	—	—	●	●	—
CH3D-SED	USACE	—	—	●	●	●	●	—	●	—	—	—	—	—	—
DELFT3D	WL | Delft Hydraulics	—	—	●	●	●	●	●	●	●	●	●	●	●	●
DWSM	Illinois State Water Survey	—	—	●	●	—	—	—	●	●	●	—	—	—	—
ECOMSED	HydroQual, Inc.	—	—	●	●	●	●	—	●	—	—	—	—	—	—
EFDC	USEPA & Tetra Tech, Inc.	—	—	●	●	●	●	●	●	●	●	●	●	●	●
GISPLM	College of Charleston, Stone Environmental, & Dr. William Walker	—	—	—	—	—	—	—	—	●	—	—	—	—	—
GLLVHT	J.E. Edinger Associates, Inc.	—	—	●	—	—	●	—	●	●	—	—	●	—	●
GSSHA	USACE	—	—	●	—	●	—	—	●	—	—	—	—	—	—
HEC-6	USACE	—	—	●	●	—	—	—	●	—	—	—	—	—	—
HEC-6T	USACE	—	—	●	●	—	—	—	●	—	—	—	—	—	—
HEC-RAS	USACE	—	—	●	●	—	—	—	—	—	—	—	—	—	—
HSCTM-2D	USEPA	—	—	●	—	●	—	—	●	—	—	—	—	—	—
HSPF	USEPA	—	—	●	●	—	—	●	●	●	●	●	●	●	●
LSPC	USEPA & Tetra Tech, Inc.	—	—	●	●	—	—	●	●	●	●	●	—	—	●

Table 9-4. Overview of Various Receiving Water Models (continued)

Model	Source	Type			Level of Complexity			Water Quality Parameter							
		Steady-state	Quasi-dynamic	Dynamic	1-dimensional	2-dimensional	3-dimensional	User-defined	Sediment	Nutrients	Toxic substances	Metals	BOD	Dissolved oxygen	Bacteria
MIKE 11	Danish Hydraulic Institute	●	—	●	—	●	—	—	—	—	—	—	—	—	—
MIKE 21	Danish Hydraulic Institute	—	—	●	—	●	—	—	●	●	●	●	●	●	●
MINTEQA2	USEPA	●	—	—	—	—	—	—	—	—	—	●	—	—	—
PCSWMM	Computational Hydraulics International	—	—	●	●	—	—	●	●	●	●	●	—	—	●
QUAL2E	USEPA	—	●	—	●	—	—	●	—	●	—	—	●	●	●
QUAL2K	Dr. Steven Chapra, USEPA TMDL Toolbox	—	●	—	●	—	—	●	—	●	—	—	●	●	●
RMA-11	Resource Modelling Associates	—	—	●	●	●	●	●	●	●	—	—	●	●	—
SED2D	USACE	—	—	●	—	●	—	—	●	—	—	—	—	—	—
SED3D	USEPA	—	—	●	●	●	●	—	●	—	—	—	—	—	—
SHETRAN	University of Newcastle (UK)	—	—	●	●	—	—	—	●	—	—	—	—	—	—
SWAT	USDA-ARS	—	●	—	●	—	—	—	●	●	●	●	●	●	—
SWMM	USEPA	—	—	●	●	—	—	●	●	●	●	●	—	—	●
Toolbox	USEPA	—	●	●	●	●	●	●	●	●	●	●	●	●	●
WAMView	Soil and Water Engineering Technology, Inc. (SWET) & USEPA	—	—	●	●	—	—	—	●	●	—	—	●	●	●
WARMF	Systech Engineering, Inc.	—	—	●	●	●	—	—	●	●	●	●	●	●	●
WASP	USEPA	—	—	●	●	●	●	●	●	●	●	●	●	●	—
WinHSPF	USEPA	—	—	●	●	—	—	●	●	●	●	●	●	●	●
WMS	Environmental Modeling Systems, Inc.	—	—	●	●	●	—	●	●	●	●	●	●	●	●
XP-SWMM	XP Software, Inc.	—	—	●	●	—	—	●	●	●	●	●	—	—	●

Note: BOD = biochemical oxygen demand.

— Not supported ● Supported

Source: USEPA. 2005. *TMDL Model Evaluation and Research Needs*. EPA/600/R-05/149. U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Cincinnati, OH. *www.epa.gov/nrmrl/pubs/600r05149/600r05149.htm*

9.5 Focus the Load Reductions

Regardless of what approach you use to estimate your allowable loadings or necessary reductions, it's likely that several scenarios or combinations of source reductions will meet your targets. Depending on the magnitude of your load reductions, you might be able to distribute them among your sources or you might have to focus on one dominant source to meet your targets. Table 9-5 illustrates how different target reductions can meet the same overall goal. In addition, the location of the proposed reductions can affect the distribution and magnitude of load reductions. If you calculate the load reduction only at the mouth of the watershed, a large number of scenarios will meet the load reduction target—at least on paper. Sometimes impacts from load reductions are not adequate to meet targets at downstream locations. Although the upstream reductions will no doubt improve downstream conditions, they might be such a small portion of the overall load that they won't have a measurable effect on the overall watershed loading. In addition, the load reductions calculated at the bottom of the watershed might not capture the more significant reductions needed in smaller upstream subwatersheds. Be sure to estimate your load reductions at a few key locations in the watershed to capture the major problem areas and sources and to support efficient and targeted management.

Table 9-5. Examples of Different Scenarios to Meet the Same Load Target

Source	Existing Phosphorus Loading (kg/yr)	Scenario 1		Scenario 2	
		% Load Reduction	Allowable Load (kg/yr)	% Load Reduction	Allowable Load (kg/yr)
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**

Note: 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. Scenario 2 represents a more feasible scenario, in which controllable sources (e.g., roads, cropland, pasture) are targeted to meet the load reduction target.

If you used a receiving model to evaluate your load reductions, you should use a "top-down" approach to evaluating necessary load reductions. Begin by identifying necessary load reductions to meet waterbody targets in upstream portions of the watershed. The model then allows you to then evaluate the effect of the upstream load reductions on downstream conditions. Starting at the top of the watershed and moving down, you can evaluate the cumulative effects from upstream controls. In many cases, the upstream reductions will significantly decrease or even eliminate the necessary reductions for the lower watershed.

By this point, you should have identified the overall load reductions needed to meet your targets and determined generally how you want to focus reductions among sources.

The activities discussed in chapters 10 and 11 will help you to more specifically identify and select the reductions for each source.

9.6 Summarize Watershed Targets and Necessary Load Reductions

9 Now that you have identified the pollutant load reductions needed to meet your watershed goals, you should have the information needed to satisfy element *b* of the nine minimum elements. At this point you should prepare a summary to be included in your watershed plan documenting the source loads, numeric targets to meet the watershed goals and management objectives, and load reductions needed to meet the targets. The reductions should be calculated and presented at the same time and spatial scales as the source load estimations (discussed in chapter 8). As with the source loads, there are a variety of ways you can present the load reduction requirements, including bar graphs and watershed maps.

You should also include in the summary other watershed targets—the indicators and numeric targets that could not be linked to specific pollutant loads (e.g., cobble embeddedness, percent fine sediment). Even though the response of these targets could not be predicted and linked to source loads, they're important for measuring the success of your watershed plan and the attainment of your watershed goals. These targets will be integrated into the implementation and monitoring plan (discussed in chapter 12).

State-Supported Modeling Tools

Some states are supporting modeling tools for conducting current load analyses and BMP load reduction projections. For example, Pennsylvania has merged the ArcView GWLF model with companion software developed for evaluating the implementation of both agricultural and non-agricultural pollution reduction strategies at the watershed level. This new tool, called PredICT (Pollution Reduction Impact Comparison Tool), allows the user to create various scenarios in which current landscape conditions and pollutant loads (both point and nonpoint) can be compared against future conditions that reflect the use of different pollution reduction strategies. This tool includes pollutant reduction coefficients for nitrogen, phosphorus and sediment, and it also has built-in cost information for an assortment of pollution mitigation techniques. For more information, visit **http://www.predict.psu.edu/**.

Handbook Road Map

10. Identify Possible Management Strategies

Chapter Highlights

- Overview of management techniques and measures
- Reviewing existing management efforts to determine gaps
- Identifying management opportunities and constraints
- Screening management options to determine the most promising types

Read this chapter if...

- You want to learn about common types of management measures
- You need information on how to focus management efforts in your watershed
- You want help with identifying possible management practices for your watershed
- You want to identify criteria for evaluating the appropriateness of management practices

10.1 How Do I Link My Management Strategies to My Goals?

Once you have analyzed the watershed conditions, quantified the pollutant loads, and determined the loading targets needed to meet your goals and objectives, you'll be ready to identify potential management measures and management practices to achieve your goals. You can then screen potential practices to narrow the options down to those which are the most promising and acceptable (figure 10-1). During this phase, it will be important for watershed planners and scientists to consult with engineers, technicians, and professional resource managers to ensure that the actions being considered are realistic and capable of meeting water quality objectives. The importance of this interaction cannot be overstated.

Key questions to address in your evaluation of candidate management measures and practices are these:

1. Are the site features suitable for incorporating the practice (i.e., is the practice feasible)?
2. How effective is the practice at achieving management goals and loading targets?
3. How much does it cost (and how do the costs compare between alternatives)?
3. Is it acceptable to stakeholders?

This chapter addresses the first step, identifying potential management measures and practices that might be feasible for addressing the particular problems in your watershed. Using screening criteria, you'll evaluate potential management strategies (a single management practice or multiple practices used in combination). The screening criteria are based on factors such as pollutant reduction efficiencies, legal requirements, and physical constraints. Once you have identified and screened various management options, ↳ chapter 11 will show you how to calculate the effectiveness of the management practices, compare the costs and benefits, and select the final management strategies that will be the most effective in achieving the load reductions needed to meet your watershed goals.

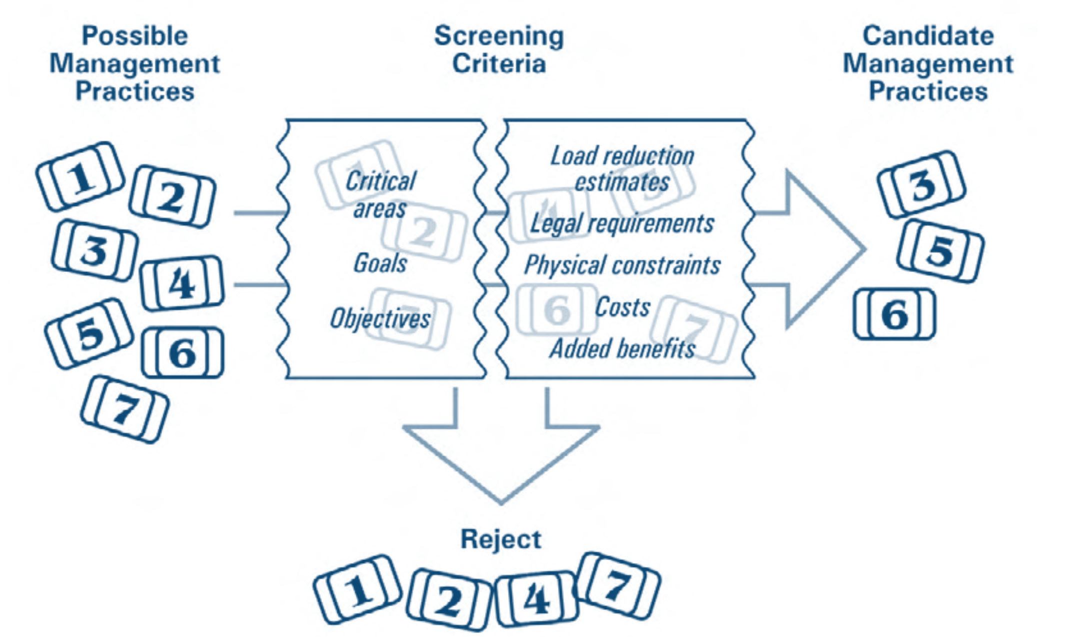


Figure 10-1. Process for Identifying Candidate Management Practices

9 The information presented in chapters 10 and 11 addresses element *c* of EPA's Nine Elements of Watershed Plans. Element *c* is *"A description of the nonpoint source management measures that will need to be implemented to achieve load reductions, and a description of the critical areas in which those measures will be needed to implement this plan."*

10.2 Overview of Management Approaches

A variety of management approaches are available to address water quality problems in the planning area. These include regulatory and nonregulatory approaches for dealing with point sources and nonpoint sources, e.g., management measures and management practices, terms that are sometimes used interchangeably. In general, management measures are groups or categories of cost-effective management practices that are implemented to achieve comprehensive goals, such as reducing the loads of sediment from a field to receiving waters. Individual management practices are specific and often site-based actions or structures for controlling pollutant sources.

Management measures and practices can be implemented for various purposes, such as

- Protecting water resources and downstream areas from increased pollution and flood risks
- Conserving, protecting, and restoring priority habitats
- Setting aside permanent aquatic and terrestrial buffers
- Establishing hydrologic reserve areas
- Acquiring ground water rights

Management measures can also help control the pollutant loads to receiving water resources by

- Reducing the availability of pollutants (e.g., reducing fertilizer, manure, and pesticide applications)
- Reducing the pollutants generated (source reduction such as erosion control)
- Slowing transport or delivery of pollutants by reducing the amount of water transported or by causing the pollutant to be deposited near the point of origin
- Causing deposition of the pollutant off-site before it reaches the waterbody
- Treating the pollutant before or after it is delivered to the water resource through chemical or biological transformation

Management measures can also be used to guide the implementation of your watershed management program. They are linked to performance expectations, and in many cases they specify actions that can be taken to prevent or minimize nonpoint source pollution or other negative impacts associated with uncontrolled and untreated runoff. The NRCS National Handbook of Conservation Practices (**www.nrcs.usda.gov/technical/standards/nhcp.html**) provides a list of practices applicable to rural and farming areas; consultation with NRCS staff when considering management actions in rural areas is highly recommended. Refer to EPA's National Management Measures guidance documents for information about controlling nonpoint source pollution **(www.epa.gov/owow/nps/pubs.html)**.

EPA National Management Measures Guidance Documents

EPA maintains published guidance documents online for the following categories (see **www.epa.gov/owow/nps/categories.html**):

- Acid mine drainage
- Agriculture
- Forestry
- Hydromodification/habitat alteration
- Marinas/boating
- Roads, highways, and bridges
- Urban areas
- Wetland/riparian management

There are many types of individual management practices, from agricultural stream buffer setbacks to urban runoff control practice retrofits in developed areas to homeowner education programs for on-site septic system maintenance. Management practices can be categorized several different ways, such as source controls versus treatment controls, structural controls versus nonstructural controls, or point source controls versus nonpoint source controls. For the purposes of this handbook, management practices are grouped into structural controls and nonstructural controls. *Structural* controls are defined as built facilities that typically capture runoff; treat it through chemical, physical, or biological means; and discharge the treated effluent to receiving waters, ground water, or conveyance systems. *Nonstructural* practices usually involve changes in activities or behavior and focus on controlling pollutants at their source. Examples include developing and implementing erosion and sediment control plans, organizing public education campaigns, and practicing good housekeeping at commercial and industrial businesses. Regulatory mechanisms like ordinances and permits are discussed separately from structural and nonstructural controls.

10.2.1 Nonpoint Source Management Practices

Structural Practices

Structural practices, such as stormwater basins, streambank fences, and grade and stabilization structures, might involve construction, installation, and maintenance. Structural practices can be vegetative, such as soil bioengineering techniques, or nonvegetative, such as riprap or gabions. Note that practices like streambank stabilization and riparian habitat restoration involve ecological restoration and an understanding of biological communities, individual species, natural history, and species' ability to repopulate a site. Such practices involve more than simply installing a structural control. Many vegetative practices can be considered "green infrastructure." The term green infrastructure has sometimes been used to describe an approach to wet weather management that is cost-effective, sustainable, and environmentally friendly. Green infrastructure management approaches and technologies mimic natural processes by capturing rainfall and runoff and infiltrating it into the soil to maintain or restore natural hydrology and by using plants to help evaporate and transpire water. Green infrastructure site-level practices might include rain gardens, porous pavements, green roofs, infiltration planters, trees and tree boxes, and rainwater harvesting for non-potable uses such as toilet flushing and landscape irrigation. Green infrastructure practices also involve preserving and restoring natural landscape features (such as forests, floodplains and wetlands). By protecting these ecologically sensitive areas, communities can improve water quality while maintaining healthy ecosystems, providing wildlife habitat, and opportunities for outdoor recreation. Examples of structural practices for rural and urban scenarios are listed in table 10-1.

You can choose to use structural practices that are vegetative, nonvegetative, or a combination, depending on which practice is best suited for the particular site and objective. For example, if a site is unable to support plant growth (e.g., there are areas with climate or soils that are not conducive to plant growth, or areas of high water velocity or significant wave action), a nonvegetative practice can be used to dampen wave or stream flow energy to protect the vegetative practice.

Natural Resources Conservation Service

The Natural Resources Conservation Service (NRCS) provides technical and other assistance to help land owners and managers conserve and protect soil, water, and other natural resources. Regional and often county-level staff are available to provide this assistance to land users, communities, units of state and local government, and other federal agencies in planning and implementing natural resource conservation systems. Technical resources include environmental, scientific, engineering, societal, and economic analysis services. State, local, and regional contact information for NRCS staff is posted at **www.nrcs.usda.gov/about/organization/regions.html**.

Table 10-1. Examples of Structural and Nonstructural Management Practices [a]

	Structural Practices	Nonstructural Practices
Agriculture	• Contour buffer strips • Grassed waterway • Herbaceous wind barriers • Mulching • Live fascines • Live staking • Livestock exclusion fence (prevents livestock from wading into streams) • Revetments • Riprap • Sediment basins • Terraces • Waste treatment lagoons	• Brush management • Conservation coverage • Conservation tillage • Educational materials • Erosion and sediment control plan • Nutrient management plan • Pesticide management • Prescribed grazing • Residue management • Requirement for minimum riparian buffer • Rotational grazing • Workshops/training for developing nutrient management plans
Forestry	• Broad-based dips • Culverts • Establishment of riparian buffer • Mulch • Revegetation of firelines with adapted herbaceous species • Temporary cover crops • Windrows	• Education campaign on forestry-related nonpoint source controls • Erosion and sediment control plans • Forest chemical management • Fire management • Operation of planting machines along the contour to avoid ditch formation • Planning and proper road layout and design • Preharvest planning • Training loggers and landowners about forest management practices, forest ecology, and silviculture
Urban	• Bioretention cells • Breakwaters • Brush layering • Infiltration basins • Green roofs • Live fascines • Marsh creation/restoration • Establishment of riparian buffers • Riprap • Stormwater ponds • Sand filters • Sediment basins • Tree revetments • Vegetated gabions • Water quality swales • Clustered wastewater treatment systems	• Planning for reduction of impervious surfaces (e.g., eliminating or reducing curb and gutter) • Management programs for onsite and clustered (decentralized) wastewater treatment systems • Educational materials • Erosion and sediment control plan • Fertilizer management • Ordinances • Pet waste programs • Pollution prevention plans • No-wake zones • Setbacks • Stormdrain stenciling • Workshops on proper installation of structural practices • Zoning overlay districts • Preservation of open space • Development of greenways in critical areas

[a] Note that practices listed under one land use category can be applied in other land use settings as well.

Nonstructural Practices

Nonstructural practices prevent or reduce runoff problems in receiving waters by reducing the generation of pollutants and managing runoff at the source. These practices can be included in a regulation (e.g., an open space or riparian stream buffer requirement), or they can involve voluntary pollution prevention practices. They can also include public education campaigns and outreach activities. Examples of nonstructural practices are listed in table 10-1. Nonstructural controls can be further subdivided into land use practices and source control practices. Land use practices are aimed at reducing impacts on receiving waters that result from runoff from development by controlling or preventing land use in sensitive areas of the watershed (e.g., critical habitat). Source control practices are aimed at preventing or reducing potential pollutants at their source before they come into contact with runoff or ground water. Some source controls are associated with new development, whereas others are implemented after development occurs. Source controls include pollution prevention activities that attempt to modify aspects of human behavior, such as educating citizens about the proper disposal of used motor oil and proper application of lawn fertilizers and pesticides (when needed).

10.2.2 Regulatory Approaches to Manage Pollutant Sources

The management practices you select can be implemented voluntarily or required under a regulatory program. Point sources are most often controlled using regulatory approaches. It's important to consider that regulatory approaches work well only when adequate mechanisms are in place to provide oversight and enforcement.

Regulatory Approaches for Nonpoint Sources

- **Local stormwater ordinances and permits.** Local stormwater ordinances may require development applicants to control stormwater peak flows, total runoff volume, or pollutant loading. Stormwater ordinances that apply these requirements to redevelopment projects (not just new development areas) can help mitigate current impacts from existing development. Developers could be required to implement stormwater practices such as bioretention cells, stormwater ponds, or constructed wetlands to meet performance standards for the development set forth in the ordinance.

- **Local development ordinances and permits.** Local development and subdivision ordinances may require development applicants to meet certain land use (e.g., commercial versus residential), development intensity, and site design requirements (e.g., impervious surface limits or open space, riparian buffer, or setback requirements). See section 5.5.2 for examples. Again, ordinances that apply these requirements to redevelopment projects (not just new development areas) can help mitigate current impacts from existing development. Although it might be difficult to add open space to the redevelopment plan of an already-developed area, equivalent off-site mitigation or payment in lieu might be required. Similarly, a riparian area might be revegetated and enhanced.

- **Federal or state forest land management plans.** Corporate, federal, and state owners of forest lands are often required to develop and implement forest management plans. These plans usually include management practices for logging, road construction, replanting, and other activities. A number of states also have forestry practice regulations that cover logging practices by individuals or private landowners. Such regulations may have requirements such as notification of intent to log, development of and compliance with a management plan that includes the use of management practices, and notification of termination of activities. Watershed planners can review recent or existing forest management plans in the watershed, discuss with managers which plans and practices are working well, and identify areas that could be strengthened.

- **Federal or state grazing permits.** Federal or state lands that are leased to individuals often require permits that specify conditions and management practices that must be adhered to for the term of the permit. These practices and conditions might include limiting the number of livestock allowed to graze, establishing off-stream watering or fencing in sensitive watershed areas, and other water quality protection measures. Again, watershed planners can review existing permits in the watershed, discuss with managers which practices are working well, and identify areas that could be improved.

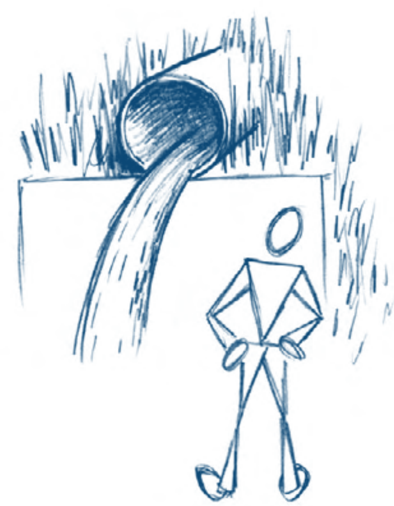
- **State regulatory authority.** Some states, such as California, have the authority to regulate nonpoint sources. California is beginning to issue waivers for traditional nonpoint sources, such as irrigated agriculture in the Central Valley. The waivers may require growers to implement management practices and develop farm plans, notice of which is submitted to the state's water board through a Notice of Intent (NOI). Irrigated agriculture facilities may be required to submit an NOI indicating that management practices have been implemented before irrigation return flows may be discharged to receiving waters.

  In 1990 Congress passed the Coastal Zone Act Reauthorization Amendments (CZARA) to address the nonpoint source pollution problem in coastal waters. Section 6217 of CZARA required the 29 coastal states and territories with approved Coastal Zone Management Programs to develop Coastal Nonpoint Pollution Control Programs. In its program, a state or territory describes how it will implement nonpoint source management measures to control nonpoint source pollution. States and territories ensure the implementation of the management measures through mechanisms like permit programs, zoning, bad actor laws, enforceable water quality standards, and other general environmental laws and regulations. Voluntary approaches like economic incentives can also be used if they are backed by appropriate regulations.

- **Decentralized wastewater management.** Many states and counties are developing or upgrading their management programs for onsite and clustered wastewater treatment systems. These programs usually include an inventory and analysis of existing systems; inspections; risk assessments; projections of future treatment needs; and development of standards for new system designs, operation and maintenance, inspections, corrective actions, and residuals management.

Regulatory Approaches for Point Sources

Point sources are regulated under the National Pollutant Discharge Elimination System (NPDES) permit program. Authorized by section 402 of Clean Water Act, the NPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. The NPDES program covers discharges from industrial facilities, municipal stormwater conveyances, concentrated animal feeding operations (CAFOs), construction sites, publicly owned treatment works (POTWs), combined sewer overflows (CSOs), and sanitary sewer overflows (SSOs). These categories are briefly described below.



- **Wastewater discharges from industrial sources.** Wastewater discharges from industrial facilities might contain pollutants at levels that could affect the quality of receiving waters. The NPDES permit program establishes specific requirements for discharges from industrial sources. Depending on the type of industrial or commercial facility, more than one NPDES program might apply. For example, runoff from an industrial facility or construction site might require an NPDES permit under the stormwater program. An industrial facility might also discharge wastewater to a municipal sewer system and be covered under the NPDES pretreatment program. If the industrial facility discharges wastewater directly to a surface water, it will require an individual or general NPDES permit. Finally, many industrial facilities, whether they discharge directly to a surface water or to a municipal sewer system, are covered by effluent limitation guidelines and standards.

- **Municipal stormwater discharges.** Stormwater discharges are generated by runoff from land and impervious areas like paved streets, parking lots, and building rooftops during rainfall and snow events. This runoff often contains pollutants in quantities large enough to adversely affect water quality. Most stormwater discharges from municipal separate storm sewer systems (MS4s) require authorization to discharge under an NPDES permit as part of the Phase I or Phase II (depending on the size of the population served) NPDES Stormwater Program. Operators of regulated MS4s must obtain coverage under an NPDES stormwater permit and must implement stormwater pollution prevention plans or stormwater management programs, both of which specify how management practices will be used to control pollutants in runoff and prevent their discharge to receiving waters. For example, regulated small MS4s (in general, cities and towns with populations between 10,000 and 100,000) must include the following six minimum control measures in their management programs:
  - Public education and outreach on stormwater impacts
  - Public involvement/participation
  - Illicit discharge detection and elimination
  - Construction site runoff control
  - Post-construction stormwater management in new development and redevelopment
  - Pollution prevention/good housekeeping for municipal operations

The NPDES stormwater program also requires operators of construction sites 1 acre or larger (including smaller sites that are part of a larger common plan of development) to obtain authorization to discharge stormwater under an NPDES construction stormwater permit.

Management practices appropriate for controlling stormwater discharges from MS4s, construction sites, and other areas are discussed in more detail under Nonpoint Source Management Practices.

- **Publicly owned treatment works (POTWs).** These facilities are wastewater treatment works owned by a state or municipality and include any devices and systems used in the storage, treatment, recycling, and reclamation of municipal sewage or industrial wastes of a liquid nature, as well as the sewers, pipes, and other conveyances that convey wastewater to a POTW treatment plant. Through NPDES permits, discharges from POTWs are required to meet secondary treatment standards established by EPA. These technology-based regulations apply to all municipal wastewater treatment plants and represent the minimum level of effluent quality attainable by secondary treatment for removal of biochemical oxygen demand (BOD) and total suspended solids (TSS). Discharges from POTWs may also be subject to water quality-based effluent limitations to reduce or eliminate other pollutants, if needed to achieve water quality standards.

- **Combined sewer overflows.** Combined sewer systems are designed to collect runoff, domestic sewage, and industrial wastewater in the same pipe system. In 1994 EPA issued its Combined Sewer Overflow Control Policy (**www.epa.gov/npdes/pubs/owm0111.pdf**), which is a national framework for controlling CSOs through the NPDES permitting program. The first milestone under the CSO Policy was the January 1, 1997, deadline for implementing minimum technology-based controls, commonly referred to as the "nine minimum controls." These controls are measures that can reduce the frequency of CSOs and minimize their impacts when they do occur. The controls are not expected to require significant engineering studies or major construction. Communities with combined sewer systems are also expected to develop long-term CSO control plans that will ultimately provide for full compliance with the Clean Water Act, including attainment of water quality standards.

- **Separate sanitary systems.** Separate sanitary collection systems collect and transport all sewage (domestic, industrial, and commercial wastewater) that flows through the system to a treatment works for treatment prior to discharge. However, occasional unintentional discharges of raw sewage from municipal separate sanitary sewers occur in almost every system. These types of discharges are called sanitary sewer overflows (SSOs). There are a variety of causes, including but not limited to severe weather, improper system operation and maintenance, and vandalism. Examples of management practices that can reduce or eliminate SSOs are:
  - Conducting sewer system cleaning and maintenance
  - Reducing infiltration and inflow by rehabilitating systems and repairing broken or leaking service lines
  - Enlarging or upgrading sewer, pump station, or sewage treatment plant capacity and reliability
  - Constructing storage and treatment facilities to treat excess wet weather flows.

Communities should also address SSOs during sewer system master planning and facilities planning or when extending the sewer system into unsewered areas.

- **Concentrated animal feeding operations.** AFOs are agricultural operations in which animals are kept and raised in a confined setting. Certain AFOs that meet a minimum threshold for number of animals are defined as concentrated AFOs (CAFOs). CAFOs require NPDES permits. The permits set waste discharge requirements that need to be met by implementing animal waste management practices such as reducing nutrients in feed; improving storage, handling, and treatment of waste; and implementing feedlot runoff controls.

- **Industrial stormwater permits.** Activities that take place at industrial facilities such as material handling and storage are often exposed to the weather. As runoff from rain or snowmelt comes into contact with these materials, it picks up pollutants and transports them to nearby storm sewer systems, rivers, lakes, or coastal waters. Stormwater pollution is a significant source of water quality problems for the nation's waters. Of the 11 pollution source categories listed in EPA's *National Water Quality Inventory: 2000 Report to Congress*, urban runoff/storm sewers was ranked as the fourth leading source of impairment in rivers, third in lakes, and second in estuaries.

  In order to minimize the impact of stormwater discharges from industrial facilities, the NPDES program includes an industrial stormwater permitting component. Operators of industrial facilities included in one of the 11 categories of stormwater discharges associated with industrial activity that discharge or have the potential to discharge stormwater to an MS4 or directly to waters of the United States require authorization under a NPDES industrial stormwater permit.

Most of the management practices listed in the following section could be required through regulations or encouraged through training and education programs. Your watershed management plan might include both regulatory and nonregulatory methods to get landowners, citizens, and businesses to adopt the practices needed.

10.3 Steps to Select Management Practices

This section describes a process for selecting management practices that might be feasible to implement in the critical areas identified in your watershed. The first step in the process is to inventory what has been or is being accomplished in the watershed. Future projects and management practices should augment efforts already under way. This analysis will allow you to determine where modifications are needed to existing programs, practices, or ordinances and where new practices are needed.

Steps to Select Management Practices

1. Inventory existing management efforts in the watershed
2. Quantify the effectiveness of current management measures
3. Identify new management opportunities
4. Identify critical areas in the watershed where additional management efforts are needed
5. Identify possible management practices
6. Identify relative pollutant reduction efficiencies
7. Develop screening criteria to identify opportunities and constraints
8. Rank alternatives and develop candidate management opportunities

The next step involves quantifying the effectiveness of existing management efforts. This step will allow you to establish a baseline level of pollutant load reductions that are already occurring and will help guide the selection of additional management practices to meet target load reductions.

The third step entails identifying new opportunities for implementing management measures. ↳ Based on the identification of pollutant sources from chapter 7, you can locate critical areas where management measures will likely achieve the greatest pollutant load reductions.

Once opportunities for pollutant load reductions are identified, you can match them with candidate management practices, alone or in combination, that could effectively reduce pollutant loads. This step will involve research into management practice specifications to help you determine which practices will be most feasible (considering site constraints), which practices are most acceptable to landowners, and which have the greatest pollutant removal effectiveness under similar conditions. ↳ For example, EPA lists management measures for urban areas and cost/benefit and other information at **www.epa.gov/owow/nps/urbanmm/index.html**.

Managing Onsite and Clustered Wastewater Treatment Systems

EPA has developed several tools designed to help local communities manage decentralized (distributed) wastewater treatment systems. The tools include a handbook for developing or improving existing management programs, a set of guidelines that describe five generalized management models, a design guide, technology fact sheets, case studies of successful programs, a homeowners' guide, and more. ↳ To access these tools, visit **http://cfpub.epa.gov/owm/septic/index.cfm**.

After researching candidate management measures and practices, you should have enough information to analyze each management opportunity using screening criteria that you develop. The screening criteria are based on various factors, such as your critical areas, site conditions, and constraints. The criteria will help you sort through the different attributes of each practice so you can select the practices worthy of more detailed analysis. Then you can quantify their effectiveness and conduct the associated cost versus benefit analysis. ↳ You'll conduct these more detailed analyses in chapter 11.

10.3.1 Identify Existing Management Efforts in the Watershed

Before you identify the additional management measures needed to achieve management objectives, you should identify the programs, management strategies, and ordinances already being implemented in the watershed. In some cases, the existing management practices themselves might be adequate to meet water quality goals, but they might not be maintained correctly or there might not be enough of them in place. Perhaps, for example, NRCS conservation practices on farmland are effective for the farms using them, but not enough farmers have adopted the practices to meet the goals in the watershed. In other cases, you might want to modify an existing practice, for example, by increasing stream setback requirements from 25 feet to 100 feet. When identifying the existing programs and management efforts, be sure to record the responsible party, such as an agency or landowner, and the pollutants the efforts address.

Tip Remember to incorporate the existing management efforts into your implementation plan in addition to any new management measures you identify. Often, existing management efforts have already incorporated complex site-specific social and economic factors, as well as considerable local knowledge of regional environmental constraints. Understanding why existing management measures were selected and choosing options for new ones is important business. This points to the need to make sure those entities that will be asked to implement practices are part of the team developing your plan.

Communities in the Mill Creek watershed in Michigan first evaluated existing local regulations and programs to help identify ways to strengthen local policies to help meet multiple watershed objectives. These programs and policies are described in table 10-2. Appendix A includes references of example watershed plans.

Low-Impact Development and Watershed Protection

Stormwater management programs and antidegradation implementation procedures have embraced low-impact development as a preferred management measure for minimizing water resource impacts from new areas of development. Low-impact development is based on preserving the existing hydrology (drainage system) of the development site, including vegetation growing along the drainage features; minimizing overall disturbance by carefully siting buildings, roads, and other design elements; promoting infiltration of rain and snowmelt by routing runoff from impervious surfaces to nearby rain gardens, swales, and other infiltration areas; and reducing the total amount of impervious surface area by minimizing the footprint of structures built on the site. For more information, visit **www.epa.gov/owow/nps/lid**.

Table 10-2. Existing Programs and Policies Identified in the Mill Creek Subwatershed Communities

Stakeholder	Existing Program or Policy	Pollutant Addressed
USDA, Natural Resources Conservation Service	Wetland restoration (Wetlands Reserve Program)	Hydrologic flow
	Controlling erosion/soil information	Sediment
	Streambank stabilization expertise	Sediment
	Riparian revegetation (Conservation Reserve Program)	
	Forested revegetation/filter strips	
	Agricultural waste management (Environmental Quality Incentives Program)	Nutrients
	Soil testing	
	Cross wind strips	Wind erosion

Table 10-2. Existing Programs and Policies Identified in the Mill Creek Subwatershed Communities (continued)

Stakeholder	Existing Program or Policy	Pollutant Addressed
Washtenaw County Road Commission	Leave buffers when grading gravel roads	Sediment
	Assess and manage erosion at stream crossings	
	Follow soil erosion and sediment control practices	
Village of Chelsea	Soil erosion and sediment controls and stormwater retention requirements on new developments	Sediment
	Stormwater calculations must account for roads in new development in addition to the other development	Hydrologic flow
	Large detention on wastewater treatment plant site	
	Stormwater collectors, proprietary treatment devices	
	Oil and grease separators installed; add outlet devices to existing development	Sediment, oil and grease
Daimler Chrysler Chelsea Proving Grounds	Leave buffers (of minimal width) along creek	Nutrients
	Switching products to no- or low-phosphorus alternatives	
	Ongoing monitoring of phosphorus levels in Letts Creek for NPDES permit	
	Pursuing alternative treatment chemical to reduce phosphorus	
	Soil erosion and sediment control permits and practices	Sediment
	Oil-grease separators installed	Oil and grease
	Devices in manholes checked monthly	
Washtenaw County Drain Commissioner's Office	Planning incentives or requirements for infiltration	Hydrologic flow
	Require first flush and wet ponds	
	Implementation of Phase II NPDES stormwater permits	All
	Work to balance drain maintenance and channel protection	
	Drains are being entered into a GIS for enhanced use	
	Community Partners for Clean Streams program encourages business and community partners to improve operations to protect streams	
	Stormwater BMP Demonstration Park nearly complete	
Scio Township	Adopted Drain Office standards	Hydrologic flow
	Follows county Soil Erosion and Sediment Control rules	Sediment
Sylvan Township	Part of regional plan to limit sprawl	All
	Lake communities connecting to sanitary sewer	Nutrients

Note: GIS = geographic information system; BMP = best management practice.

Worksheet 10-1 is an excerpt of a worksheet that can be used to begin identifying and evaluating existing efforts. A blank worksheet 10-1 is provided in appendix B.

Excerpt of Worksheet 10-1 *Identifying Existing Management Efforts*

Wastewater Discharges

- Where are the wastewater discharges located in the watershed? If possible, map the locations.
- What volume of wastewater is being discharged?
- What are the parameters of concern in the effluent?

Onsite Wastewater Treatment Systems

- Where are onsite systems located? If possible, map the locations and identify system type, age, and performance.
- Are there known malfunctioning onsite systems? If so, where?

Urban Stormwater Runoff

- Are cities and counties in the watershed covered by an NPDES stormwater permit? If so, what are the conditions of the permit?
- Do local governments in the watershed have stormwater ordinances? If so, what are the requirements?

Agricultural and Forestry Practices

- Are there areas with active farming or logging in the watershed? If so, map them if possible.
- Are management plans in place where these activities are occurring?
- What percentage of the area uses management practices for controlling sediment and other pollutants? Are these practices effective? If not, why? Are monitoring data available?

Wetlands and Critical Habitat Protection

- Have wetlands been identified and evaluated for the habitat value, water quality benefits, and flood control contributions?
- To what extent do natural buffers and floodplains remain in the watershed?
- To what extent are critical habitats such as headwater streams, seeps, and springs that provide many critical functions (e.g., habitat for aquatic organisms) being protected?
- Has the natural hydrologic connectivity been mapped? If so, are there management practices in place to restore any fragmentation of stream networks?

10.3.2 Quantify the Effectiveness of Current Management Measures

After you've identified existing management efforts in the watershed, you'll determine the effectiveness of the measures in terms of achieving desired load reductions or meeting other management goals and objectives. The difference between the levels of pollutant load reductions achieved by existing practices and the targeted reductions you identified in chapter 9 will help determine the additional practices needed.

Quantifying the effectiveness of existing programs and measures can be a challenging task. First, take a look at whether the source quantification analyses performed earlier (Chapter 8) reflect existing programs adequately so that you can determine the gap. For example, if you don't expect the programs to achieve more than what was represented in earlier modeling analyses and a gap exists between the current level of loading and the target, additional measures will need to be added to fill that gap. In addition, if the existing management measures are not aimed at controlling the stressors of greatest concern, a gap is clearly evident and new management measures are needed. On the other hand, if the existing programs are evolving and greater participation or improved performance is expected with respect to the parameters of concern, you can estimate how much that gap will be further reduced by programs already in place. Additional measures would be needed only to the extent that a gap is expected to remain.

If the modeling tools previously applied to conduct the loading analysis can't be used to predict the future performance of existing management programs, you can approximate the additional reductions expected based on best professional judgment or you can develop additional modeling tools to estimate effectiveness. Chapter 11 discusses methods for evaluating the effectiveness of new management measures, from the relatively simple to the complex; some of the methods could be used to evaluate existing measures as well.

10.3.3 Identify New Management Opportunities

Now that you've identified the existing management efforts in the watershed and their relative effectiveness in reducing pollutant loads, you can begin to identify potential new management measures that could be used to achieve the additional load reductions required. At this stage you'll conduct a preliminary screening of these management measures to determine their potential usefulness. Once this screening is complete, you'll conduct more rigorous evaluations in chapter 11.

This section provides a process for screening management opportunities and identifying good candidate options, which will be subjected to a more detailed evaluation. The process includes

- Identifying critical areas where additional management is needed
- Identifying candidate management practices
- Identifying relative pollutant loading reductions
- Identifying opportunities and constraints for each management measure
- Documenting good candidate opportunities

> NRCS published *National Catalog of Erosion and Sediment Control and Storm Water Management Guidelines for Community Assistance* (**www.info.usda.gov/CED/ftp/CED/Natl-Catalog-Erosion-and-Sed-Guidelines.pdf**). This document contains a comprehensive list of urban and development management practices from every state, as well as representative standards and specifications for each type of management practice.

10.3.4 Identify Critical Areas in the Watershed Where Additional Management Efforts Are Needed

In general, management practices are implemented immediately adjacent to the waterbody or upland to address the sources of pollutant loads. Streamside practices include streambank protection and riparian habitat enhancement to address the channel, floodplain, and riparian corridor of the waterbody. Upland management practices are typically divided into practices for agricultural lands, forestry, and urban or developed lands. Related to these upland practices, and important to the ecological integrity of watersheds, is the management of surface water flow and groundwater pumping.

As part of your screening process, you'll want to identify which management practices can be implemented in the critical areas that you have identified. Using the location of the pollutant sources you identified in chapter 7, you'll start to identify possible opportunities for installing additional management practices.

You can use a geographic information system (GIS) or hand-drafted maps to conduct an analysis of management opportunities. A simple mapping analysis for a rural residential and farming area that has nutrient problems might include the following geographic information: location of section 303(d)-listed waterbodies, existing agricultural areas (using a GIS coverage of existing land use or land cover data that indicates grazing versus cropland if possible), areas where existing management practices are being employed (if any), and the degree of riparian buffer disturbance. These maps can often be generated using the land use/land cover databases and watershed tools from the scoping and watershed analysis.

Figure 10-2 shows a map that was generated to help identify the critical areas where management practices were needed in the rural Troublesome Creek watershed. The map shows the impaired waters, along with the percentage of buffer area disturbed in the Troublesome Creek subwatersheds. The subwatersheds that have buffers more than 15 percent disturbed indicate the potential for riparian area restoration efforts to limit sediment loading. Maps for an urban or suburban area might include waters on the section 303(d) list with an overlay of subwatersheds that have impervious area greater than 10 percent and greater than 25 percent, indicating the medium and high potential for stream degradation, degree of riparian buffer disturbance, and industrial sites.

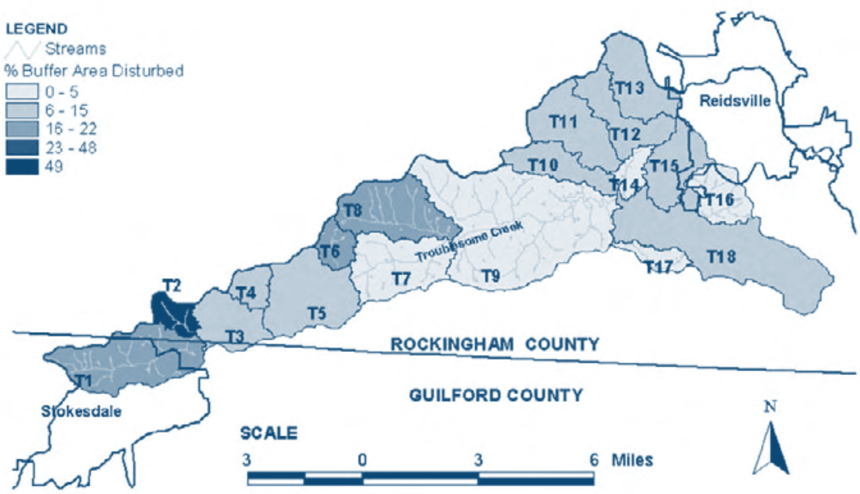


Figure 10-2. Percentage of Buffer Area Disturbed and Impaired Waters in the Troublesome Creek Watershed

10.3.5 Identify Possible Management Practices

Dozens of resources are available to help provide a sound basis for your research and preliminary screening of management practices. The resources you select should depend on the pollutant sources and causes in your watershed and the land use characteristics (chapter 7). For example, some resources focus on practices to control urban stormwater runoff, some focus on agricultural practices to manage farm runoff, and some concentrate on forestry practices to control impacts from logging. These resources provide information on the practice, such as description, cost, and planning considerations. Although data on management practice effectiveness and program-related load reductions can be very limited, the resources provide insight on relative performance. For example, NRCS's (2005) *National Conservation Practice Standards* allows you to identify the level of technical expertise necessary to successfully design, install, and maintain specific activities: passive management, active management, mild engineering, moderate engineering, and intensive engineering. Appendix A provides several resources that can be used to begin identifying possible management practices.

As you conduct your research, it's helpful to develop a one- or two-page summary of each promising management option. (These can be included in an appendix to your management plan.) Each summary should eventually include, at minimum, the information listed in Worksheet 10-2. As you move through the screening process you'll add information to the worksheet, such as the pollutant reduction effectiveness, planning considerations, legal requirements, and opportunities and constraints. Full-size, blank worksheets are provided in appendix B.

Excerpt of Worksheet 10-2 Documenting Management Measure Opportunities and Constraints

Sources (e.g., streambanks, urban stormwater, malfunctioning septic systems, livestock in stream)

Causes (e.g., eroding streambanks, unlimited access of livestock, undersized culverts)

Name of management measure or program (NRCS code if applicable)

Data source (i.e., where you obtained your information on the management measure)

Description (what it is and what it does)

Approximate unit cost (including installation and operation and maintenance costs; may be expressed as a range)

Approximate or relative load reduction for each parameter of concern (could be high, moderate, low, or unit reduction per acre per year)

Planning considerations (e.g., project factors such as site size and contributing watershed area; physical factors such as slope, depth of water table, and soil type limitations or considerations; operation and maintenance requirements)

Skill needed to implement the management measures (e.g., engineering, landscape design, construction)

Permitting considerations

Other (e.g., stakeholders' willingness to use the measure)

The *National Conservation Practice Standards* provides a one-page summary of each of 50 management practices. Drawing from this manual, Table 10-3 lists some commonly used practices for reducing sediment, total dissolved solids (TDS), and salinity, along with the pollution sources they address and the expected level of load reduction. The load reduction potential qualitatively describes the potential reduction of loading achieved by implementing the practice. The actual load reduction depends on the extent of the practice, existing loading levels, and local features like soils and hydrology.

This handbook and others like it can provide a good basis for screening, with some adaptation to local circumstances. For example, because *National Conservation Practice Standards* was developed in the West, if you're developing a plan for an eastern watershed, you might need to consult your local NRCS office or local engineering department staff regarding the potential load reductions and cost of selected practices in your area.

Although dozens of management practices can be implemented, you should identify those practices that will have the greatest likelihood of achieving your watershed goals. You should relate the management practices back to the sources of pollutants in the watershed, the types of impairments found, and the amount of load reduction needed. In addition, it is also useful to consider complementary or overlapping benefits or issues. For example, regional sediment management plans might be developed to provide an inventory and budget for local sediment resources. Excess instream sediment might be used for beach or wetland restoration, highway construction, landfill cover, or other uses.

The management practices selected should be targeted to the sources of a particular stressor. For example, full-scale channel restoration can be pursued along reaches where channel incision and streambank failure result from historical channelization, whereas exclusion fencing of cattle might be more appropriate when the sediment source is streambank trampling along cobble bed reaches. In cases where instream habitat is degraded, the components of the

Table 10-3. Commonly Used Management Practices for Salinity, Sediment, and Total Dissolved Solids

Pollution Sources (✓ = Management practice applies)						Management Practice	Load Reduction (H, M, or L)
AFO	Ag Practices	Industry Runoff	Urban Runoff	Disturbed Areas	Stream Erosion		
		✓		✓		Construction site mgt	L
	✓			✓	✓	Grazing mgt	M
✓	✓					Nutrient mgt	M
	✓			✓		Cover crop	H
✓	✓			✓	✓	Fencing	H
✓	✓			✓	✓	Filter strip	H
	✓			✓		Mulching	L
	✓	✓	✓	✓	✓	Riparian buffer	M
	✓			✓	✓	Seeding	M
				✓	✓	Tree planting	L
					✓	Brush layer	H
✓	✓				✓	Brush trench	H
✓	✓			✓	✓	Erosion control fabric	H
✓	✓			✓	✓	Silt fence	M
✓				✓		Straw bale barrier	M
	✓				✓	Watering facility	M
✓	✓	✓	✓		✓	Constructed wetland	M
✓	✓	✓		✓		Detention basin	M
	✓	✓		✓		Road stabilization	L–M
	✓	✓		✓	✓	Grade stabilization	H
					✓	Willow fascines	H
	✓	✓	✓			Water quality pond	M
	✓			✓	✓	Rock riprap	H
	✓			✓	✓	Stream channel stabilization	H
				✓	✓	Brush mattress	M
	✓			✓	✓	Pole/post plantings	M
✓	✓					Residue mgt	M
	✓				✓	Rock vane	H
	✓				✓	Rock weir	H
	✓	✓	✓	✓		Sloped drain	M
✓	✓			✓	✓	Terrace	H
	✓					Pest mgt	H

Resources on Management Practices

Select appropriate sources of management practice information on the basis of the pollutant type and land use characteristics. The following are examples:

Urban Sources

The International Stormwater Best Management Practice Database at **www.bmpdatabase.org** provides access to performance data for more than 200 management practice studies.

Agricultural Sources

NRCS offers a *National Handbook of Conservation Practices* at **www.nrcs.usda.gov/technical/standards/nhcp.html**.

All Sources

EPA has developed several guidance documents broken out by type of management measure. Draft and final manuals are available for agriculture, forestry, urban areas, marinas and recreational boating, hydromodification, and wetlands. These manuals can be downloaded from **www.epa.gov/owow/nps**.

Note: In addition to the resources mentioned above, many states have published BMP handbooks or guidance documents for in-state use. For example, the California Stormwater Quality Task Force published the California Stormwater Best Management Practice Handbooks to provide information on current practices, standards, and knowledge gained about the effectiveness of management practices. These documents can be downloaded from **www.cabmphandbooks.com**.

habitat that are most affected can be used to guide management actions. Slightly degraded habitat due to limited microhabitat (e.g., leaf packs, sticks, undercut banks), poor cover (e.g., logs and overhanging vegetation), and a thin canopy could be improved through revegetation of the riparian area; habitat degraded by poorly defined and embedded riffles, pools filled with sediment, and unstable streambanks might better be addressed through natural channel design. In the case of excessive nutrients from upland areas, passive actions such as designating conservation easements and limiting development might be the most prudent choices.

It's important to look at how the management practice being considered addresses the stressor of concern because that factor can considerably affect performance. Thus, in cases where sediment is identified as a stressor, stabilizing streambanks and limiting incision will be of little value if poor erosion and sediment control practices in a developing watershed are the overwhelming source of sediment contributed to the reach.

When you're screening management practices, selecting two or more practices will usually be more effective than choosing a single practice to achieve the needed load reductions. When you combine multiple practices, the result is called a *management practice system* or *treatment train*. Multiple practices are usually more effective in controlling a pollutant because they can be used at two or more points in the pollutant delivery process. For example, the objective of many agricultural nonpoint source pollution projects is to reduce the delivery of soil from cropland to waterbodies. A system of multiple practices can be designed to reduce soil detachment (e.g., soil additives to make soils less erodible), erosion potential (e.g., turf reinforcement mats), and off-site transport of eroded soil (e.g., vegetated buffer strips).

When reviewing multiple practices, consider spatial and temporal factors. For example, if you're trying to reduce impacts from an agricultural area, you should review management practices that might address upland agricultural activities as well as management practices that might address stream erosion (if both impacts exist). Complementary practices also have a time dimension. For example, streambank erosion is often caused by a reduction of woody vegetation along the stream due to intensive cattle grazing. Before the streambank can be successfully revegetated, the grazing issue should be addressed through fencing or other controls that protect the riparian zone from grazing and trampling. You should also screen for management practices that do not conflict with each other or with other management objectives in the watershed.

In addition to selecting management practices focused on pollutant reductions, you should also select practices for protecting, conserving, and restoring aquatic ecosystems. Those practices include, but are not limited to, the following:

- Ordinances for protecting habitats
- Aquatic buffers

- Fee simple land purchase
- Conservation easements (landowner grants recipient responsibility for protection and management)
- Conservation tax credits
- Transfer development rights (TDRs)
- Purchase development rights (PDRs)
- Landowner and public sector stewardship
- Greenways (ecologically significant natural corridors)
- Greenprinting
- Open space preservation
- Conservation or biodiversity banking
- Reserving or reclaiming flow (legal)
- Adoption of regulatory floodways
- Floodplain and riparian zoning
- Dam removal
- Conservation education
- Monitoring

There are resources available to help you weigh the pros and cons of these types of practices and select the practices that are most appropriate for your watershed planning goals. For example, every state wildlife action plan (refer to section 5.4.7) has a section that describes the conservation actions proposed to conserve the species and habitats identified in the plan. Many times, these plans provide pros and cons of the proposed actions or practices. Some questions to ask when selecting these practices include:

- What are the highest priorities for land conservation?
- Does a land trust exist to accept and manage conservation areas?
- How should conservation areas be delineated?
- What fraction of the watershed needs to be conserved, protected, or restored?
- How much pollutant removal might be gained from the buffer or conservation area?

10.3.6 Identify Relative Pollutant Reduction Efficiencies

Once you've selected potential management practices based on the pollutant type addressed, you should identify the relative effectiveness of each practice in reducing pollutant loading. At the screening stage, this means using or developing simple scales indicating high, medium, or low reduction potential (see table 10-3). The actual load reduction will depend on the extent of the practice and the existing loading levels, which will be addressed in more detail in chapter 11. Many of the resources and references mentioned previously also identify the relative load reduction potential of various practices.

Keep in mind that in addition to reducing pollutant loads, you might also want to evaluate management practices to reduce hydrologic impacts like high peak flows and volume through infiltration or interception. The ability of management practices to address these hydrologic impacts should be documented using a scale of high, medium, or low potential for peak flow or volume reduction.

Table 10-4 shows how a community can screen management practices for their relative performance in addressing pollutant loading and hydrologic issues. The table also shows the multiple and complementary benefits of the management practices.

Table 10-4. Example Management Practice Screening Matrix

Structural Management Practice	Hydrologic Factor				Pollutant Factor				
	Interception	Infiltration	Evaporation	Reduced Peak Flow	Total Suspended Solids	Nutrients	Fecal Coliform Bacteria	Metals	Temperature
Bioretention	●	◗	◗	◗	●	●	●	●	●
Conventional dry detention	○	○	◗	●	○	○	●	◗	◗
Extended dry detention	○	○	◗	●	◗	◗	●	◗	○
Grass swale	◗	◗	○	○	◗	○	○	●	◗
Green roof	●	○	●	◗	○	○	○	○	●
Infiltration trench	○	●	○	◗	●	●	●	●	●
Parking lot underground storage	◗	◗	○	●	●	●	◗	●	●
Permeable pavement	◗	◗	◗	◗	◗	○	◗	○	◗
Sand filter	○	○	○	○	●	●	◗	●	●
Stormwater wetland	●	○	◗	●	●	●	●	●	◗
Vegetated filter strip with level spreader	◗	◗	○	○	◗	◗	○	◗	◗
Water quality swale	◗	◗	◗	◗	●	●	○	●	●
Wet pond	○	○	●	●	●	●	●	●	○

○ Poor, low, or no influence ◗ Moderate ● Good, high

10.3.7 Develop Screening Criteria to Identify Opportunities and Constraints

Once you've identified general areas in the watershed that might benefit from management practices that address the sources of pollutants, you can apply additional screening to further hone in on feasible sites, for which you will conduct your more detailed evaluation and final selection (↳ chapter 11).

Which screening criteria you select depends on where the practice is to be implemented and the nature of the practice. At this stage you can use the following screening criteria to help identify candidate management measures:

- **Location of management practice within the critical area.** Check to see if the candidate management practice will help achieve the load reductions that were identified in one of the critical areas of the watershed.

- **Estimated load reductions.** Using the information you collected in section 10.3.5, record whether the anticipated load reduction is low, medium, or high.
- **Legal and regulatory requirements.** Identify legal or regulatory requirements for projects, and determine whether any pose significant constraints. For example, if the restoration project involves working in the stream channel, a section 404 dredge and fill permit might be required. You should also check for the presence of wetlands because disturbance of wetland resources might be prohibited. Also, if the project is adjacent to a stream, make sure local stream buffer ordinances do not prohibit disturbance of the buffer for restoration purposes. Are there other resource conservation constraints (e.g., endangered species)? Federal Emergency Management Agency (FEMA) floodplain regulations also might affect the project. If the project is adjacent to a stream, make sure local stream buffer ordinances allow management practices within the buffer.
- **Property ownership.** Determine the number of property owners that need to agree to the restoration project. It's often easier to obtain easements on lands in public ownership.
- **Site access.** Consider whether you will be able to physically access the site, and identify a contact to obtain permission if private property must be traversed to access the site. Consider whether maintenance equipment (e.g., front-end loaders, vacuum trucks) will be able to reach the site safely. Design and costs might be affected if a structural control requires hand-cleaning because of maintenance access constraints.
- **Added benefits.** In addition to management practices fulfilling their intended purpose, they can provide secondary benefits by controlling other pollutants, depending on how the pollutants are generated or transported. For example, practices that reduce erosion and sediment delivery often reduce phosphorus losses because phosphorus is strongly adsorbed to silt and clay particles. Therefore, a practice like conservation tillage not only reduces erosion but also reduces transport of particulate phosphorus. In some cases, a management practice might provide environmental benefits beyond those linked to water quality. For example, riparian buffers, which reduce phosphorus and sediment delivery to waterbodies, also serve as habitat for many species of birds and plants.
- **Unintended impacts.** In some cases management practices used to control one pollutant might inadvertently increase the generation, transport, or delivery of another pollutant. Conservation tillage, because it creates increased soil porosity (large pore spaces), can increase nitrate leaching through the soil, particularly when the amount and timing of nitrogen application are not part of the management plan.

Sources of Cost Information

A list of currently available cost references is given below. Most of these references are available for free download, but some might be available only at a university library or by purchase. You should look for local costs before using these references because construction costs and designs vary between states. A more detailed list of resources on costing information is included in appendix A.

EPA Management Practice Fact Sheets

This comprehensive list of BMP fact sheets contains information on construction and maintenance costs, as well as other monetary considerations. Information is provided on both structural and non-structural management practices. Go to **http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm**.

National Management Measures to Control Nonpoint Source Pollution from Agriculture

This EPA document provides cost information on a number of management options for agricultural land. Go to **www.epa.gov/owow/nps/agmm**.

USDA Natural Resources Conservation Service

Some state NRCS offices publish cost information on agricultural practices. Some cost data are published to support the Environmental Quality Incentives Program (EQIP). For an example of this cost information, go to the "cost lists" section of the following Web site: **www.nc.nrcs.usda.gov/programs/EQIP/2005Signup.html**.

Center for Watershed Protection

The Center for Watershed Protection has published numerous support documents for watershed and management practice planning. The Web site has documents available for free download and purchase. Go to **www.cwp.org**.

- **Physical factors.** Many physical factors will determine whether you'll be able to install management practices. Look for constraints like steep slopes, wetlands, high water tables, and poorly drained areas. Also look for opportunities such as open space, existing management practices that can be upgraded, outfalls where management practices could be added, and well-drained areas. For example, a site proposed for a stormwater wetland that has steeply sloping topography might not be feasible for a wetland.
- **Infrastructure.** Look for sites that don't have utilities, road crossings, buried cables, pipelines, parking areas, or other significant physical constraints that could preclude installation or cause safety hazards.
- **Costs.** The appropriateness of a management practice for a particular site can be affected by economic feasibility considerations, which encompass short- and long-term costs. Short-term costs include installation costs, while long-term costs include the cost of continued operation and maintenance. Most of the guidance manuals referenced earlier in the chapter also provide cost information for each of the management practices discussed. In section 11.5 you'll consider more detailed cost elements associated with the management practices, such as construction, design and engineering, and operation and maintenance costs, as well as adjustment for inflation.
- **Social acceptance.** Consider how nearby landowners will perceive the management practice. Will it cause nuisances such as localized ponding of water, unsightly weed growth, or vector control problems? Can these issues be addressed in the siting and design of the practice? How can you involve nearby residents in selecting and designing the practice to address their concerns?

The optimal method for evaluating site feasibility for riparian and upland management practices is a site visit, preferably with staff from permitting or extension agencies. Actual constraints and opportunities can be identified, and input from the agencies can be incorporated to expedite the permitting process. When a site visit is not practical, however, many physical constraints can be evaluated remotely using a GIS. When the GIS approach is used, it's important to recognize that the input data might not be entirely accurate (e.g., land cover data from 1999 might have changed by now).

10.3.8 Rank Alternatives and Develop Candidate Management Opportunities

Now that you've identified various management practices that you could install in the watershed to achieve your goals and objectives, you should screen them to document the candidate management opportunities. At this stage, you're working with the stakeholders to identify which management options should go through a more rigorous evaluation to determine the actual pollutant reduction that can be achieved through combined management measures, as well as the costs and feasibility of the measures.

Using the worksheets from your research, develop a summary chart and map, along with a ranking of alternatives, to present and discuss with the stakeholders. Summarize and weigh such factors as

- Relative load reduction expected
- Added benefits
- Costs

- Public acceptance
- Ease of construction and maintenance

When developing your summary worksheets, it's helpful to group similar types of practices. Once you have collected all the information on the various practices, you can rate practices according to the screening criteria you've selected (table 10-5). You can create a basic rating system from 1 to 4, with 1 the lowest rating and 4 the highest. For example, practices receive higher ratings for high pollutant removal effectiveness, lower cost, lower required maintenance, high likelihood of public acceptance, and added benefits.

Table 10-5. Example Ranking Table to Identify Candidate Management Practices

Management Practice	Pollutant Reduction Effectiveness	Cost	Added Benefits	Public Acceptance	Maintenance	Average Score
Gradient terraces	2	3	1	2	4	2.4
Grassed swales	3	4	3	4	4	3.2
Wet extended detention ponds	2	3	2	3	3	2.6
Model ordinances	4	3	2	4	4	3.4

Before you rate each practice, you might want to develop some assumptions like the following:

- The management practices will be installed and maintained properly.
- Although public involvement activities will not directly reduce pollutant loads, they will contribute to an increase in awareness that might lead to people's adopting pollutant-reducing behaviors.
- The management practice is rated for reducing a specific pollutant of concern, not a suite of pollutants.

When you have rated all the practices, average the values in each row. Comparing the averages will give you a general idea of which management practices might be good candidates for implementation. Next, present the summaries to your stakeholders and ask them to review the information and agree or disagree. If they disagree with the ratings, review the criteria used, provide them with more information, or change the rating based on their input. Once you've narrowed down the candidate practices, you're ready to move on to chapter 11 and conduct more detailed analyses.

When developing good candidate options for watersheds with multiple sources, make sure you've identified management options for each source and that the options are complementary. Finally, map out upstream-to-downstream management options, making sure that you begin work on the upstream projects first. Working on upstream projects first, if possible, will aid in determining BMP effectiveness because water quality improvements can be measured without interference caused by multiple upstream pollutant sources that might not be addressed initially. As implementation proceeds, BMPs can be selected, installed, and adapted as needed to ensure that water quality is improving from upstream to downstream locations. ↳ Chapter 11 provides more detail on evaluating multiple projects in a watershed or subwatershed.

11. Evaluate Options and Select Final Management Strategies

Chapter Highlights

- Approaches used to evaluate management practice performance.
- Estimating management performance and comparing to objectives
- Cost considerations
- Evaluating options
- Selecting final strategies

Read this chapter if...

- You want to evaluate potential management strategies to select the final strategy for your watershed plan
- You want to learn about approaches to quantify the effectiveness of management practices
- You want to understand the capabilities of available models for evaluating management practices
- You need examples of applications for quantifying the effectiveness of management practices
- You need to identify criteria for ranking and selecting your final management strategy

11.1 How Do I Select the Final Management Strategy?

In chapter 10 you conducted an initial screening to determine the feasibility of using various management practices in your implementation program. The screening was based on factors like the critical areas in the watershed, estimated pollutant removal efficiencies, costs, and physical constraints. In this chapter you'll take those candidate options and refine the screening process to quantitatively evaluate their ability to meet your management objectives in terms of pollutant removal, costs, and public acceptance (figure 11-1).

You'll work with your stakeholders to consider various strategies that use a combination of management practices, to rank and evaluate the strategies, and finally to select the preferred strategies to be included in your watershed plan.

This chapter presents various techniques to help you to quantify the potential of the management actions to meet the watershed objectives, thereby providing the information you'll need to make final selections. There are five major steps to selecting your final management strategies:

1. Identify factors that will influence selection of the preferred management strategies.
2. Select the suitable approach to evaluate the ability of the management techniques to meet the watershed objectives.
3. Quantify the expected load reductions from existing conditions resulting from the management strategies.
4. Identify capital and operation and maintenance costs and compare initial and long-term benefits.
5. Select the final preferred strategies.

Before you conduct detailed analyses of the management strategies, you should first identify the factors that will influence which approach you'll use and then select the actual approach or method you'll use to evaluate the effectiveness of the proposed management practices in meeting your objectives. The factors that will influence the selection of your approach are discussed below, followed by a discussion of various approaches.

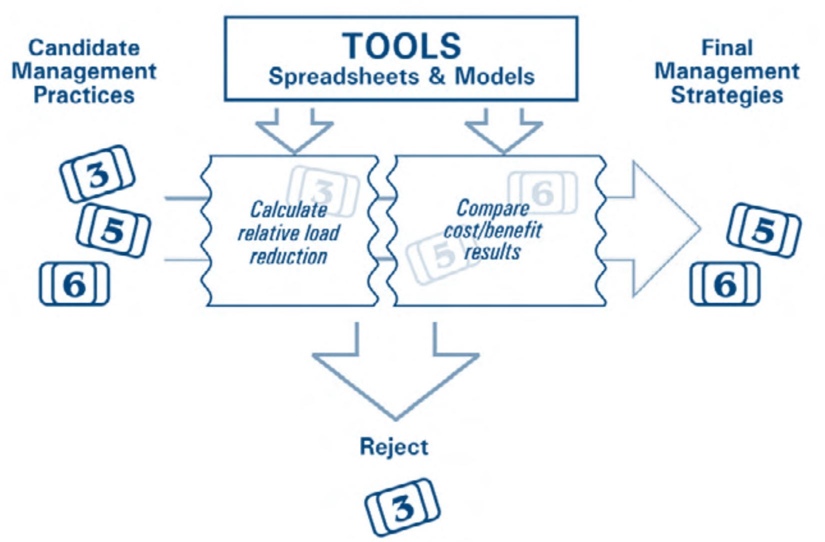


Figure 11-1. Evaluate Candidate Management Practices to Select Final Strategies

11.2 Identify Factors that Influence the Selection of Approaches Used to Quantify Effectiveness

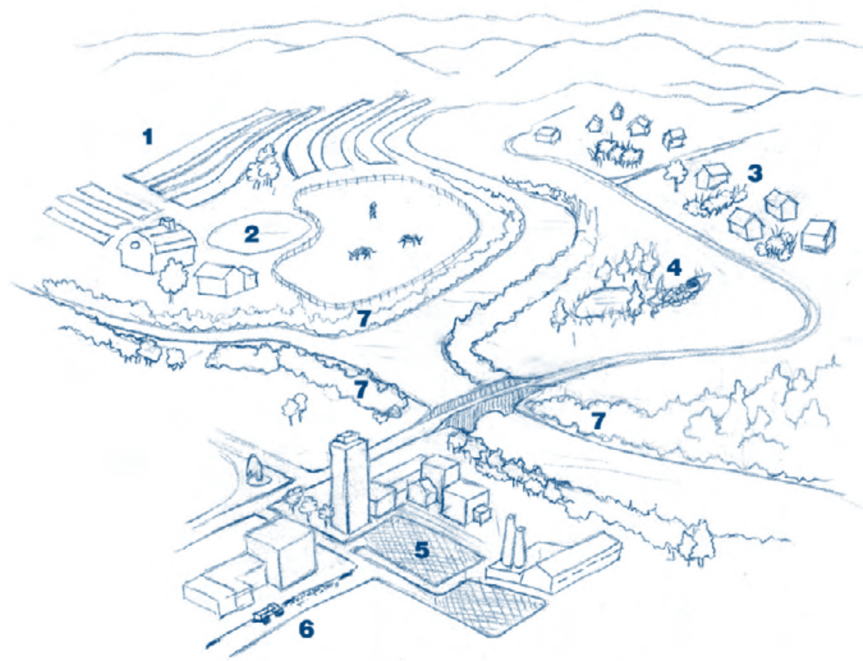
You should consider several factors before you select an approach to evaluate your candidate management strategies. These include identifying the general and specific types and locations of management practices that will be used, what indicators you'll use to evaluate their performance, and the appropriate scale and detail of the analysis to assess the cumulative benefit of multiple practices.

> **Tip** While you're setting up your evaluation of management practices, you might find it helpful to develop metrics or measures that can be combined readily with your cost evaluation to facilitate the cost-effectiveness analysis (discussed further in section 11.5). For instance, pounds per acre per year of pollutant removal can be combined easily with dollars per acre of cost to produce dollars per pound removed.

11.2.1 General Types of Management Practices

Which approaches you choose to evaluate the performance of the management practices depends in part on the location of the sources being managed and the types of management practices used. A source in an upland area (e.g., cropland erosion) is different from a source in a stream (e.g., streambank erosion). To evaluate upland loading management, you could use a tool that estimates sediment loading (on an area basis) from land uses in your watershed and could calculate a load reduction from changes in land use management practices. For streambank erosion, you might need to evaluate the effectiveness of stream restoration measures in terms of reduction in tons of sediment per linear foot of stream.

When selecting the approaches used to assess management, consider the general characteristics of the management practices. One way to group the various practices is to consider how they are applied. Are the practices applied across a land area, along a stream corridor, or at a specific location? Some types of management practices, such as tillage and fertilizer management techniques, are applied over large land areas.



1 CONTOUR TILLAGE
2 DETENTION POND
3 RAIN GARDEN
4 WETLAND
5 POROUS PAVEMENT
6 STREET SWEEPING
7 BUFFER STRIP

These land area-based practices are measured by the area affected and often include large regions of the watershed. Practices applied along a stream corridor are linear practices that stretch across long areas, such as riparian or stream buffer zones. By instituting a stream buffer zone, some water from uphill areas can be filtered; the vegetation might also provide additional shade and improved habitat. Practices installed at a point or specific location provide treatment for runoff from a specific drainage area. Point practices include detention ponds, bioretention areas, and many other practices that collect and treat runoff through settling or infiltration of water and pollutants. These types of practices require slightly different assessment techniques and have different data collection needs for evaluating their pollutant removal benefits.

11.2.2 Identify the Types of Indicators You're Using to Measure Performance

In chapter 9 you developed indicators to help measure progress toward meeting your watershed goals and management objectives. Your indicators and associated targets might be based on pollutant loads, hydrologic factors, concentration values, or habitat measures. The types and expression of your indicators will affect the types of analyses you can use to assess your management practices and strategies.

If your indicator is a pollutant load, performance measures for practices are easy to find. For concentration- or value-based indicators, you should take greater care to ensure that the information you find is applicable to your situation. Assume, for example, that your watershed has been listed as impaired because of frequent exceedances of fecal coliform counts during storm events. When locating data about management practice performance, you should make sure that the information you find applies to storm event performance, not to base flow performance.

If you have more than one indicator to address, note how each management practice performs for all of your indicators. Practices that benefit multiple indicators might have greater overall benefit as part of a watershed-wide management strategy.

11.2.3 Consider the Scale of Your Watershed

Understanding how to develop your management strategy will depend in large part on how big and complicated the watershed is and how expensive the management will be. When looking at how to evaluate a management plan, scale is a major concern. A management strategy for a small urban watershed (e.g., approximately 1,000 acres) might include hundreds or even thousands of individual actions such as changes in fertilizer applications, increased street sweeping and vacuuming, retrofit of existing detention ponds, or restoration of shoreline areas. In large watersheds, both urban and rural, the effect of multiple actions is often generalized to get an estimate of the overall impact. For a smaller-scale watershed, you might conduct a more detailed analysis of the benefit of specific management practices or restoration activities. These studies might include examining what will happen if practices are installed or adopted in defined locations within the watershed. Practices can also be evaluated at the smallest scale, such as an individual development or lot. At that level, however, analyses typically focus on meeting regulatory requirements or design requirements of a funding program. Individual practices provide a cumulative benefit when considered as part of a larger program of implementation, but their individual benefit might be more difficult to discern.

How to bridge the various scales is an ongoing issue in watershed planning. Tools are needed to evaluate the cumulative benefit of management strategies to select the best alternatives, evaluate the most cost-effective solutions, and ultimately be assured that restoration will be successful. But it's not always appropriate or necessary to use models or perform detailed analyses of each management practice. In subsequent sections the capabilities of available models to assess the benefits of management practice installation are discussed. In applying models to management analysis, keep in mind that sometimes simplifying or generalizing the impacts of management practices is appropriate. Sometimes very detailed simulation or testing of land use practices and small-scale practices can be performed and the results extrapolated to a larger scale. Such studies can be described as "nested" modeling studies. For example, a detailed evaluation of fertilizer and tillage practices can be performed at the field scale using modeling or monitoring. The results from the study can be used to evaluate the implications of using similar practices on similar fields in the region. Similar approaches can be used to examine the implications of urban development and redevelopment practices.

In larger watersheds there are also additional considerations in aggregating results to the entire watershed and accounting for physical and chemical processes that occur on a large scale (e.g., instream nutrient uptake, the timing and duration of storm event peak flow at the mouth of the watershed). If the upstream conditions of your watershed significantly influence the downstream portions, it might be necessary to use models to evaluate the link between upstream and downstream indicators.

11.2.4 Consider the Synergistic Effects of Multiple Practices

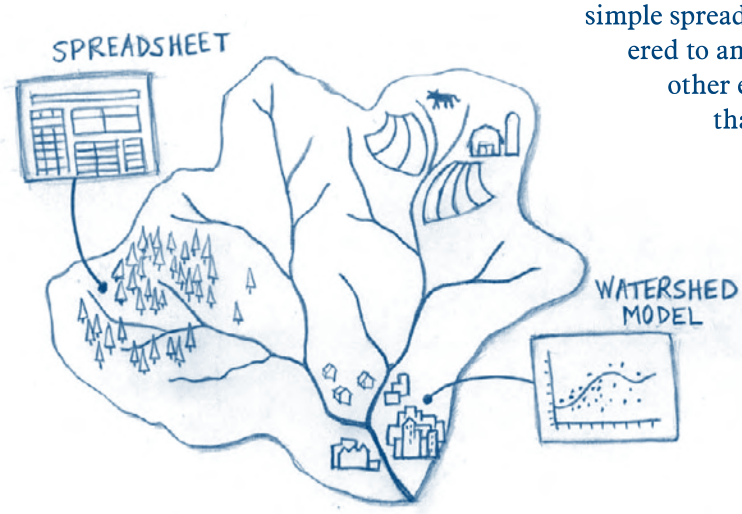
The combined effects of all management practices implemented in a watershed should be considered to determine whether water quality goals will be achieved. In watersheds with easily characterized problems (e.g., where bacterial contamination is due to a few obviously polluting animal operations in a watershed that has no other identifiable sources of pathogens), it might be very easy to project that water quality benefits will be achieved by implementing, for example, management practices for nutrient management, erosion and sediment control, and facility wastewater and runoff. However, in a watershed with multiple land uses where agriculture is considered to contribute only a portion of the pollutants, it is more difficult to estimate the combined impacts of various management practices on a fairly large number of diverse farming operations. Further complicating the assessment is the possibility that historical loading of pollutants has caused the water quality impairment and several years might be required for the water resource to recover fully.

If you need to evaluate the interaction of multiple management practices simultaneously, you'll want to evaluate the degree to which they complement or conflict with one another. Their combined effect could be different from their individual influence. The cumulative effect of management practices spread throughout a large watershed might need to be assessed with complex tools. Sometimes multiple management activities at the site scale are evaluated simultaneously within a single watershed. Most commonly, individual sites are evaluated in a watershed framework to investigate the downstream effects. An example of a downstream effect is the magnitude of peak flows at the junction of the main stem and the tributary on which the management practice is located. Though unlikely, it is possible that the reduced peak outflow hydrograph from a proposed stormwater management practice could exacerbate the peak flow in the main stem channel because of differences in timing. The only way that this unintended, and likely undesirable, downstream effect could be discovered is through a watershed-scale evaluation. On the other hand, it is possible that multiple management practices could work in concert to cumulatively reduce peak flows more than the sum of their individual contributions.

The next section discusses various approaches for quantifying the effectiveness of management practices, including the role of modeling and the types of models available.

11.3 Select an Approach to Quantify the Effectiveness of the Management Strategies

You can use various approaches to evaluate the performance of management practices and strategies. Choosing the one that is right for you will depend on several factors, including the objectives and targets you need to achieve, the types of sources and management practices, the scale of the analysis, and the cost of implementation. Some of the technical considerations associated with modeling are the types of models that were used for loading analysis, the availability of data or resources to collect management practice information, and the availability of the appropriate modeling techniques. A wide variety of approaches can be used to evaluate management strategies. At one end, you can use published literature values and a simple spreadsheet-based tool that calculates loads delivered to and removed by management practices. At the other end, you can use a detailed watershed model that requires substantial amounts of input on each management technique. Sometimes a combination of approaches are used to address various indicators and management practices that might need to be addressed. Very simple approaches can be appropriate for planning and alternatives analysis and can provide relative comparisons of various management strategies. The common limitations of simplified techniques include a lack of sensitivity to precipitation, seasonal patterns, and storm events.



11.3.1 Using Literature Values

One of the most commonly used methods for predicting the performance of management strategies is the use of literature values of the removal percentage typically associated with each type of management practice and pollutant (e.g., detention pond and sediment). The removal percentage is typically estimated from one or more monitoring studies in which the performance of practices was measured using flow and chemical monitoring.

The percentages from various literature sources and studies can include ranges or variations in the expected reductions from practices. This is because the effectiveness of management practices in removing pollutants depends on many factors, including local climate and conditions, design specifications, and type of pollutant. Some monitoring studies have detailed data for only part of the year, such as a few storms, and do not fully consider what the annual load reduction might be for one or more years. When you use studies that document removal percentages, consider the location and climate of the study area (e.g., arid, wet region, cold weather) and the amount of data collected. If you have data that range in values (e.g., from 20 to 80 percent), consider using a range of values in your analysis.

Note that the effectiveness of a series of management practices is not necessarily cumulative. The removal percentage is typically calculated on the basis of monitoring of an individual practice. Management practices are frequently combined on a site to provide enhanced performance. If the same runoff is treated by more than one practice, the configuration is referred to as a treatment train. One common pitfall is that people add the performance results for all the management practices to obtain a combined performance (e.g., 65 percent load removal plus 25 percent load removal equals 90 percent removal). This method of calculation is not accurate and overestimates reduction.

Management practice combinations have some cumulative benefit; however, depending on the pollutant type and the removal mechanism (e.g., settling), the removal percentages can change for subsequent practices. If the removal is cumulative, the removal rate is calculated as follows. If the first practice removes 65 percent of the load, 35 percent of the total load is passed to the second practice. The second practice removes 25 percent of the remaining 35 percent, or 8.75 percent of the total load. The overall performance is 65 percent plus 8.75 percent, or 73.75 percent. If the process is not cumulative, the second practice might be slightly less effective than the first, resulting in a cumulative reduction of less than 73.75 percent. Typical practices that are not cumulative include those which rely on settling. For instance, the first practice might remove coarse, heavy sediment, but the second practice might be less efficient in settling the remaining fine-grained sediment.

Questions to Ask Before You Select a Management Evaluation Approach

- What is the time frame for your analysis? Determine whether the management practice performance is compared to indicators on an annual, seasonal, or storm basis. Determine whether you have to perform calculations daily, or even hourly.
- Is your analysis continuous through time, or can you evaluate discrete events? For instance, you might need to look at only large storm events, not a continuous hydrologic record.
- Are you calculating loads, concentrations, flow, or some other measure? Make sure that your approach reflects the units of measure of your indicator(s).
- Do you need to account for variation in environmental conditions in your analysis, such as weather, wet versus dry years, and so forth?

It might be tempting to apply more than two practices in a series to achieve better results, but the mechanisms of pollutant removal suggest that additional removal is not likely to be achieved. Pollutants are often composed of components with different physical properties; for example, ammonia, nitrate/nitrite, and organic nitrogen make up total nitrogen. Frequently, a practice can remove only one component of a pollutant well. If the next practice in the treatment train removes the same component, less removal results. What is left over is often difficult for any practice to remove. For this reason, you should usually consider using no more than two practices in a given treatment train.

Watershed-scale reductions can be calculated by using simple spreadsheets to provide an accounting of the estimated loading, areas treated, and the percent reductions (or ranges of reductions) expected. Through the use of spreadsheets, multiple scenarios or combinations of load reduction practices can be easily evaluated. Figure 11-2 shows a simple spreadsheet analysis that evaluates one management practice at one site and then broadens the analysis to the watershed scale.

11.3.2 Using Models to Assess Management Strategies

Watershed models or management practice-specific models can also be used to evaluate individual management practices or watershed-scale management strategies. These approaches can build on models developed previously to assess source loads, or they can be set up to supplement other approaches used to estimate source loading. Watershed management modeling is an active research and development area. The goal is to make existing models more flexible and to develop new tools for assessing the placement, selection, and cost of management practices. You're encouraged to check EPA Web sites, publications, and journal articles for ongoing research on management practice analysis.

Currently available models have significant capabilities to represent management practices. The practices they represent, however, vary depending on the specialities of the models. Some agriculture-oriented models have excellent tools for assessing area-based management

A rural/agricultural watershed is listed as impaired because of the impacts of sedimentation on fish communities. During the watershed characterization portion of the study (chapters 7 and 8), you determined that upland sources are a major source of sediment. Much of the load originates from fields planted in conventional-till row cropland. One of the potential management practices you identified in chapter 10 is implementing no-till in areas currently farmed with conventional till. You want to evaluate the effectiveness of the no-till practice on a 120-acre field. During your modeling analysis of sources, you determined that conventional-till row cropland at this site has a sediment loading rate of 1.6 tons/ac/yr. According to your local extension agent, no-till practices are expected to reduce sediment loading by 75 percent. You perform the following calculation to determine the pre-practice and post-practice sediment load:

Conventional till: 120 ac x 1.6 tons/ac/yr = 192 tons/yr

No-till: 120 ac x 1.6 tons/ac/yr x (1 - 0.75) = 48 tons/yr

Your net reduction is 144 tons/yr for the selected site.

If you want to evaluate this practice on a larger scale for several sites throughout the watershed, you can use a spreadsheet to facilitate the calculation. For example, suppose your watershed has 10 potential sites where conventional till could be converted to no-till. Each site has a unique area, of course, but you have also calculated loading rates for each site, based on variations in slope and soil composition:

Site	Area (ac)	Loading Rate (tons/ac/yr)	Load (tons/yr)	Removal Percentage	Load Removed (tons/yr)	Net Load (tons/yr)
1	120	1.6	192	75	144	48
2	305	1.8	549	75	412	137
3	62	1.9	118	75	88	30
4	245	1.7	417	75	312	105
5	519	1.6	830	75	623	208
6	97	2.1	204	75	153	51
7	148	1.9	281	75	211	70
8	75	1.5	113	75	84	28
9	284	2.0	568	75	426	142
10	162	1.8	292	75	219	73
Total	2,017	N/A	3,564	N/A	2,672	892

From this analysis, you estimate that altogether converting to no-till on 10 sites will remove 2,672 tons of sediment. The spreadsheet provides a powerful tool for testing and combining results for various scenarios. For example, you might test combinations of other management practices, with varying percent removal at each site.

Figure 11-2. Using a Spreadsheet Analysis to Evaluate One Management Practice at a Single Site such as fertilizer and tillage practices. Others that specialize in urban areas include techniques for assessing structural solutions like detention ponds. Similar to the watershed modeling discussions highlighted in chapter 8, which model you use depends on what questions you need to answer and the strategies under consideration. The modeling approach you select should provide a process for assessing pollutant loads, evaluating management practices, and ultimately testing the recommended approach for the watershed plan.

The following sections discuss how you can use the seven models highlighted in chapter 8 to evaluate management strategies. The capabilities, strengths, and weaknesses of each model are summarized. In addition to the selected models, descriptions are provided for additional models, supplementary tools, or specialized techniques that can be used to assess management practices. Key data needs and technical considerations in applying the models for management analysis purposes are also discussed.

Summary of Management Practices Simulated by the Seven Models

- **AGNPS**—agricultural practices, tillage, nutrient application
- **STEPL**—removal percentages for multiple practices
- **GWLF**—agricultural practices, tillage, simplified nutrient/manure applications
- **HSPF**—urban and agricultural practices, nutrient applications, detention, and buffer areas
- **SWMM**—urban practices, including detention and infiltration
- **P8-UCM**—urban practices, including detention
- **SWAT**—agricultural practices, tillage, nutrient applications

Modeling Management Strategies with the Selected Models

The models discussed in chapter 8 have various capabilities for representing management practices (table 11-1). As shown in the summary table, each model can assess a variety of practices and each has associated strengths and weaknesses. The models tend to specialize in the following areas:

- Agricultural practices: SWAT, AGNPS, GWLF, STEPL
- Urban practices: P8-UCM, STEPL, SWMM
- Mixed land use: STEPL, HSPF

For agricultural practices, the SWAT model provides the ability to examine specific practices and specialized agricultural techniques like irrigation, drainage, and ponds. STEPL includes a generalized capability to include management practices and assign a removal percentage of pollutant loading. The P8-UCM model provides a flexible set of tools for evaluating specific urban management practices such as ponds and infiltration structures. For mixed-land-use watersheds, STEPL or similar spreadsheet-based models can provide a generalized description of the load reductions from a variety of sources. HSPF can provide a more detailed representation of agricultural, forested, and urban areas, although it is more limited than SWMM in representing structural practices. Chapter 8 provides additional information on the selected models.

Each model has a slightly different approach for including management practices, as summarized in table 11-2. For example, the agricultural techniques in SWAT, AGNPS, GWLF, and STEPL are already recognized during model setup by the selection of parameters for predicting runoff (e.g., curve number equation) and sediment loading (e.g., Universal Soil Loss Equation [USLE]). Other practices might need to be specifically identified and separately input into the model. Some of the agricultural models provide a continuous evaluation of the availability of nutrients in the active soil layer or root zone. This feature provides for tracking of nutrient loading, fertilizer applications, crop uptake, and leaching of nutrients. The HSPF model, with its AGCHEM module, provides a similar ability to track nutrients in the soil.

Table 11-1. Summary of Management Practice Representation Capabilities of the Selected Models

Model	Types of Practices Considered	Strengths	Limitations
STEPL	• Contour farming • Filter strips • Reduced-tillage systems • Streambank stabilization and fencing • Terracing • Forest road practices • Forest site preparation practices • Animal feedlot practices • Various urban and low-impact development (LID) practices (e.g., detention basin, infiltration practices, swale/buffer strips)	• Easy to use; good for giving quick and rough estimates • Includes most major types of management practices	• Simplified representation of management practices using long-term average removal percentage does not represent physical processes • Developed based on available literature information that might not be representative of all conditions
GWLF	• Agricultural area management practices (e.g., contouring, terracing, no-till)	• Easy to use • Long-term continuous simulation	• Does not have structural management practice simulation capabilities
HSPF	• Agricultural practices • Impoundment • Buffer	• Can simulate both area and point management practices • Provides long-term continuous simulation • Land and management practice simulation are linked	• Weak representation of structural point practices • Requires moderate to high effort to set up
SWMM	• Detention basin • Infiltration practices	• Can simulate both area and point management practices • Long-term continuous simulation • Physically based simulation of structural management practices • Management practice simulation is coupled with land simulation	• Limited representation of non-urban area practices • Requires moderate to high effort to set up
P8-UCM	• Detention basin • Infiltration practices • Swale/buffer strip • Manhole/splitter	• Tailored for simulating urban structural practices • Long-term continuous simulation • Process-based simulation for structural practices • Management practice simulation is coupled with land simulation, which provides dynamic input to drive practice simulation	• Cannot simulate nonstructural and area practices
SWAT	• Street cleaning • Tillage management • Fertilizer management • Pesticide management • Irrigation management • Grazing management • Impoundment • Filter strips	• Strong capabilities for simulating agricultural area practices • Ability to consider crop rotation • Long-term continuous simulation	• Limited urban and structural practice simulation
AnnAGNPS	• Feedlot management • Tillage management • Fertilizer management • Pesticide management • Irrigation management • Impoundment	• Strong capabilities for simulating agricultural area management practices • Long-term continuous simulation	• Limited urban and structural practice simulation

Table 11-2. Summary of Management Practice Simulation Techniques of the Selected Models

Model	Management Practice Evaluation Techniques	Water Quality Constituents
AnnAGNPS	• Sediment - RUSLE factors • Runoff curve number changes • Storage routing • Particle settling	• Sediment • Nutrients • Organic carbon
STEPL	• Sediment - RUSLE factors • Runoff curve number changes • Simple percent reduction	• Sediment • Nutrients
GWLF	• Sediment - USLE factors • Runoff curve number changes • User-specified removal rate	• Sediment • Nutrients
HSPF	• HSPF infiltration and accumulation factors • HSPF erosion factors • Storage routing • Particle settling • First-order decay	• Sediment • Nutrients
SWMM	• Infiltration • Second-order decay • Particle removal scale factor • Sediment - USLE (limited)	• Sediment • User-defined pollutants
P8-UCM	• Infiltration - Green-Ampt method • Second-order decay • Particle removal scale factor	• Sediment • User-defined pollutants
SWAT	• Sediment - MUSLE parameters • Infiltration - Curve number parameters • Storage routing • Particle settling • Flow routing • Redistribution of pollutants/nutrients in soil profile related to tillage and biological activities	• Sediment • Nutrients • Pesticides

Note: MUSLE = Modified Universal Soil Loss Equation; RUSLE = Revised Universal Soil Loss Equation; USLE = Universal Soil Loss Equation.

Urban models use representation of impoundments to represent a variety of point practices that collect runoff and remove pollutants through infiltration and settling. Most of the urban models use settling of sediment and decay as the primary removal mechanisms. SWMM can emulate the major management practice processes—storage, infiltration, first-order decay, and sediment settling. The recently added overland flow rerouting (land-to-land routing) options can be used to mimic riparian buffers or infiltration areas.

Modifying a watershed modeling application using any of the reviewed models typically includes the following additional steps:

1. Identify the specific or general practices to be included.
2. Identify the practices that were included in the existing conditions.

3. Incorporate each practice as appropriate into the model.
4. Vary the adoption of the practices according to the management strategy.
5. Summarize the results.

Typical data needs for simulating management strategies using the selected models include specific information for area, point, and linear management practices. For modeling purposes, you'll need information on the existing and proposed management practices, including location, drainage area for each practice, size, type, and key characteristics. Consider carefully the current adoption of management practices in the watershed and what might change in the future. Make sure that you include the current practices in areas where significant restoration has already taken place.

If you're using the same model or approach from your watershed characterization, you might need to add new land use categories. For instance, if you defined urban development in terms of low intensity and high intensity, you might need to break out urban categories in greater detail (e.g., low-density residential, high-density residential, commercial, industrial, institutional). Some of your management practices might be suited for only certain land uses.

You might also need to add a layer of complexity to an existing approach. For instance, your assessment might have been based on generic land use classes, but the evaluation of your management practice is driven by land cover (impervious surface, lawn, forest). In this case, you should provide direct measures of land cover or estimate proportions of land cover for each land use class.

Table 11-3 lists typical information needs for each of the selected models and major practices. The specific information might vary depending on the level of detail of the modeling tools used. For example, a detailed simulation of detention ponds in SWMM might require detailed characteristics of the pond design (e.g., depth-volume relationship, depth-outflow rate relationship), in addition to information on location and the drainage area contributing to the pond.

In general, area-based practices require information on area affected and land use management practices (e.g., tillage, fertilizer/manure applications), including application date, amount, and technique. Simulating point practices generally requires information on the drainage area to each practice and the design specifics for each practice. Detention ponds would generally require information on storage volume, shape, outlet structure, and retention time. Bioretention structures might require information on the infiltration rate, volume of storage, soil media, and pollutant removal rate.

The performance of the model with management practices is typically tested for the existing conditions, where historic monitoring data are available. However, because management practices are dispersed across the watershed and are adopted sporadically over time, the available monitoring data might not provide a distinct response at the watershed scale. One solution to this problem is to use smaller-scale pilot studies that simulate individual practices or combinations of practices for more detailed small-scale testing. In addition, management practice simulations can build on the available data on removal effectiveness. These results are used to build the best estimates of the potential benefits of implementing management practices. Ultimately, these forecasts can be tested or evaluated for accuracy only through monitoring after implementation. Once implementation has begun, a post-audit can include monitoring of management effectiveness and a reassessment of modeling results.

Table 11-3. Data Needs for Management Strategy Modeling

Model	Data Needs for Management Practices
AnnAGNPS	• Tillage area, type and date, crop rotation • Fertilizer application rate, method, and dates • Manure application rate, method, and dates • Strip cropping location and area • Impoundment size and discharge rate • Sediment settling rate
STEPL	• Land use type and condition • Practice type
GWLF	• Crop type and condition • Manure application rate and date • Runoff nutrient concentration
HSPF	• Land use type and pollutant accumulation rates • Nutrient and pathogen application rates and dates • Impoundment size and discharge rates • Settling rate and pollutant decay rate
SWMM	• Land use type and pollutant accumulation rates • Impoundment size, shape, and discharge rate • Settling rates and pollutant decay rates • Street cleaning frequency and areas affected
P8-UCM	• Point practice drainage area • Impoundment size and discharge rate, pollutant decay rate • Bioretention size and infiltration rate • Street cleaning frequency and area affected
SWAT	• Tillage area, type and date, crop rotation • Fertilizer and pesticide application rate, method, and dates • Manure application rate, method, and dates • Filter strip width • Grazing dates and vegetation biomass affected • Street sweeping pollutant removal rate, date, and curb length

Other Models Available for Analysis of Management Practices

Although the selected models consider various management practices, sometimes you might need an additional model or models that specialize in a particular type of management practice simulation. In some cases, models are used to perform a detailed small-scale (small representative watersheds or fields) analysis of management practices. Some of the specialized management practice models available today are the Site Evaluation Tool (SET), the Prince George's County [Maryland] BMP Module (PGC-BMP), Model for Urban Stormwater Improvement Conceptualization (MUSIC), and Integrated Design and Evaluation Assessment of Loadings (IDEAL). SET provides a simplified spreadsheet-based approach for assessing management practices and is used in several examples throughout this chapter. PGC-BMP,

Build on Existing Model or Perform Separate Analysis

When evaluating modeling approaches for evaluating management practices, consider the following alternatives:

- Modify original loading model to incorporate management practices.
- Add supplemental analyses for specific management practices.
- Perform alternative analyses for management practices using spreadsheet or other simplified tools.

MUSIC, and IDEAL provide options for more detailed simulation of multiple management practices. These systems are oriented to examining networks of one or more management practices.

Many models, however, do not include ways to evaluate the benefits of buffer zones. The models that specialize in the representation of buffer strips include the Vegetative Filter Strip Model (VFSMOD) and Riparian Ecosystem Management Model (REMM). Options for reducing sediment loading, including forest and agricultural area management, can be evaluated using Water Erosion Prediction Project (WEPP); the Erosion Productivity Impact Calculator (EPIC) also provides evaluation of agricultural area management. WETLAND and Virginia Field Scale Wetland Model (VAFSWM) provide the capability to evaluate wetlands. These specialized models are summarized in table 11-4 and described in more detail below.

Table 11-4. Specialized Models for Analyzing Management Practices

Model	Types of Management Practices Considered	Management Practice Evaluation Techniques	Water Quality Constituents
SET	• Detention basin (e.g., wet pond, extended dry detention, conventional dry detention) • Infiltration practices (e.g., infiltration trench, dry well, porous pavement, sand filter) • Vegetative practices (e.g., wetland, swale, buffer/filter strip, bioretention, green roof) • Wetland • Storage (e.g., cistern/rain barrels)	• Simple percent reduction • Simple regression	• Sediment • Nutrients (total nitrogen and total phosphorus)
GC-BMP	• Detention basin • Infiltration practices (e.g., infiltration trench, dry well, porous pavement) • Vegetative practices (e.g., wetland, swale, filter strip, bioretention)	• Infiltration: Holtan's equation • Storage routing • Weir/orifice flow • First-order decay	• User-defined pollutants
MUSIC	• Detention basin • Infiltration practices • Vegetative practices	• Infiltration • Settling • First-order decay (k-C* model)	• User-defined pollutants
IDEAL	• Vegetative filter strip • Detention/retention basin	• Infiltration • Storage routing • Settling • Trapping efficiency • Bacteria die-off rate	• Sediment • Nutrients • Bacteria
VFSMOD	• Vegetative filter strip	• Infiltration: Green-Ampt equation • Kinematic wave • Sediment deposition and resuspension	• Sediment
REMM	• Riparian buffer strip	• Infiltration: Green-Ampt equation • Sediment: USLE parameters • Storage routing • Nutrient cycling: Century Model • Nitrification: First-order Weir/orifice flow • Sediment transport: Einstein and Bagnold equations	• Sediment • Nutrients • Organic matter

Table 11-4. Specialized Models for Analyzing Management Practices (continued)

Model	Types of Management Practices Considered	Management Practice Evaluation Techniques	Water Quality Constituents
WEPP	• Impoundment • Tillage management • Irrigation management • Grazing management • Filter strips • Forest roads • Forest and rangeland fire management	• Infiltration: Green-Ampt Mein-Larson equation • Erosion: Steady-state sediment continuity equation • Kinematic wave • Subsurface: Kinematic storage-discharge	• Sediment
EPIC	• Tillage management • Fertilizer management • Irrigation management • Feedlot management (lagoons)	• Infiltration: Curve number equation or rational formula • Six variations of USLE equation for soil erosion and sediment delivery • Storage routing • Nitrogen and phosphorus cycling	• Sediment • Nutrients • Pesticides
WETLAND	• Detention basin • Wetland	• Water budget • Monod kinetics • Nutrients cycling (carbon, nitrogen, phosphorus) • Constant vegetative growth rate • Freundlich isotherms for phosphorus sorption/desorption • First-order mineralization	• Nitrogen • Phosphorus • Carbon • Dissolved oxygen • Sediment • Bacteria
VAFSWM	• Detention basin • Wetland	• Water budget • Infiltration • Particle settling • Continuously stirred tank reactors in series • First-order kinetics (adsorption, plant uptake)	• User-defined • Sediment

SET was developed to assess the impacts of development, including sediment and nutrient loading, on a site scale. It provides a more robust environment for testing multiple management practices and site configurations than simple export calculations, and it incorporates several principles discussed previously in this section. The tool lets the user define pre- and post-treated land use/land cover, allowing for multiple drainage areas and various combinations of practices. An important benefit of SET is that the user can test management practices in combination with each other, in the context of a site or small catchment. In addition, both structural and nonstructural practices can be represented, offering a suite of options for evaluation.

PGC-BMP is an example of a more detailed management practice simulation tool. It evaluates the effect of management practices or combinations of management practices on flow and pollutant loading. It uses simplified process-based algorithms to simulate management practice control of modeled flow and water quality time series generated by watershed models like HSPF. These simple algorithms include weir and orifice control structures, storm swale characteristics, flow and pollutant transport, flow routing and networking, infiltration and saturation, and a general loss/decay representation for pollutants. The tool offers the flexibility to design retention-style or open-channel management practices; define flow routing through a management practice or management practice network; simulate integrated management practices (IMPs), such as reduced or discontinued imperviousness through flow networking; and compare management practice controls against a defined benchmark, such as a simulated pre-development condition. Because the underlying algorithms are based on physical processes, management practice effectiveness can be evaluated and estimated over a wide range of storm conditions, management practice designs, and flow routing configurations.

MUSIC (Wong et al. 2001, Wong et al. 2005) was developed by the Cooperative Research Center for Catchment Hydrology in Australia. It was developed to evaluate small- and large-scale (0.01 km^2 to 100 km^2) urban stormwater systems using modeling time steps that range from 6 minutes to 24 hours. MUSIC provides an interface to help set up complex stormwater management scenarios. The interface also allows the user to view results using a range of graphical and tabular formats. The stormwater control devices evaluated by MUSIC include ponds, bioretention, infiltration buffer strips, sedimentation basins, pollutant traps, wetlands, and swales. The major techniques used to evaluate management practices are settling in ponds and decay of pollutants (first-order). For more information go to the MUSIC Web site at **www.toolkit.net.au/music**.

IDEAL (Barfield et al. 2002) provides a spreadsheet-based technique for assessing the beneficial effects of urban management practices on flow, sediment, nutrients, and bacteria. The model predicts watershed runoff, concentrations, and loads based on your selection of vegetative filter strips, dry detention ponds, and wet detention ponds. Urban areas are defined as pervious, impervious connected, and impervious unconnected areas. Flow and loads can be directed to a pond that can be dry (no permanent pool) or wet (permanent pool). The model then calculates the pollutant removal efficiencies of the practices using empirical equations. The model predicts single storm values and converts them to average annual storm values using a statistical process. IDEAL is designed to help managers estimate long-term management practice pollutant removal efficiencies and is not designed for evaluating individual storms.

VFSMOD (Muñoz-Carpena and Parsons 2003) provides specialized modeling of field-scale processes associated with filter strips or buffers. This model provides routing of storm runoff from an adjacent field through a vegetative filter strip and calculates outflow, infiltration, and sediment-trapping efficiency. The model is sensitive to the characteristics of the filter, including vegetation roughness or density, slope, infiltration characteristics, and the incoming runoff volume and sediment particle sizes. VFSMOD includes a series of modules—Green-Ampt infiltration module, kinematic wave overland flow module, and sediment filtration module. The model can also be used to describe transport at the edge of the field when flow and transport are mainly in the form of sheet flow and the path represents average conditions across the vegetative filter strip. VFSMOD uses a variable time step that helps to more accurately solve the overland water flow equation. The model inputs are specified on a storm basis, and the model summarizes all the information after each event to generate storm outputs. For more information go to the VFSMOD Web site at **http://carpena.ifas.ufl.edu/vfsmod**.

REMM is used to simulate hydrology, nutrient dynamics, and plant growth for land areas between the edges of fields and a waterbody. Output from REMM allows watershed planners to develop buffer systems to help control nonpoint source pollution. USDA's Agricultural Research Service (ARS) developed REMM at the Southeast Watershed Research Laboratory, Coastal Plain Experiment Station, in Tifton, Georgia. ↬ For more information go to the REMM Web site at **www.cpes.peachnet.edu/remmwww**.

WEPP (Flanagan and Nearing 1995) simulates water runoff, erosion, and sediment delivery from fields or small watersheds. Management practices, including crop rotation, planting and harvest date, tillage, compaction, stripcropping, row arrangement, terraces, field borders, and windbreaks, can be simulated. WEPP has been applied to various land use and management conditions (Liu et al. 1997, Tiscareno-Lopez et al. 1993). ↬ For more information go to the Web site **http://topsoil.nserl.purdue.edu/nserlweb/weppmain/wepp.html**.

EPIC (Sharpley and Williams 1990) simulates the effect of management practices on edge-of-field water quality and nitrate nitrogen and pesticide leaching to the bottom of the soil profile. The model considers the effect of crop type, planting date, irrigation, drainage, rotations, tillage, residue, commercial fertilizer, animal waste, and pesticides on surface water and shallow ground water quality. EPIC has been used to evaluate various cropland management practices (Edwards et al. 1994, Sugiharto et al. 1994).

WETLAND (Lee 1999, Lee et al. 2002) is a dynamic compartmental model used to simulate hydrologic, water quality, and biological processes and to assist in the design and evaluation of wetlands. WETLAND uses the continuously stirred tank reactor prototype, and it is assumed that all incoming nutrients are completely mixed throughout the entire volume. The model can simulate both free-water surface and subsurface-flow wetlands. WETLAND is modular and includes hydrologic, nitrogen, carbon, dissolved oxygen, bacteria, sediment, vegetation, and phosphorus submodels. The strength of this model lies in the linked kinetics for the water quality variables and the consideration of seasonal variation (variable user-defined parameter by season/time period). The weaknesses include the completely mixed assumption, which overlooks the effect of the system shape, and the need for extensive kinetic parameters.

VAFSWM (Yu et al. 1998) is a field-scale model for quantifying the pollutant removal in a wetland system. It includes a hydrologic subroutine to route flow through the treatment system and precipitation, evapotranspiration, and exchange with subsurface ground water. VAFSWM simulates settling, diffusion, adsorption to plants and substrate, and vegetative uptake for a pollutant in dissolved and particulate forms in a two-segment (water column and substrate), two-state (completely mixed and quiescent) reactor system by employing first-order kinetics. The governing equations for the quiescent condition are identical to that for the turbulent condition; however, far lower settling velocities are assumed to account for the greater percentage of finer particles during the quiescent state. VAFSWM is a relatively simple model that includes the most dominant processes within the wetland system. However, the user needs to provide and calibrate the requisite kinetics parameters.

Considerations in Modeling of Management Strategies

Whether you use simplified approaches, one of the selected models, or a combination of supplementary tools, there are some common considerations in developing your approach to model management practices. Summarized below are some of the key issues in the emerging area of watershed management practice simulation. It's important to recognize that simulating management practices can make the modeling process much more complicated and data-intensive, primarily because of scale and the amount of information needed. For example, in a 1,000-acre watershed, hundreds of management practices could be used. Some management practices, such as cropping practices that affect a percentage of corn fields, cover large areas. Others, such as an individual pond that drains part of a watershed, are at specific locations.

Others, such as a riparian buffer zone on either side of several miles of a river, might stretch across part of the watershed. For large watersheds, the information collection needs can quickly become formidable. In addition, there are often issues related to privacy and protecting information related to management practices installed on private lands. Collecting some information on current management practice adoption, however, is very important for the purposes of estimating benefits and evaluating needs for future management.

When setting up models, some approaches involve identifying and inputting information on each management practice. This is appropriate for small watersheds and can provide a system for evaluating the benefit of management actions and new initiatives. For large watersheds, modelers use a variety of techniques to extrapolate or estimate the benefits of management. One technique is a "nested" modeling approach, in which a more detailed model is applied to a smaller representative area. The results of the detailed modeling are then used to define the land use characteristics used for the large-scale watershed model. For example, a detailed model might be used to evaluate new residential development techniques. The results of the detailed small-scale assessment would be used to create a new alternative "new residential development" land use that would then be used in the watershed-wide simulation. Sample or pilot studies can be used to test and evaluate a variety of management techniques on a small scale before initiating a large, more complex and time-intensive application. Sometimes watershed-wide or large-scale applications can be adjusted by using simple percentage reductions at the subwatershed or land use level to reflect estimates of load reduction due to management practices.

> *Tip* Regardless of the technique used, you should record the rationale and justification for why the various changes were made. This will provide documentation for what was done and give you a basis for future updates or improvements in the methodology as more information becomes available.

Consider carefully what areas are really being treated by the management practices. The drainage area or treatment area is used for calculations of loading and percent removal. Site constraints usually prevent 100 percent treatment of a particular development. Assume, for example, that a residential development will be treated by a stormwater wetland. Site topography prevents 10 percent of the site from draining to the wetland. If you're using an ordinance to require a set-aside of undisturbed open space, the untreated area increases because the open space cannot be graded. In this example, complementary practices result in a change in the evaluation of one of the practices.

Another consideration might be the drainage area for a buffer zone. The buffer is located laterally along a channel and receives runoff from the drainage adjacent to the channel. In an urban setting, however, runoff from storm events tends to accumulate into concentrated flow within a short distance, probably no more than 150 feet (Schueler 1995). These concentrated flows will likely bisect or cross a buffer without treatment. In the eastern United States, this area of concentrated flows usually translates to less than 10 percent of a watershed for perennial streams. The pollutant removal rates in the literature reflect runoff received as overland flow. Removal performance is therefore limited by the proportion of a site draining to it.

11.3.3 Example Model Applications to Assess Management Strategies

Using the approaches discussed in the previous section, you will now quantify the effectiveness of the proposed management practices in meeting watershed goals and objectives. This section presents three examples that reflect various management objectives, such as addressing multiple indicators using a variety of practices, assessing sediment loading reductions, and improving habitat.

Quantify the Effectiveness of Multiple Management Practices

You can use a spreadsheet tool to assist with quantifying multiple practices. This example demonstrates how a management strategy can be assessed for multiple indicators using a simplified spreadsheet tool, SET. The example includes a suite of structural management practices, nonstructural management practices and detailed site layout, and a need to define multiple drainage areas and management practice combinations, including treatment trains (figure 11-3).

Quantify the Effectiveness of Management Practices in Reducing Sediment Loading

When reducing sediment loading is the management objective, rates of sediment generation from channel enlargement can provide a tool for quantifying effectiveness. A monitoring approach is a good strategy for assessing longer-term sediment loading and stream channel characteristics. Historical aerial photographs allow comparison of channel width and location over discrete points in time, and translating changes to an average annual rate can provide an estimate of the rate of sediment loading due to instream sources. A more direct method of calculating erosion rates is to install and monitor bank pins in the reach of interest. Stakes or pins can be driven into channel banks flush with the surface. The amount of pin exposed due to erosion is the amount of change at the streambank erosion site between your times of observation. (Note: This would have been done during the earlier data collection phase; refer to chapter 6). Reductions in sediment loading can then be quantified by comparing the estimated erosion rates with the rate for a stable reach (figure 11-4).

Quantify the Effectiveness of Management Practices in Improving Aquatic Habitat

For stream reaches where instream habitat is degraded, habitat sampling can provide a gauge for quantifying the effectiveness of a management action. A straightforward comparison of conditions before and after implementation can numerically quantify the improvement in aquatic habitat. State agencies typically have habitat evaluation forms that provide numerical rankings for observed conditions for various components of aquatic habitat. By using such forms, some of the subjectivity of visual interpretations can be reduced, leading to better evaluations of effectiveness (figure 11-5). Also, evaluation of community assemblages (e.g., macroinvertebrates, fish, periphyton) is a critical measure of the overall effectiveness of habitat protection management measures. EPA's *Rapid Bioassessment Protocols (RBPs) for Use in Wadeable Streams and Rivers* (Barbour et al. 1999) provides more information about evaluating habitat (**www.epa.gov/owow/monitoring/rbp/index.html**). Additional descriptions of state protocols for assessing habitat quality can be found in EPA's *Summary of Assessment Programs and Biocriteria Development for States, Tribes, Territories, Interstate Commissions: Streams and Wadeable Rivers* at **www.epa.gov/bioindicators**. (See section 6.5.6 for more information on assessing habitat quality.)

Modeling can be used where nutrient reductions associated with improving vegetation in riparian areas are the management goal. Loading rates for constituents of concern within a limited distance of riparian areas can be coupled with the removal efficiencies of the buffers to evaluate how effective the management action is at reducing contaminant input to the stream. However, the benefits of nutrient reduction associated with riparian revegetation are typically limited, especially in locations where stormwater outfalls or drainage ditches result in concentrated flow through the buffer.

Mecklenburg County, North Carolina, is home to rapidly growing Charlotte and other surrounding communities. It has several watersheds listed as impaired in part due to the impacts of upland sedimentation. In addition, nutrient loading from much of the county affects several reservoirs on the Catawba River. The following example explores how the SET might be used to evaluate various combinations of management practices. The team located sites in the watershed that were publicly owned, were larger than 5 acres, and could be adapted for retrofit of possible management practices. The selected 10-acre site contains a public school and lends itself well to placement of a structural practice to capture most of the runoff. Three scenarios are being tested—a stormwater pond, a combination of bioretention cells in series with an extended dry detention basin, and the conversion of 2 acres of lawn into forest. Thirty percent of the site is impervious surface, and the remainder is lawn or managed herbaceous. The site configuration for each scenario is as follows:

Stormwater Pond: The pond is at the lowest point on the site, and it captures all runoff except that from 1 acre of lawn area.

Bioretention Cells and Extended Dry Detention Basin: Bioretention cells treat all the impervious area and 2.75 acres of the lawn area; all bioretention cells are configured to drain completely to the extended dry detention basin. Another 3.25 acres of the site drain to the extended dry detention basin only. One acre of lawn is not treated.

Forest Conversion: Two acres of lawn area are planted with saplings, fenced off, and no longer mowed. Modeled conditions reflect brush/immature forest.

The amount of land in each of the three land cover types is summarized below for existing conditions and the three proposed management alternatives:

Treatment	Land Cover in Drainage Area (acres)		
	Lawn	Impervious	Forest
Existing Site			
Untreated	7	3	
Stormwater Pond Scenario			
Stormwater pond	6	3	
Untreated	1		
Bioretention and Extended Dry Detention Scenario			
Bioretention + dry detention	2.75	3	
Dry detention only	3.25		
Untreated	1		
Forest Conversion Scenario			
New land cover	5	3	2

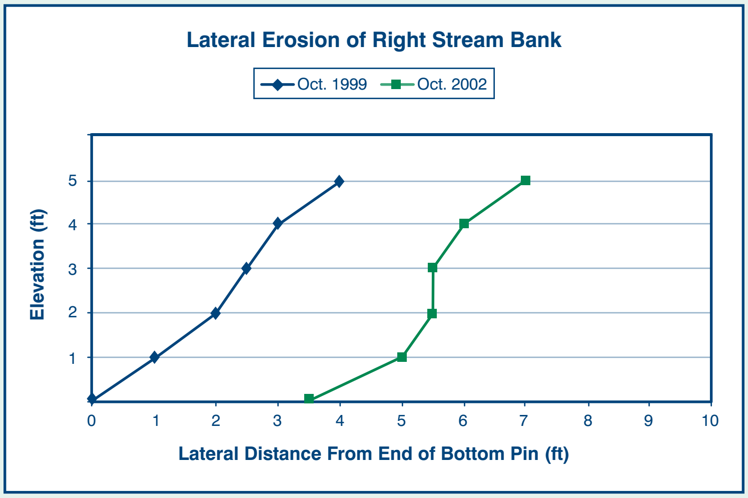
The SET calculates annual loads from the site under each scenario for total suspended solids, total phosphorus, and total nitrogen and shows the percent reduction in load between the existing site and each scenario. The forest conversion scenario by itself performs poorly, but results suggest it might be a good candidate as a complementary practice. The two structural management practice scenarios perform better for pollutant reduction. Note that the bioretention/extended dry detention scenario performs better than the stormwater pond for nutrient removal but worse for sediment removal.

	TSS		TP		TN	
	tons/yr	% red.	lb/yr	% red.	lb/yr	% red.
Existing Site	5.11		11.5		70	
Stormwater Pond	1.79	65%	6	48%	50	29%
Bioretention/Ext. Dry Detention	1.97	61%	4.6	60%	36	49%
Forest Conversion	4.1	20%	10.6	8%	66	6%

Figure 11-3. Analysis of Multiple Management Practices Using Multiple Indicators

Bank pins (e.g., rebar with painted ends) were installed in a streambank in October 1999 to determine the rate of streambank erosion. In October 2002, three years after the pins were installed, the distance that the pins extended from the streambank was recorded. The streambank profiles are illustrated in the figure. Six bank pins were installed at approximately one-foot vertical intervals between the toe of the bank and top of the bank.

This location along the stream is representative of nearly 400 feet of channel. If the streambank along this reach were stabilized, what would be the effect on the average annual contribution to the total sediment load, at current erosion rates?



The lengths that the six bank pins extended from the bank at the October 2002 measurement, from the lowest pin to the highest, were 3.5, 4.0, 3.5, 3.0, 3.0, and 3.0 feet, respectively.

Average amount of erosion = (3.5 + 4 + 3.5 + 3 + 3 + 3) / 6 = 3.3 feet

Conversion to average annual rate = 3.3 feet / 3 years = 1.1 feet per year

Average annual volumetric loading (using length of 400 feet and average bank height of 5 feet)
= 1.1 ft/yr * 400 ft * 5 ft = 2,200 cubic feet per year

To convert to a weight-based sediment loading, a unit weight of the streambank soil is needed.

Assume a unit weight of 100 pounds per cubic foot for this streambank soil.

Average annual weight of sediment loading
= 2,200 cubic feet per year * 100 pounds per cubic foot = 220,000 pounds per year
= 110 tons per year.

Unimpacted, stable channels tend to have negligible rates of streambank erosion, so an eroding channel that is stabilized can be assumed to have a negligible rate of erosion as well. Thus, stabilization efforts along this reach of stream can be expected to reduce average annual sediment loading by about 110 tons per year. Caution should be exercised to determine the overall effects of any streambank stabilization work, to ensure that erosive forces are not simply transferred to another—possibly unprotected—location downstream.

Figure 11-4. Quantifying the Effectiveness of Stabilization Practices in Reducing Sediment Loads

In this section you were shown how to quantify the effectiveness of various management practices to evaluate how well they achieve the management goal. Next, you'll compare the estimated costs of various management actions to identify the most cost-effective opportunities.

11.4 Identify Costs and Compare Benefits of Management Practices

Now that you've quantified the effectiveness of various management practices in achieving your goals and objectives, you should incorporate cost considerations into your evaluation. Economics is always a consideration in the evaluation and formulation of management strategies. Stakeholders might offer insights and concerns regarding the cost of various management options. This is why an ongoing dialogue with stakeholders is critical to selecting management alternatives that they will support. Cost considerations can also help to identify opportunities for collaboration or leveraging practices with existing programs.

A stream reach that is classified as impaired because of the condition of the instream aquatic habitat is being considered for rehabilitation efforts. A few rehabilitation options are under consideration because of various levels of effort and the associated costs. How can the effectiveness of the rehabilitation efforts be evaluated?

A physiographic region-specific instream aquatic habitat evaluation method can be used to characterize habitat condition, and the numeric score linked to a functional level of support for the aquatic community. In this example, the overall score can range from 0 (most impaired conditions) to 200 (capable of fully supporting a diverse and abundant aquatic community). The functional levels of support are provided in table A.

Table A. Habitat Quality and Use Classifications by Habitat Score

Habitat Assessment Score	Habitat Quality	Use Classification
170–200	Excellent	Supporting
145–169	Good	Supporting
95–44	Good–Fair	Partially Supporting
50–94	Fair	Not Supporting
0–9	Poor	Not Supporting

The field form used for the example reach includes 10 key habitat parameters with a numeric scale for each parameter for assigning 0–20 points. An example breakdown of possible points for the degree of physical channel alteration is shown in Table B. Under the current conditions, the example reach scores a total of 90 points, corresponding to *Fair* habitat quality and *Not Supporting* its use. Of the 90 points, 3 points were assigned to the parameter for Physical Channel Alteration because of historical channelization (i.e., 100 percent of the reach is disturbed, but no embankments are present).

For the proposed full-scale rehabilitation effort, a new natural channel will be excavated on the existing floodplain. Because of the location of a sanitary sewer line along the right side of the floodplain, the sinuosity of the new channel will be limited and channel bends will be no tighter than 45 degrees. Therefore, if the full-scale restoration effort is pursued, the scoring for the Physical Channel Alteration is expected to increase from 3 points to 18 points.

Figure 11-5. Quantifying the Effectiveness of Management Practices in Improving Aquatic Habitat

To fully evaluate the effectiveness of the full-scale rehabilitation option, the anticipated conditions will need to be compared with the existing scores. Although the scores for many parameters will be expected to increase, decreases are possible and need to be realistically evaluated. (For example, if the existing canopy cover is dense and scores high, but the restoration effort would result in clearing and revegetation that would not provide dense cover until the vegetation had time to grow, the result would be a lower score.) In this manner, the effectiveness of the various rehabilitation efforts can be quantified.

Table B. Scoring Thresholds for Physical Channel Alteration

Stream follows a normal and natural meandering pattern; alteration is absent	
No evidence of disturbance; bend angles greater than 60 degrees	20
No evidence of disturbance; bend angles between 40 and 60 degrees	18
No evidence of disturbance; bend angles less than 40 degrees	16
Some stream alteration present but NO evidence of recent alteration activities	
Bridge abutments present but older than 20 years; no other disturbances	15
10% of reach or less has channel disturbance other than bridge	14
20% of reach has channel disturbance	13
30% of reach has channel disturbance	12
40% of reach has channel disturbance	11
Somewhat altered; 40%–80% of reach altered; alterations might be within past 20 years	
40% of reach has channel disturbance	10
50% of reach has channel disturbance	9
60% of reach has channel disturbance	8
70% of reach has channel disturbance	7
80% of reach has channel disturbance	6
More than 80% of reach altered; instream habitat highly affected	
90% of reach has channel disturbance	5
100% of reach disturbed; straightened with no artificial embankments	3
100% of reach disturbed; straightened with artificial embankments	2
100% of reach disturbed; straightened with natural and artificial embankments	1
100% of reach disturbed; concrete or gabion lining	0

Figure 11-5. Quantifying the Effectiveness of Management Practices in Improving Aquatic Habitat (continued)

To the extent possible, a cost estimate should consider all future costs of the management strategy, including design and engineering, construction, labor, and operation and maintenance. The following sections explain what to consider when estimating the cost of management options and how to conduct a cost/benefit analysis. Most of the guidelines center on structural management practices, but the discussions of labor, inflation, discounting, and information sources are applicable to nonstructural management options as well.

11.4.1 Identify Cost Considerations

Construction Costs

The construction costs of various management practices can be estimated in one of two ways: (1) with a total per unit cost or (2) with a detailed breakdown of individual cost components. Total per unit costs are more appropriate when you're considering a large number of management practice sites or management practices that would be applied throughout the watershed but at no specific location. If you need to estimate the size of a specific practice, use published design guidelines or consult with a stormwater engineer to ensure the accuracy of the cost estimate.

If you're comparing a few specific management practices, using a detailed cost estimate would be more accurate than using a total per unit cost estimate. For example, if you were comparing the use of a stormwater wetland with the use of a wet pond for a single site, you should consider how the costs of these management practices would differ on that particular site. You would estimate the cost of each construction component (e.g., excavation, grading, outlet structure) and then sum the component costs to arrive at a total cost estimate. Use guidance from a stormwater engineer when determining preliminary quantities and costs of individual management practice components.

Whether you're looking for total per unit costs or component costs, look for local cost estimates that use the same design guidelines that your project will require. It's also important to use costs that represent soil, climatic, and geographic conditions similar to those of your future project. Check several sources to determine whether cost estimates vary geographically.

The accuracy of cost estimates depends on how unit costs are used to translate management practice design quantities into management practice costs. Although your management practice might be appropriately sized, you can describe the management practice size in many different ways. For example, a detention pond has at least three volumes: a permanent pool, a detention volume, and a volume up to the emergency spillway. You should determine to which measurements the unit cost refers. Table 11-5 shows example formats of management practice unit costs and the information you need before using the unit costs.

Table 11-5. Considerations for Applying Management Practice Unit Cost Measures

Example Management Practice	Example Cost Units	Issues to Consider Before Using Unit Costs
Grass swale	$ per linear foot	Find out the width of swale assumed in the unit cost, and make sure the width is appropriate for your project. You will overestimate the cost if you use a unit cost based on a swale that is wider than your proposed swale.
Water quality swale (dry swale)	$ per square foot	Find out whether the width should be measured across the filter media or across the entire swale. You will overestimate the cost if you measure across the entire swale and the unit cost refers to only the filter media width.
Wet detention pond	$ per cubic foot	Determine the height at which to measure the pond volume. If the cost estimate assumes the volume up to the emergency spillway, using the volume of the permanent pool would underestimate the pond cost.
Bioretention	$ per impervious acre treated	This cost estimate format might not be appropriate for all uses. If your bioretention cell is treating a large amount of pervious area (e.g., grass lawn), this unit cost would not accurately represent the size of the bioretention cell needed.
Stormwater wetland	$ per acre of drainage area treated	This unit cost would not account for how drainage areas vary in the amount of impervious surface. Before using this type of estimate, you should make sure that it assumes a level of imperviousness similar to that of your stormwater wetland's drainage area.

Management practice retrofit costs can differ from the costs of management practices used in new development. Check whether the cost information refers to new construction or retrofit sites. If you're estimating costs for a retrofit site and can't find information on retrofit costs, consider how your project will differ from new construction. A retrofit on an agricultural site is likely to be similar in cost to a management practice on a new construction site, whereas a management practice retrofit on a highly developed site could have a much higher cost than new construction. For highly developed sites, you should estimate costs for demolition, regrading, and other components in addition to new construction management practice costs.

Overall, construction cost information can be an important deciding factor for targeting management practices in a watershed. Figure 11- 6 shows a comparison of the costs of different treatment trains for a mixed-use development. Each treatment train achieves a 70 percent total phosphorus removal objective, and the cost analysis shows that treating runoff with water quality swales leading to a wet detention pond is the least expensive option for this development. Although this treatment train is the least expensive for one development, a different combination of management practices might be more economical for a different type of development or treatment objective.

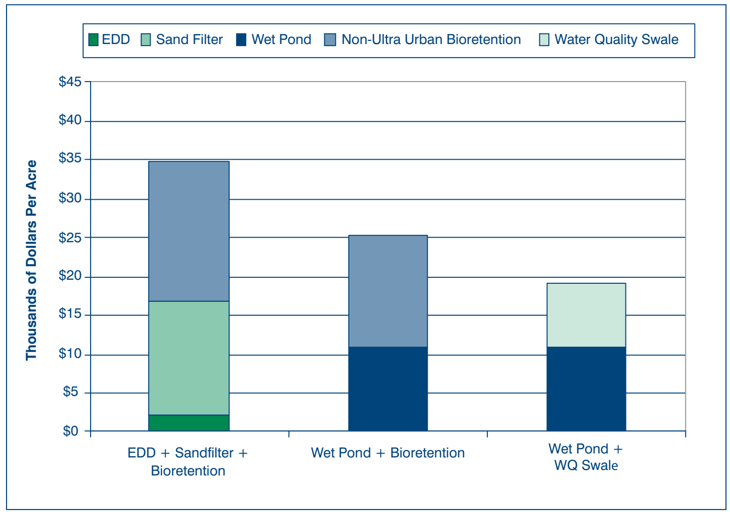


Figure 11-6. Cost Comparison of Alternative Treatment Trains to Meet Specific Water Quality and Detention Performance Standards

Labor and Nonstructural Management Options

When estimating construction costs, check that the cost information includes labor. Most total construction cost estimates include labor. If you're estimating costs for a nonstructural management practice like training programs or site-specific nutrient management plans, most of the costs will be labor. Request cost information from local agencies that have recently developed a similar policy or plan. Also consider how project costs vary by the site acreage or type of watershed being managed. If no local information is available, you can check Internet references that provide cost estimates for nonstructural management practices. For example, the EPA Web site provides cost information for agricultural management practices, including a number of nonstructural management options: **www.epa.gov/owow/nps/agmm**. Information is also available for management practices for other source types, including forestry (**www.epa.gov/owow/nps/forestrymgmt/**), marinas and recreational boating (**www.epa.gov/owow/nps/mmsp/index.html**), and urban areas (**www.epa.gov/owow/nps/urbanmm/index.html**).

Design and Engineering Costs

When researching construction cost estimates for various management practices, determine whether the cost estimates include design and engineering. Typical design and engineering costs represent an additional 25 to 30 percent of the base construction cost. Use a local estimate if available; otherwise, consult a national management practice reference for the approximate design and engineering costs of your specific management practices. See appendix A for example management practice reference guides.

Operation and Maintenance Costs

Operation and maintenance costs vary by the type of management practice and local requirements. Use local cost estimates when available; otherwise, use the most recent estimates from national sources. Reference sources might report operation and maintenance costs as average annual costs or as a percentage of the base management practice construction cost. For example, *Post-Construction Storm Water Management in New Development & Redevelopment* (USEPA 2003b) estimates that the annual routine maintenance cost for a wet detention pond ranges from 3 to 5 percent of the pond's construction cost. Maintenance for a $150,000 wet detention pond would therefore cost about $4,500 to $7,500 per year.

Inflation Adjustment

Prices of goods and services increase every year because of inflation. You should adjust cost estimates for inflation if they are reported before the first year of your project. You need to adjust only historical prices; maintenance and other costs after the first project year do not have to be adjusted because your estimate should be in the perspective of the first project year, or in "real" terms. The U.S. inflation rate averages about 3 percent per year. Inflation rates for specific products are available but are probably not necessary for preliminary cost estimates.

To adjust historical costs, increase the cost by the inflation rate for every year that the historical cost differs from the first project year. For example, a cost of about $4 per cubic foot for an infiltration trench in 1997 would be converted to a cost of about $5 per cubic foot in 2005 according to the following calculation:

$$\text{2005 cost} = \$4.00 \times (1 + 0.03)^{(2005\text{-}1997)} = \$5.07$$

Discounting

The costs that occur after the first project year should be estimated in "present value" terms. The present value is the current value of the projected stream of costs throughout a project's lifetime. The process of calculating present value is known as discounting. Discounting is important because the money allocated to future costs could earn an average return in another investment. For example, assume that the first project year is 2005 and your project will require maintenance after construction. If you can invest the project's maintenance funds in another project or fund and earn at a return of r, consuming one unit of maintenance in 2006 would have a present value of $1/(1+r)$ in 2005. One unit consumed in 2007 has a present value of $1/(1+r)^2$ in 2005, and so on. The r at which future returns are discounted to the present value is called the discount rate (Helfert 1997; Sugden and Williams 1981). Discounting simply reflects the time preference for consumption. Although not synonymous with the interest rate, for governments it often reflects the rate at which funds can be borrowed and loaned. Discounting is especially important if you're comparing projects with different maintenance costs and frequencies.

Project costs should be discounted if they are incurred after the first project year. Costs are discounted according to the following formula:

$$PV = C \,/\, (1{+}r)\,(Y^{C} - Y^{0})$$

where PV = present value, C = cost, r = discount rate, Y^C = year of cost, and Y^0 = first year of cost.

After discounting, costs for all years should be summed to calculate the total present value cost.

The U.S. Office of Management and Budget (OMB) publishes the discount rates required for use in federal project evaluations. OMB currently requires a 7 percent discount rate for projects evaluated in real terms (USOMB 2005). A discount rate of 7 percent would be appropriate to use with a government-funded project; a higher discount rate should be used if the project is privately funded.

Table 11-6 gives a hypothetical example of discounting costs for two management practices, in which MP 1 is $2,000 more expensive to construct than MP 2. Over 20 years, the present value of maintenance costs for MP 1 is $2,000 less expensive than that of MP 2. When construction and maintenance are considered together, MP 1 is about $100 less expensive than MP 2. Although MP 1 is the more expensive management practice to construct, the present value calculation shows that it is the less expensive management practice when construction and maintenance are considered.

Table 11-6. Example of Discounting Management Practice Cost for Comparison Purposes

Management Practice	Construction Cost	Annual Maintenance	Present Value of Maintenance Costs over 20 Years, r = 7%	Total Present Value of Costs
MP 1	$12,000	$300	$3,178	$15,178
MP 2	$10,000	$500	$5,297	$15,297

11.4.2 Compare Costs and Effectiveness of Management Practices

Choosing the most beneficial management practices for your watershed involves comparing the costs and pollution reductions of the available options. At a minimum, you should compare the total costs and effectiveness of the management practices. First, compare the total benefits and determine which management practices achieve the goals of your project. Then, compare the total costs of the management practices that achieve your goals and determine which ones are the least expensive. If you wish to prioritize further, calculate a cost-effectiveness ratio to determine which management practice is the most cost-effective for achieving your goals.

Buffer$: A Conservation Buffer Economic Tool

Buffer$, a Microsoft Excel-based tool, can be used to analyze the cost benefits of buffers compared to those of traditional crops. To download the tool, visit **www.unl.edu/nac/conservation** (right click on the picture and click "save target as"; the file size is 6.0 Mb, so it might take a while to download). To request a CD with the tool, contact Gary Bentrup at **gbentrup@fs.fed.us**.

The following example illustrates how a cost-effectiveness ratio can be calculated. Assume that you're proposing a treatment train of bioretention cells draining to an extended dry detention pond for a residential development. The total present value cost of the management practice construction, operation, and maintenance is about $200,000. The estimated annual reduction in total phosphorus load is 7 pounds per year. Assuming a project lifetime of 20 years, the total reduction in phosphorus load would be 7 lb × 20, or 140 lb. The cost per pound of phosphorus removed is $200,000 divided by 140, or about $1,430. In this example, the pounds of phosphorus removed are not discounted over the project lifetime. If you are comparing practices with differing benefits over time, you might consider discounting pollution load reduction and other nonmonetary benefits as prescribed by OMB (USOMB 2005).

You can determine which options are the most cost-effective by comparing the cost- effectiveness ratios of your management options. The management option with the lowest cost-effectiveness ratio provides the most benefit for the least dollars spent. However, you also need to evaluate whether the most cost-effective options are adequate to meet your management goals. Sometimes you need to select less cost-effective options because they represent the only way to achieve the required load reductions or other specific goals. For example, in a watershed targeted for sediment reduction that has significant sediment contribution from eroding banks, more expensive structural stream restoration might be the only way to achieve the necessary reduction; more cost-effective upland management practices might not be able to achieve targets by themselves.

The examples above assume that you're comparing management options for one type of development or condition. Comparing costs and benefits is also useful when targeting management practices across different types of land uses. Figure 11-7 compares the costs and pollutant loadings across 14 types of developments; the percentage on the horizontal axis refers to the average percentage imperviousness of the developments. A simplified spreadsheet, SET, was used in this example to estimate the pollutant loading with and without management practices, and each management practice treatment train achieved 70 percent phosphorus removal. The figure shows that developments with a higher percentage of impervious area can cost substantially more to treat than developments with lower levels of imperviousness.

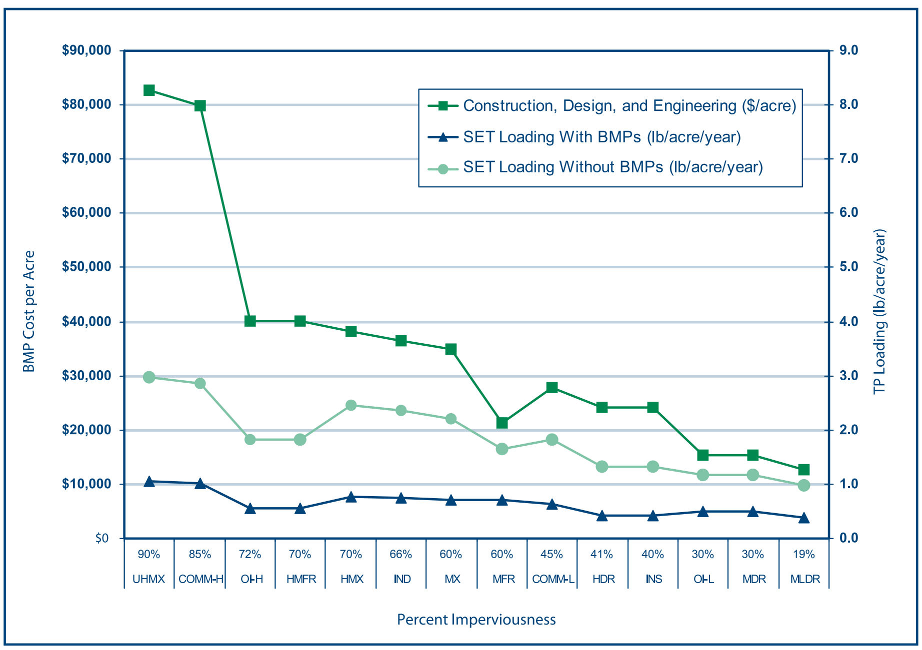


Figure 11-7. Example Comparing Construction Cost and Pollutant Loading for Different Urban Land Use Types with Decreasing Levels of Imperviousness

Figure 11-8 compares the management practice construction cost per acre with the cost per pound of total phosphorus removed. At below 70 percent imperviousness, the cost-effectiveness ratio is fairly constant for the developments, but above that level the cost-effectiveness ratio increases substantially. In this situation, you should consider how much impact the developments with high imperviousness have on the water quality of your watershed. You might find that these land uses are a small percentage of your watershed and that a less-expensive treatment option for these land uses could achieve your watershed-wide water quality objectives. When certain land uses are found to be the least cost-effective, stakeholders can be consulted to determine the importance of treating all land uses versus saving on costs. Beyond cost-effectiveness, stakeholders might be concerned about localized impacts on water quality from highly impervious developments.

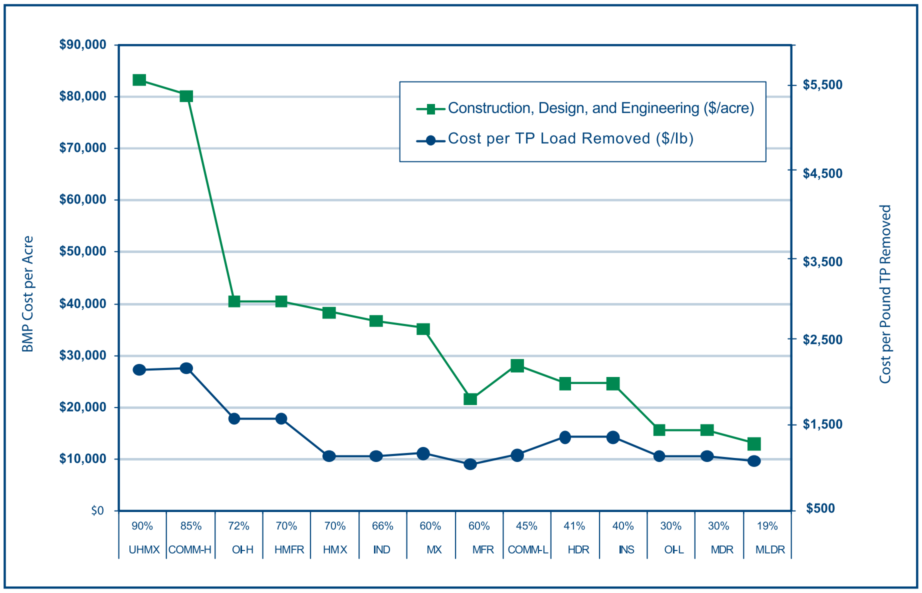


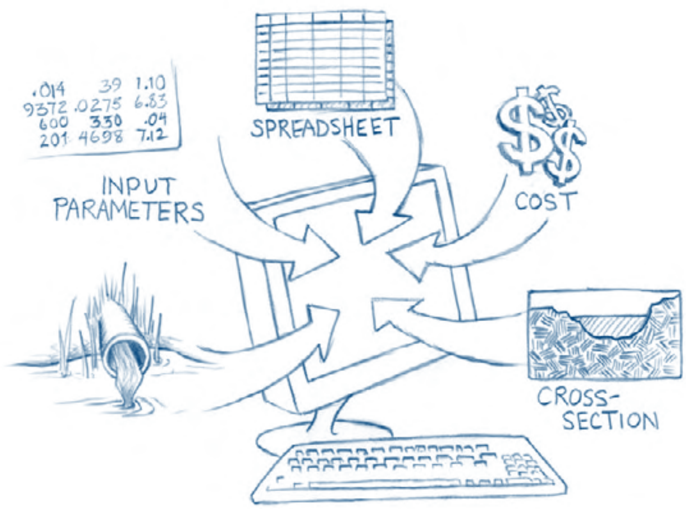
Figure 11-8. Example Showing Increased Cost per Pound of Total Phosphorus Removed for Urban Land Uses with Highest Levels of Imperviousness

When used in combination with an assessment of the project objectives and stakeholder concerns, a comparison of costs and benefits can be useful in management decisionmaking. The examples and strategies outlined above do not cover all the possible watershed conditions and issues to be considered. With each project, look at the situation critically and ensure that you've covered the most important factors before making a decision on management practices.

11.5 Select Final Management Strategies

The process of narrowing down possible management options involves ultimately matching the best candidate practices to your needs.

When you screened management options (chapter 10), you used worksheets to summarize promising alternatives, noting potential pollutant removal efficiencies, identifying constraints in using the practice, and so forth. In this chapter, you've refined those worksheets, quantified estimates of the total potential pollutant removal, and identified which combinations of management practices meet your load reduction or hydrology targets. You've also



estimated costs for these different watershed management strategies (or different combinations of management practices). Now it's time to pull together information from the environmental and cost analysis and select the preferred strategies.

11.5.1 Decision Process

In general, you'll work through a process using established decision criteria to identify the management strategies that are most likely to succeed. The process is likely to follow some variation of the following steps:

- Develop decision criteria.
- Summarize evaluation results and present to stakeholders.
- Obtain feedback from stakeholders.
- Rank preferences and select management strategy(ies).

Develop Decision Criteria

In such watershed planning efforts, you should address not only the state or local water quality or hydrology targets but also such issues as

- Fiscal impact on local governments
- Cost to the development community
- Benefits that will be realized
- Overall regulatory feasibility of the strategy
- Compatibility with other local planning objectives and policies
- Overall political feasibility

Pulling together the "big picture" for watersheds is critical for those trying to select the preferred management strategies, but it can also be challenging. Most likely you'll select indicators and objectives that include both quantifiable indicators (Does it meet the target? How much will it cost the development community?) and more subjective indicators (Is it compatible with local policies? Is it politically feasible?).

Summarize Evaluation Results and Present to Stakeholders

Before meeting with the stakeholder committee, develop a summary chart that can convey the big-picture evaluation, noting which indicators you are able to quantify versus those which must be evaluated subjectively. Fill in the chart for the indicators you are able to quantify and evaluate (in absolute numbers or in relative percentages). For more subjective indicators, you can use a "straw man" or "blank slate" approach with the committee. The straw man approach involves conducting a preliminary evaluation (e.g., evaluating how compatible the differing strategies are with local planning policies) and presenting your evaluation to the committee for review, discussion, and final evaluation. The blank slate approach allows the committee to jointly or independently evaluate the criteria and develop a response. This evaluation could be conducted through a survey of committee members, deliberations of the committee, or both.

Obtain Feedback from Stakeholders

If stakeholders have concerns about a particular management strategy, determine whether there is information that is already available or could be readily obtained that would address their concerns. For example, if the stakeholders are not familiar with a particular management practice and are therefore hesitant to implement it, consider bringing in an extension agent familiar with the practice who can further educate concerned stakeholders about the practice and answer questions credibly. Perhaps increasing familiarity and confidence is all that will be required for the stakeholders to support the practice.

Stakeholders

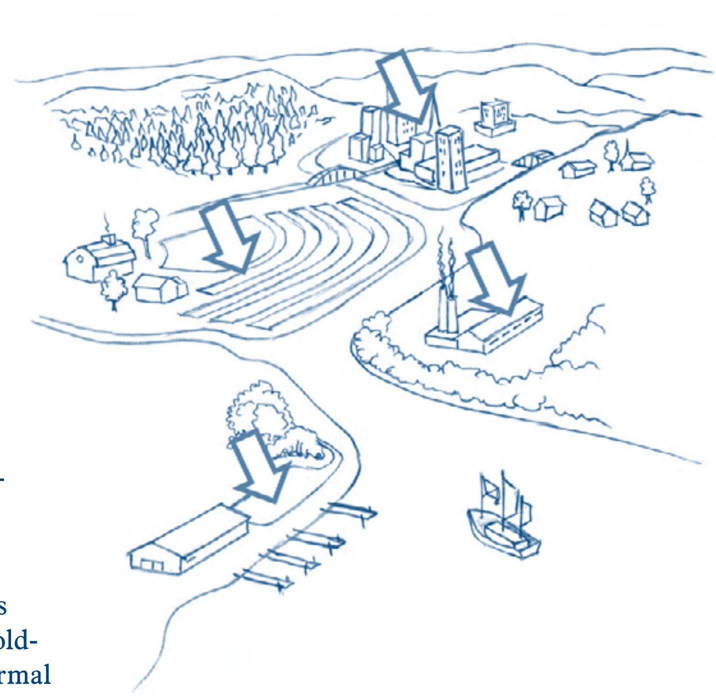
Refer to appendix A for additional resources concerning stakeholders.

Where cost feasibility is an issue, present information regarding cost-sharing sources or other funding options that might make implementation feasible. Consider accessing technical support from organizations like Cooperative Extension, NRCS, or other resource agencies or nonprofit organizations that can offer technical assistance or cost-sharing dollars. Always keep the end in view, reminding those around the table of the loading that you are trying to achieve and the load reduction needed. Then focus on the solutions—practices that landowners are willing to implement and can implement on their own or with assistance of agencies, nonprofit groups, or other stakeholders. The more that you ensure that initial questions and concerns are adequately addressed, the more buy-in you're likely to have when the time for implementation arrives.

Rank Preferences and Select Final Strategies

The process for selecting preferred strategies can be very straightforward if you have a small watershed with a limited number of landowners and a limited number of problems or issues to resolve. Cost-effective choices might be quite clear, and there might not be many other issues to work through.

In a small watershed or a watershed with a limited number of landowners and parameters of concern, your management practice worksheets can be used as the basis for evaluating management strategies and making a final selection. The task might be as simple as sharing the information regarding the effectiveness and cost of the different practices with the landowners, explaining how practices could be combined in complementary ways to address the problem, and then discussing which management practices they would be willing and able to implement. Discussions about feasible options also need to address a reasonable timetable for implementing the options.



A more complex process is often needed when managing larger watersheds or small watersheds with multiple issues and a broader set of stakeholders. In such cases it can be helpful to develop formal criteria and methods for ranking stakeholder preferences to support final decisions on selection. These formal methods can include weighting some criteria as more important than others to best represent stakeholder preferences. In addition, it might not always be necessary for stakeholders to agree on exactly the same practices; if different stakeholders are willing to implement separate practices that still achieve the objectives, there is no reason to force a single ranking or preference.

The degree to which you feel the need to formally rank the candidate strategies will depend on the circumstances. You can use a ranking process similar to the one you conducted in section 10.3.8. The ranking factors and assumptions will change, however.

In reality, there are many more ways you can use to rank and select management practices than can possibly be covered here. The following section provides two examples in the range of options for selecting the preferred strategies.

11.5.2 Example Procedures for Selecting Final Management Strategies

The following two examples are provided to help illustrate the range of methods for selecting the preferred strategies. The first example represents a simple case in which a less formal process was used to select preferred practices; the second example includes a more formal process in which evaluation criteria and objectives were established and results were weighted before making final selections.

Muddy Creek Selects Final Strategies to Implement TMDL

Watershed planners in the Muddy Creek watershed went through a ranking process to select management practices to implement their portion of the Virgin River Total Maximum Daily Load (TMDL). Table 11-7 lists the management techniques evaluated. Note that each is categorized by the level of engineering intensity. A separate worksheet was developed for each technique during the screening and then refined during the evaluation process. Table 11-8 lists the final selection of management practices that the landowners plan to use to meet the load reduction requirement, along with the estimated load reduction of the practices and a timeline for implementation.

Table 11-7. Selected Management Techniques for the Muddy Creek Subwatershed, Virgin River TMDL Implementation

Level A Management Changes	1	Rotational grazing
	2	Seasonal grazing
	3	No-till farming techniques
Level B Management Practices and Altruistic Techniques	1	Installation of cross-fencing
	2	Use of sprinkler irrigation system
	3	Decreased water usage
Level C Mild Engineering	1	Stream grade stabilization structures
	2	Revegetation of streambanks
	3	Replacement of open ditches and diversions with piped systems
Level D Moderate Engineering	1	Installation of stream barbs
	2	Installation of weirs
	3	Stabilization of road cuts
Level E Intensive Engineering	1	Slope stabilization
	2	Change in meander and profile of stream sections

Table 11-8. Summary of Load Reduction Requirements and Expected Removal Efficiencies for Selected Management Practices for Muddy Creek Subwatershed

TMDL Target Values	Total Dissolved Solids (lb/day)	Implementation Technique(s)	Estimated Percent Load Reduction (%)	Timeline for Implementation Reductions (mo)
Overall load allocation	12,320	A1	4	4–12
		B2	8	6–12
		B3	8	6–12
Current measured load	20,550	C1	10	9–24
		C2	15	36–120
		C3	15	12–36
Overall required load reduction	8,230	D2	20	24–48
		E1	20	24–48

Town of Cary, North Carolina, Selects Final Strategies to Manage Stormwater Runoff

The Town of Cary used a summary chart to evaluate different options and criteria for managing future stormwater runoff from its Town Center area. The town had adopted a redevelopment plan that encouraged urban redevelopment along a planned rail corridor in the Town Center and the use of smart growth principles. However, the planned redevelopment needed to meet a number of stormwater management regulations, including an existing nutrient TMDL and drinking water supply protection regulations and pending National Pollutant Discharge Elimination System (NPDES) Phase II stormwater requirements.

At the *beginning* of the planning process, the stakeholder committee was instrumental in developing and adopting the evaluation criteria in the box at right for different management options. Easily understood consumer report symbols were then used to convey how well each option met the evaluation criteria (figure 11-9). The options being compared by Cary included onsite stormwater water quality and volume/peak detention controls, an off-site shared facility (e.g., constructed wetlands) for local control, regional controls to meet volume and water quality performance standards, and combinations, including a buy-down allowance for achieving nitrogen reductions.

When presenting and discussing the results of the evaluation of management options, the stakeholder committee prioritized two of the criteria:

1. Meets state Nutrient-Sensitive Water TMDL and Phase II requirements
2. Supports the Town Center Area Plan and preferred growth areas

Criteria Used to Evaluate Management Options

State Regulations

- Meets state Nutrient-Sensitive Water TMDL and Phase II requirements
- More protective than state regulations
- Comparable to existing Swift Creek watershed drinking water supply protection rules
- Regulatory feasibility

Town Plans and Policies

- Supports Town Center Area Plan and preferred growth areas
- Provides adequate infrastructure
- Preserves and protects natural resources
- Encourages attractive development

Fiscal Impact

- Cost-effectiveness in meeting targets

Overall Feasibility

Although the other criteria were important in the evaluation, these two became the most important in selecting the preferred management option. Therefore, option 1 was selected as the final management strategy (figure 11-9).

Now that you've selected the recommended management strategy that will meet the objectives of your program, the more detailed implementation planning can begin. In the next chapter implementation plans, schedules, and funding are discussed in more detail.

Criteria	Meets State TMDL	More Restrictive than State TMDL			
	Option 1 On-site/ Shared	Option 2 On-site/ Shared	Option 3 Regional Volume, TSS, TN	Option 4 Regional Volume, TSS, N Buy-Down	Option 5 On-site/ Shared Water Quality Control; Regional Volume
State Regulations					
Meets State Nutrient-Sensitive Water and Phase II Requirements—*High Priority*	●	●	◗	◗	◗
More Protective than State Regulations	—	●	—	—	◗
Swift Creek Watershed: Comparable to Existing Swift Creek Land Management Plan	●	●	●	●	●
Regulatory Feasibility	●	●	◗	◗	◗
Town Plans and Policies					
Supports Town Center Area Plan (Urban Form/ Preferred Growth Areas)—*High Priority*	●	—	◗	◗	—
Provides Adequate Infrastructure	●	●	●	●	●
Preserves/Protects Natural Resources	●	●	◗	◗	●
Encourages Attractive Development	●	●	◗	◗	●
Fiscal Impact					
Cost-Effectiveness of Mitigation Target	●	●	◗	◗	●
Overall Feasibility (Counts ●/◗/—)	8/0/1	7/1/1	2/6/1	2/6/1	5/3/1
Percent that Option Meets Criteria	90%	85%	55%	55%	72%
Meets Both High-Priority Criteria	Yes	No	No	No	No

● Meets Criteria ◗ Partially Meets Criteria — Does Not Meet Criteria

Figure 11-9. Evaluation of Stormwater Management Options for the Town of Cary

12. Design Implementation Program and Assemble Watershed Plan

Chapter Highlights

- Information/education component
- Schedule for implementation
- Milestones
- Criteria to measure progress
- Monitoring component
- Financial and technical resources needed
- Evaluation framework
- Assembling watershed plan

Read this chapter if...

- You want to integrate information and education components into your watershed plan
- You want to know how to develop the implementation component of your watershed plan
- You want to develop a schedule, milestones, criteria for measuring progress, and a monitoring plan
- You would like information on finding sources to help you implement your plan
- You want to know how to set up an evaluation framework for your watershed plan

12.1 What Do I Need to Design My Implementation Program?

Now that you've identified watershed management measures that when implemented should meet your objectives, it's time to develop the remaining elements of your implementation program. Designing the implementation program generates several of the basic elements needed for effective watershed plans:

- An information/education (I/E) component to support public participation and build management capacity related to adopted management measures
- A schedule for implementing management measures
- Interim milestones to determine whether management measures are being implemented
- Criteria by which to measure progress toward reducing pollutant loads and meeting watershed goals
- A monitoring component to evaluate the effectiveness of implementation efforts
- An estimate of the technical and financial resources and authorities needed to implement the plan
- An evaluation framework

12.2 Develop Information/Education Component

Every watershed plan should include an I/E component that involves the watershed community. Because many water quality problems result from individual actions and the solutions are often voluntary practices, effective public involvement and participation promote the adoption of management practices, help to ensure the sustainability of the watershed management plan, and perhaps most important, encourage changes in behavior that will help to achieve your overall watershed goals.

9 This phase of the watershed planning process should result in element *e* of the nine elements for awarding section 319 grants. Element *e* is "*An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.*"

12.2.1 Integrate I/E Activities into the Overall Watershed Implementation Program

Where to Go for More Help on I/E Activities

For more information on planning and implementing outreach campaigns, refer to EPA's Getting in Step: A Guide for Conducting Watershed Outreach Campaigns. This comprehensive guide will walk you through the six critical steps of outreach—defining your goals and objectives, identifying your target audience, developing appropriate messages, selecting materials and activities, distributing the messages, and conducting evaluation at each step of the way. You can download the guide at **www.epa.gov/owow/watershed/outreach/documents/getnstep.pdf** or order it by calling 1-800-490-9198. Ask for publication number EPA 841-B-03-002.

The objectives of the public outreach program should directly support your watershed management goals and implementation of the watershed management plan. For example, the overall goal for your watershed plan might be to restore water quality to Brooker Creek, which has been badly degraded due to nutrient inputs from fertilizers. To help meet that goal, you might develop a public participation program that will "*make residents aware of proper fertilizer use to reduce application rates*." The I/E components identified should include measurable objectives and indicators for measuring progress. The objectives will also be shaped by the size of the community and the resources available to support efforts.

You can develop a separate public outreach component in your watershed plan that provides the foundation of your I/E activities, but be sure to include the specific tasks, costs of implementation, and responsible parties in the overall implementation matrix.

12.2.2 Develop an I/E Program

Although it's important to let people know about the water quality problems in the watershed, sometimes simply informing and educating people on the issues is not enough to initiate behavior change. Behavior change occurs over time. First, audiences should be made aware of the issue or problem. Then they should be educated on the problems facing the watershed. Finally, they should know what actions they can take to help address those problems.

To develop an effective I/E program, you should follow these six steps:

1. Define I/E goals and objectives.
2. Identify and analyze the target audiences.
3. Create the messages for each audience.
4. Package the messages for various audiences.
5. Distribute the messages.
6. Evaluate the I/E program.

The activities that occur in each of these steps are briefly summarized below.

Step 1: Define I/E Goals and Objectives

In developing an I/E component, you should identify I/E goals for the watershed plan implementation program. Start with the driving forces that you outlined at the beginning of the watershed planning effort in chapter 4. This will help set the foundation for, and focus, your I/E activities.

The outreach goals and objectives will reinforce the overall watershed goals and objectives and should be specific, measurable, action-oriented, and time-focused. Keep the desired outcome in mind when developing your objectives. Do you want to create awareness, provide information, or encourage action among your target audience? It's very important to make your objectives as specific as possible and to include a time element as well as a result. This approach will make it easier to identify specific tasks and will enable you to evaluate whether you've achieved the objectives.

Don't Reinvent the Wheel

EPA has developed a "Nonpoint Source Outreach Digital Toolbox," which provides information, tools, and a catalog of more than 700 outreach materials that state and local agencies and organizations can use to launch their own nonpoint source pollution outreach campaign. The toolbox focuses on six nonpoint source categories: stormwater, household hazardous waste, septic systems, lawn care, pet care, and automotive care, with messages geared to urban and suburban residents. Outreach products include mass-media materials, such as print ads, radio and television public service announcements, and a variety of materials for billboards, signage, kiosks, posters, movie theater slides, brochures, factsheets, and everyday object giveaways that help to raise awareness and promote non-polluting behaviors. Permission-to-use information is included for outreach products, which makes it easy to tailor them to local priorities. Evaluations of several outreach campaigns also offer real-world examples of what works best in terms of messages, communication styles, formats, and delivery methods. The toolbox is available online and as a CD at **www.epa.gov/nps/toolbox/**.

Objectives Will Change

As you progress through implementation, your outreach objectives and activities will evolve. For example, during the early stages it might be necessary to generate basic awareness of watershed issues, but as problems are identified during watershed characterization your objectives will focus on educating your target audiences on the causes of the problems. Next, your objectives will focus on actions your target audience can take to reduce or prevent adverse water quality impacts. Finally, your objectives will focus on reporting progress.

Step 2: Identify and Analyze the Target Audience

Next, you should identify the audiences you need to reach to meet your objectives. The target audience is the group of people you want to reach with your message. You should break down your target audience into smaller segments using demographics, location, occupation, watershed role, and other factors. If your target audience is too broad, chances are you won't be able to develop a message that engages and resonates with the entire audience. Be creative in defining and developing perspectives on your target audiences and in finding out what makes them tick.

Step 3: Create the Message

After gathering information on members of the target audience, you're ready to craft a message that will engage them and help achieve your watershed planning objectives. To be effective, the message must be understood by the target audience and appeal to people on their own terms. The message should articulate what actions the audience should take. These actions might include letting vegetation grow taller along a stream, pumping septic tanks, or conducting soil tests before fertilizing lawns. The actions should tie directly back to the goals of the watershed plan because one of the goals of your I/E program will be to help implement the watershed plan. In addition, your message should be clear, specific, and tied directly to something the target audience values, such as

- Money savings
- Time savings
- Convenience
- Health improvements
- Efficiency
- Enhancing public values
- Improving ecosystem function
- Enhancing quality of life and environmental amenities
- Economic development benefits

Step 4: Package the Message

Now it's time to determine the best package or format for the message for eventual delivery to the target audience. The information you collected in Step 2 while researching the audience will help to determine the most appropriate format. When selecting your message format, think about where the target audience gets its information. A farming community might respond more positively to door-to-door visits or articles in farm publications than to an Internet and e-mail campaign.

Work with the Media

If your message needs to be understood and embraced by the public, it should be covered by the mass media. The media can be a very cost-effective and efficient way to get your message delivered. Formats using the mass media can be broken down into two major categories—news coverage and advertising. News coverage includes interviews, news stories, letters

Lake Champlain Wins Award for TV Spots

In the Lake Champlain Basin, a cooperative venture between the Lake Champlain Basin Program and a local TV station produced weekly spots on the evening news between May 1999 and September 2004 that provided an in-depth look at many of the important environmental issues surrounding the lake, its basin, and restoration efforts. Periodic half-hour special reports showed compilations of these spots and provided videos as a resource for teachers and communities. The series won many awards, including awards from EPA and the North American Lake Management Society.

www.lcbp.org/

to the editor, and event coverage. Advertising includes the development of public service announcements (PSAs). Publicity generated from news coverage is dependent on the news organization, whereas you create radio, TV, and newspaper advertising yourself. In many cases the advertising you do can be leveraged later into news coverage. For example, one state bought informational ads on agriculture-related water quality issues from a radio station and received as a benefit some free news coverage of the issues during the year.

Develop Effective Print Materials

By far the most popular format for outreach campaigns is print. Printed materials include fact sheets, brochures, flyers, booklets, posters, bus placards, billboards, and doorknob hangers. These materials can be created easily, and the target audience can refer to them again and again. The Texas Commission on Environmental Quality (TCEQ) launched a nonpoint source outreach campaign in 2001 that targeted watersheds with water quality problems where the causes were known. In watersheds where pet waste was identified as contributing to these problems, TCEQ developed a full-color billboard display of a dog with the message, "Please pick up my poop." The billboards served as prompts to encourage behavior change. For more information, visit **www.tceq.state.tx.us/assistance/education/nps.html**.

Hold Events

Also consider using activities to spread your message. A watershed event can be one of the most energizing formats for distributing messages targeted at awareness, education, or direct action. A community event plays into the desire of audience members to belong to a group and have shared goals and visions for the community. In urban areas, where knowing your neighbors and other members of your community is the exception rather than the rule, community events can help to strengthen the fabric of the community by creating and enhancing community relationships, building trust, and improving the relationships between government agencies and the public. And if such events are done well, they're just plain fun.

Neighbors Help Spread the Word on Water Stewardship

The Livable Neighborhood Water Stewardship Program in Falls Church, Virginia, fulfilled community members' desire to take part in watershed protection activities at the neighborhood level. Volunteer leaders recruited their neighbors to form household EcoTeams to help each other become better water stewards. The teams adopted behaviors such as creating a rain garden and reducing the use of household chemicals. The team aspect provided the motivation to carry out the actions while establishing relationships that helped create a more livable neighborhood. Studies show that such community activities are successful in sustaining significant behavior change. Go to **www.empowermentinstitute.net/files/WSP.html** for more information on this program.

Leverage Resources

If resources are limited and the message is fairly focused, try to piggyback onto an existing event that involves the target audience. Trade shows and other events for farmers, developers, boaters, fishers, the automobile industry, and other groups can often be accessed with a little research and a few phone calls. As in all outreach, you can't deliver a message to the target audience if you don't have access to it. Approaches for generating interest and attention are limited only by your creativity. Watershed groups have used bands, balloons, face-painting, mascots, interactive displays, video games, giveaways, clowns, jugglers, and celebrities to draw crowds. You can also increase the exposure of your event by inviting local TV and radio stations to cover it.

Step 5: Distribute the Message

Once the message has been packaged in the desired format, you can proceed with distribution. Fortunately, you've already considered distribution mechanisms somewhat while researching the target audience and selecting a format. Common means of distribution are by direct mail, door-to-door, by phone, through targeted businesses, during presentations, as hand-outs at events, through media outlets, and by posting your message in public places. Consider which distribution method(s) is best for your community. Local governments, for example, might choose to add inserts to utility bills, whereas local community groups might prefer door-to-door visits. One of the ways the City of Fresno, California, distributed its stormwater pollution prevention message was through placemats at area fast food restaurants. Be creative in your distribution mechanisms.

In addition to *how* you're going to deliver the message, you should decide *who* will deliver the message. Analyzing the target audience can help you to identify the most trusted members of the community. An organization trusted by the public can use a staff representative of its own. If the organization is a government agency, having a member of the target audience deliver the message might be more effective.

Example I/E Indicators

Programmatic

- Number of newspaper stories printed
- Number of people educated/trained
- Number of public meetings held
- Number of volunteers attending activities
- Number of storm drains stenciled

Social

- Number of calls to hotline
- Number of people surveyed with increased knowledge of watershed issues
- Number of people surveyed with changes in behavior
- Participation at watershed events
- Number of trained volunteer monitors

Environmental

- Number of gallons of used paint collected
- Number of people who purchased rain barrels
- Pounds of trash collected on stream cleanup days
- Number of pet waste bags taken at kiosks
- Pounds of yard waste collected

In Grapevine, Texas, the "Conservation Cowboy" conducts numerous visits throughout the year within the community to promote environmental responsibility and nonpoint source pollution prevention. The Conservation Cowboy has been a huge hit with children and has become an effective environmental education messenger.

Remember to use your watershed stakeholder group to help distribute the message. The group already has a vested interest in the success of the watershed plan and will help you distribute educational materials to the watershed community—perhaps through in-kind support like helping to erect watershed road signs, or through financial or technical support to cover printing costs or conduct presentations at community meetings. Members of your stakeholder group will be trusted, respected members of the watershed community and will make it easy to spread the word.

Step 6: Evaluate the I/E Program

Evaluation provides a feedback mechanism for ongoing improvement of your outreach effort. Many people don't think about how they'll evaluate the success of their I/E program until after the program has been implemented. Building an evaluation component into the plan from the beginning, however, will ensure that at least some accurate feedback on outreach program impact is generated. Ideally, feedback generated during the early stages of the project will be used immediately in making preliminary determinations about program effectiveness. Adapting elements of the I/E effort continually as new information is received ensures that ineffective components are adjusted or scrapped while components that are working are supported and enhanced. Go back to chapter 4 (section 4.6) to review the suite of potential indicators you can use to measure the effectiveness of your I/E program. Appendix A provides additional information on developing outreach programs.

12.3 Establish an Implementation Schedule

9 This phase of the watershed planning process should result in element *f* of the nine elements for awarding section 319 grants. Element *f* is a "*Schedule for implementing the nonpoint source management measures identified in the plan that is reasonably expeditious.*"

The schedule component of a watershed plan involves turning goals and objectives into specific tasks. The schedule should include a timeline of when each phase of the step will be implemented and accomplished, as well as the agency/organization responsible for implementing the activity. In addition, your schedule should be broken down into increments that you can reasonably track and review. For example, the time frame for implementing tasks can be divided into quarters. You will prepare more detailed schedules as part of your annual work plans (see section 13.4).

In developing schedules, it helps to obtain the input of those who have had previous experience in applying the recommended actions. Locate experienced resource agency staff and previous management practice project managers where possible to identify the key steps. Be sure to note sequence or timing issues that need to be coordinated to keep tasks on track.

12.4 Develop Interim Measurable Milestones

One means of supporting detailed scheduling and task tracking is to identify interim, measurable milestones for determining whether management practices or other control actions are being implemented. What do you want to accomplish by when? It usually helps to think of milestones in terms of relevant time scales. For example,

- Short-term (1 to 2 years)
- Mid-term (2 to 5 years)
- Long-term (5 to 10 years or longer)

9 This phase of the watershed planning process should result in element *g* of the nine elements for awarding section 319 grants. Element *g* is "*A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.*"

It's also helpful to think of the milestones as subtasks, or what needs to be accomplished over time to fully implement the practice or management measure. When determining time scales and subtasks for actions, place the milestones in the context of the implementation strategy. Given the selected practices and the available funds or time frame for obtaining grants, estimate what can be accomplished by when. First, outline the subtasks involved and the level of effort associated with each to establish a baseline for time estimates. Next, identify the responsible parties associated with the steps so that you can collectively discuss milestones and identify those which are feasible and supported by the people that will do the work.

Example Milestones

Short-Term (< 2 years)

- Achieve 5 percent reduction in sediment load on 1,000 acres of agricultural land in the Cross Creek subwatershed by implementing rotational grazing practices.
- Eliminate direct sources of organic waste, nutrients, and fecal coliform bacteria to the stream by installing 5,000 feet of fencing to exclude direct access to cattle along Cross Creek.

Mid-Term (< 5 years)

- Reduce streambank erosion and sediment loading rate by 15 percent by reestablishing vegetation along 3,600 feet of Cross Creek.

Long-Term (5 years or longer)

- Achieve the fecal coliform water quality standard in the upper section of Cross Creek above Highway 64.

It's important to consider economic, social, and environmental factors. When selecting a milestone, make sure that it is specific, measurable, achievable, relevant to a nonpoint source management measure, and time-sensitive.

You should also consider staff availability and funding resources and how the milestones will be evaluated. For example, will progress toward a milestone be determined through monitoring, spot-checking, participation, adoption of management practices, or some other methods? Answering this question will enable you to allocate and plan for resources and easily determine whether a milestone has been met. It would be difficult to set a milestone at "installing 30 miles of buffer strips within 2 years" if no staff were available to measure the miles of buffer strips installed. Resources should be targeted toward the highest-priority milestones.

Finally, your plan should also provide a description of what will be done if the milestones are not being achieved or how your program will take advantage of milestones being achieved in a significantly shorter time frame than expected.

12.5 Establish a Set of Criteria to Measure Progress toward Meeting Water Quality Standards and Other Goals

As part of your implementation program, you should set some criteria by which to determine whether you are achieving load reductions over time and making progress toward meeting your overall watershed goals. These criteria can also support an adaptive management approach by providing mechanisms by which to reevaluate implementation plans if you're not making substantial progress toward meeting your watershed goals.

9 This phase of the watershed planning process should result in element *h* of the nine elements for awarding section 319 grants. Element *h* is "*A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards*."

These criteria can be expressed as indicators and associated interim target values. You can use various indicators to help measure progress (chapter 4). You'll want to select indicators that will provide quantitative measurements of progress toward meeting the goals and can be easily communicated to various audiences. It's important to remember that these indicators and associated interim targets will serve as a trigger, in that if the criteria indicate that you are not making substantial progress, you should consider changing your implementation approach.

The indicators might reflect a water quality condition that can be measured (dissolved oxygen, nitrogen, total suspended solids) or an action-related achievement that can be measured (pounds of trash removed, number of volunteers at the stream cleanup, length of stream corridor revegetated). In other words, the criteria are interim targets in the watershed plan, such as completing certain subtasks that would result in overall pollutant reduction targets. Be careful to distinguish between programmatic indicators that are related to the implementation of your work plan, such as workshops held or brochures mailed, and environmental indicators used to measure progress toward water quality goals, such as phosphorus concentrations or sediment loadings.

The indicators and interim target values you select should reflect the performance of the management measures being implemented, the concerns identified early in the process by stakeholders, and the refined goals that were outlined (chapter 9). Because of the confounding, dynamic conditions that occur in a watershed, you should be careful how you interpret these indicators once implementation begins. For example, if you've selected turbidity as an indicator for measuring sediment load reductions and the turbidity value actually increases after installation of management practices, does this mean you're not making improvements in the watershed? You should determine whether additional activities, such as new development activities, are contributing additional loads that you didn't consider. You also should realize that the land disturbance that installing management practice sometimes generates initially could create a short-term increase in sediment loadings. In addition, you might actually see a decrease in sediment loads while turbidity remains the same or increases due to increased biological production. Therefore, you also want to include long-term progress measurements such as reduced frequency of dredging as an indication of reduced sediment loads, or improved aquatic habitat as a result of reduced sediment loads. Table 12-1 demonstrates how you can use a suite of indicators to measure progress in reducing pollutant loads depending on the issues of concern.

Table 12-1. Example Indicators to Measure Progress in Reducing Pollutant

Issue	Suite of Indicators
Eutrophication	• Phosphorus load • Number of nuisance algae blooms • Transparency of waterbody or Secchi depth • Frequency of taste and odor problems in water supply • Hypolimnetic dissolved oxygen in a lake or reservoir • Soil test phosphorus in agricultural fields
Pathogens (related to recreational use)	• Bacteria counts • Compliance with water quality standards (single sample or geometric mean) • Number and duration of beach closings • Number of shellfish bed reopenings • Incidence of illness reported during recreation season
Sediment	• Total suspended solids concentration and load • Raw water quality at drinking water intake • Frequency and degree of dredging of agricultural ditches, impoundments, and water supply intake structures

There are various factors to consider before setting criteria, such as the implementation schedule of the management measures, the nature of the pollutants, and the time frame for applying the criteria.

12.5.1 Schedule for Implementation of Management Measures

Before developing any criteria to measure progress in reducing loads, you should review the schedule you've developed for implementing the proposed management measures. Obviously, you won't see any load reductions until the measures are installed. Check to see if the management measures are to be installed evenly over the duration of the plan or whether most practices are to be installed in the first few years of implementation. Often, long and uncertain lag times occur between implementation and response at the watershed level.

12.5.2 Nature of Pollutants to Be Controlled

The speed with which loads can be reduced also depends on the nature of the pollutants. Pathogens in animal waste, for example, tend to die off quickly in the environment, so response to a decrease in pathogen delivery to a waterbody might be noticed quickly. If direct deposition of waste in a stream by grazing livestock is the problem, fencing the animals away from the stream might cause nearly immediate reductions in pathogen levels in the water. Implementation of erosion controls, however, might show results more slowly as sediments already in the drainage network move through the system even as soil loss from cropland or construction sites is controlled. If runoff of soluble phosphorus due to excessive soil phosphorus levels is the problem, it might take years or even decades to demonstrate a measurable change in response to nutrient management as accumulated phosphorus is slowly depleted by crop harvests.

12.6 Develop a Monitoring Component

As part of developing your watershed plan, you should develop a monitoring component to track and evaluate the effectiveness of your implementation efforts using the criteria developed in the previous section.

This phase of the watershed planning process should result in element *i* of the nine elements for awarding section 319 grants. Element *i* is "*A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.*"

Monitoring programs can be designed to track progress in meeting load reduction goals and attaining water quality standards, but there are significant challenges to overcome. Clear communication between program and monitoring managers is important to specify monitoring objectives that, if achieved, will provide the data necessary to satisfy all relevant management objectives. The selection of monitoring designs, sites, parameters, and sampling frequencies should be driven by the agreed-upon monitoring objectives, although some compromises are usually necessary because of factors like site accessibility, sample preservation concerns, staffing, logistics, and costs. If compromises are made because of constraints, it's important to determine whether the monitoring objectives will still be met with the modified plan. There is always some uncertainty in monitoring efforts, but to knowingly implement a monitoring plan that is fairly certain to fail is a complete waste of time, effort, and resources. Because statistical analysis is usually critical to the interpretation of monitoring results, it's usually wise to consult a statistician during the design of a monitoring program.

Measurable progress is critical to ensuring continued support of watershed projects, and progress is best demonstrated with the use of monitoring data that accurately reflect water quality conditions relevant to the identified problems. All too frequently watershed managers rely on modeling projections or other indirect measures of success (e.g., implementation of management measures) to document achievement, and in some cases this approach can result in a backlash later when monitoring data show that actual progress does not match the projections based on surrogate information.

There is no doubt that good monitoring can be complex and expensive. Monitoring can be done at numerous levels; the most important criterion is that the monitoring component should be designed in concert with your objectives. If documenting the performance of particular management practices under seasonal conditions is important, a detailed and intensive water quality monitoring regime might be included. If your objective is to restore swimming at a beach previously closed, you might monitor progress by keeping track of the number of days the beach is open or the number of swimmers visiting the beach. If restoration of life in a stream is the objective, annual sampling of benthic invertebrates and fish might be included, or a count of anglers and a creel census could be useful. If another agency is already conducting monitoring (e.g., making annual measurements of phosphorus load or regulating shellfish beds based on bacteria counts), you might be able to use such ongoing monitoring to track your project's progress. In North Carolina, the Long Creek Watershed Project used the frequency of dredging at a water supply intake as a measure of the progress in controlling erosion in the watershed (Lombardo et al. 2004). Regardless of the specific objective, keep in mind that documental measures of progress toward your water quality goals are important.

Because of natural variability, one of the challenges in water quality monitoring is to be able to demonstrate a link between the implementation of management measures and water quality improvements. To facilitate being able to make this connection, the following elements should be considered when developing a monitoring program.

12.6.1 Directly Relate Monitoring Efforts to the Management Objectives

The data you collect should be directly related to the management objectives outlined in your watershed plan. Often data are collected for historical purposes, but the information is not used to help determine whether watershed plan objectives are being met. The monitoring component, which will be used to assess the effectiveness of implementation strategies, can also be used to address other important information needs in the watershed with minimal changes or additional resources. Consider a range of objectives like the following when developing your monitoring program:

- Analyze long-term trends.
- Document changes in management and pollutant source activities in the watershed.
- Measure performance of specific management practices or implementation sites.
- Calibrate or validate models.
- Fill data gaps in watershed characterization.
- Track compliance and enforcement in point sources.
- Provide data for educating and informing stakeholders.

When developing a monitoring design to meet your objectives, it's important to understand how the monitoring data will be used. Ask yourself questions like the following:

- What questions are we trying to answer?
- What assessment techniques will be used?
- What statistical power and precision are needed?
- Can we control for the effects of weather and other sources of variation?
- Will our monitoring design allow us to attribute changes in water quality to the implementation program?

The answers to these questions will help to determine the data quality objectives (DQOs) (section 6.4.2), that are critical to ensuring that the right data are collected. These DQOs also take into consideration practical constraints like budget, time, personnel, and reporting requirements and capabilities. Parameters measured, sampling locations, sampling and analysis methods, and sample frequency are determined accordingly. It's helpful to know the degree of measurement variability you might encounter for a given parameter method and watershed. If variability in a parameter concentration or value is relatively high because of natural or methodological causes, it will be difficult to identify actual improvements over time. You might need to collect more samples, consider different methods, make more careful site selections, select different parameters or indicators, or use a combination of approaches.

12.6.2 Incorporate Previous Sampling Designs

If you already developed a sampling plan as part of additional data collection efforts (↳ chapter 6), start with that plan to develop the implementation monitoring component. The plan, which was focused on immediate data needs, should have followed the key steps in the monitoring process (study design, field sampling, laboratory analysis, and data management). Most important, that additional data collection plan should have been developed with an eye toward supporting your long-term monitoring program. The data collected in that effort, along with other historical data, can be analyzed to evaluate the locations of hot-spots, the sampling frequencies necessary to adequately capture variability, and other parameters of a monitoring program. The sampling and analysis done during that phase can provide an evaluation of baseline conditions; continued monitoring under a similar program during and after implementation can be used to track trends in response to plan implementation.

Many of the specific elements developed as part of that effort, including DQOs, measurement quality objectives (MQOs), and a quality assurance project plan (QAPP), can be modified or expanded for this final monitoring component. ↳ Go back to section 6.4 to review the information and resources on the selection of sample design, field and lab protocols, and standard operating procedures.

12.6.3 Monitor Land Use Changes in Conjunction with Water Quality Monitoring

The monitoring component of your watershed plan should include not only water quality monitoring but also monitoring on the land, including the land treatments being implemented and the land use activities that contribute to nonpoint source loads. Land treatment tracking is important to determine whether the plan is being implemented appropriately and in a timely manner. At a minimum, you should track where and when practices were installed and became operational. But you should look beyond dollars spent or points on a map and consider how the measures are working. Structural practices like waste storage lagoons or sediment basins might be easy to see and count, but their associated management activities are more difficult to monitor. How have nitrogen and phosphorus applications changed under nutrient management? Are riparian buffers filtering sheet flow or is runoff channelized through the buffer area? Are contractors following erosion and sediment control plans?

Sometimes such questions can be answered only by asking the landowners. Some agricultural watershed projects have had success in asking farmers to keep records of tillage, manure and fertilizer application, harvest, and other management activities. Several Vermont projects, for example, used log books and regular interviews by local crop management consultants to gather such information (Meals 1990, 1992, 2001). In urban settings, public works staff can be valuable sources of information. Aerial photography and windshield or foot surveys are also useful (section 6.5.1). Remember to monitor not just where implementation is occurring but in all areas in the watershed that might contribute to nonpoint source loads.

A good land treatment/land use monitoring program will help you to

- Know when and where measures are implemented and operational
- Determine whether measures are working as planned and how much they have accomplished
- Get a handle on contributions of non-implementation areas to watershed nonpoint loads
- Prevent surprises

Surprises can derail the best watershed plan. An accidental release from a waste storage facility, a truck spill, land use changes, technology adoption, or the isolated actions of a single bad actor can have serious water quality consequences and, if the source is not documented, can cause you to question the effectiveness of your plan.

The result of a good land use/land treatment monitoring program is a database of independent variables that will help you explain changes in water quality down the road. The ability to attribute water quality changes to your implementation program or to other factors will be critical as you evaluate the effectiveness of the implementation effort and make midcourse plan corrections.

12.6.4 Use an Appropriate Experimental Design

You can choose from many different monitoring designs, such as paired watersheds, upstream-downstream monitored before, during, and after land treatment, and multiple-watershed monitoring (Clausen and Spooner 1993; Grabow et al. 1999a, 1999b). Your decision should be based on the pollutants of concern, the length of the monitoring program, the size of the study area, and the objectives of the monitoring program.

Loads can be measured at many levels of resolution; tributaries and watersheds commonly serve as the geographic unit for load estimation. Loads can also be measured for specific subwatersheds or sources, providing watershed managers with opportunities to track priority areas and determine whether funding is being directed efficiently to solve the water quality problems. The time frame for estimating loads should be selected to fit the watershed plan and the watershed of interest. For example, seasonal loads might be most relevant for nonpoint sources, whereas annual loads might be more appropriate in watersheds with fairly consistent wastewater treatment plant discharges. Because nonpoint source loads are subject to considerable variability due primarily to weather but also to source management, it is highly advantageous to use controlled studies (e.g., paired watersheds, upstream-downstream pairs before and after implementation) and covariates (e.g., flow) to aid in interpreting load patterns. See appendix A for resources on developing an effective monitoring program.

A **covariate** is a measurement of those variables that are not controllable by the researcher.

12.6.5 Conduct Monitoring for Several Years Before and After Implementation

To increase your chances of documenting water quality changes, you should conduct multiple years of monitoring both before and after implementing management measures. Year-to-year variability is often so large that at least 2 to 3 years each of pre- and post-management practice implementation monitoring might be necessary to document a significant water quality change following management practice implementation. Also, longer-duration monitoring might be necessary where water quality changes are likely to occur gradually. Sampling frequency and collection should be consistent across years.

12.6.6 Build In an Evaluation Process

When developing your monitoring program implementation strategy, plan for evaluation and reporting processes that will record change and provide the basis for appropriate modifications to the watershed plan. Link assessments and reporting formats back to the objectives by comparing monitoring results for the indicators to the criteria for judging progress toward milestones. ↳ For more information on developing monitoring programs, see results and recommendations of National NPS Monitoring Program projects at **www.bae.ncsu.edu/programs/extension/wqg/319index.htm**.

Often, monitoring programs should be modified as they are implemented. Flexibility is important in the implementation strategy so that staff can make minor refinements "on the fly." Significant adaptations also might need to be considered periodically by sponsors and decisionmakers (e.g., following review of an annual progress report). This applies to revisions to the QAPP as well.

12.7 Estimate Financial and Technical Assistance Needed and the Sources/Authorities that Will Be Relied on for Implementation

9 This phase of the monitoring process should result in element *d* of the nine elements for awarding section 319 grants. Element *d* is "*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.*"

A critical factor in turning your watershed plan into action is the ability to fund implementation. Funding might be needed for multiple activities, such as management practice installation, I/E activities, monitoring, and administrative support. In addition, you should document what types of technical assistance are needed to implement the plan and what resources or authorities will be relied on for implementation, in terms of both initial adoption and long-term operation and maintenance (O&M). For example, if you have identified adoption of local ordinances as a management tool to meet your water quality goals, you should involve the local authorities that are responsible for developing these ordinances.

The estimate of financial and technical assistance should take into account the following:

- Administration and management services, including salaries, regulatory fees, and supplies, as well as in-kind services efforts, such as the work of volunteers and the donation of facility use
- I/E efforts
- The installation, operation, and maintenance of management measures
- Monitoring, data analysis, and data management activities

Don't Forget the O&M Costs

Improper maintenance is one of the most common reasons for failure of water quality controls to function as designed. It's important to consider who will be responsible for maintaining permanent management practices, what equipment is required to perform the maintenance properly, and the long-term cost involved in maintaining structural controls.

12.7.1 Identify Funding Sources

You can access hundreds of funding sources to help fund the implementation of your watershed plan. These sources include federal, state, local, and private sources. Try to access several different funding sources so you don't put all of your eggs into one basket. The greatest challenge is identifying funding opportunities in an efficient manner. Several online tools can help narrow the places you need to look. For example, EPA has developed *Guidebook of Financial Tools: Paying for Sustainable Environmental Systems*, which is available for download at **www.epa.gov/efinpage/guidbkpdf.htm**. The guide was designed to enable watershed practitioners in the public and private sectors to find appropriate methods to pay for environmental protection efforts. It was developed by EPA's Environmental Financial Advisory Board and the Agency's network of university-based Environmental Finance Centers. More information on funding sources for watershed programs is posted at EPA's Sustainable Finance Web site at **www.epa.gov/owow/funding.html**.

Locating Federal Funding

For a complete list of federal funding, visit the *Catalog of Federal Domestic Assistance* (**www.cfda.gov**). This Web site provides access to a database of all federal programs available.

Also visit **www.epa.gov/watershedfunding** to view the *Catalog of Federal Funding Sources for Watershed Protection*. This interactive Web site helps match watershed project needs with funding sources.

12.7.2 Leverage Existing Resources

Some of the costs of implementing your watershed plan can be defrayed by leveraging existing efforts and seeking in-kind services. Some examples follow.

Use existing data sources. Most geographic areas have some associated background spatial data in the public domain, such as digital elevation models, stream coverages, water quality monitoring data, and land cover data in the form of imagery like orthophoto quads or raster satellite image files. Note that the EPA Quality System (**www.epa.gov/quality)** (EPAQA/G-5) recommends that a QAPP be prepared for the use of existing data, as well as for the collection of new data.

Use existing studies. Many agencies have reports of previous analyses, providing useful baseline information and data, such as delineated subwatersheds or a historical stream monitoring record. The analyses might have been done for another purpose, such as a study on fish health in a particular stream, but they can contribute to understanding the background of the current concerns.

Use partnerships. State, county, or federal agencies working as technical assistance providers and implementing natural resource program initiatives can offer computer services and expertise, such as performing GIS analysis or weaving together elements of different programs that might apply to the local area. They might be in a position to write part of the overall watershed plan if they have existing generalized watershed characterization studies.

Cover incidental/miscellaneous costs through contributions. For example, staff time to assemble needed elements, supplies, and meeting rooms for a stakeholder or scoping meeting can all be donated. As a start, refer back to the checklist you compiled from your stakeholder group in section 3.3.4 to determine what resources are available within the group.

Locating Private Funding

Visit **www.rivernetwork.org** for the *Directory of Funding Sources for Grassroots River and Watershed Conservation Groups*. It lists private and corporate sources, as well as federal sources. Note: This resource is for River Network members only

12.7.3 Estimating Costs

Many factors affect the cost of implementing management measures as part of a watershed plan, including the following:

- Type of management practice/restoration activity
- Installation costs
- Operation and maintenance costs
- Method of cost calculation
- Annual tasks and milestones that you establish (see the next sections)

Plan2Fund

Plan2Fund was developed by the Environmental Finance Center (EFC) at Boise State University to help organizations determine the amount of outside funding necessary to achieve the goals and objectives of their watershed management plan. The Plan2Fund tool leads organizations through the process of estimating implementation costs for their goals and objectives, evaluating local funding options, and finally identifying gaps in funding. With the output from Plan2Fund, users can then search EFC's Directory of Watershed Resources database for federal, state, and private funding sources based on identified funding needs. **http://sspa.boisestate.edu/efc/Tools_Services/Plan2Fund/plan2fund.htm**

Go back to section 11.5, where you researched cost considerations related to the proposed management measures. Some management measures might be more diffusely implemented across the watershed, and therefore the costs might be difficult to quantify. For example, developers across the watershed are encouraged to use fencing to prevent sediment runoff on their construction sites, and homeowners are encouraged through educational outreach to keep their neighborhood storm drains free of debris. These actions are voluntary, and therefore no specific operational costs are associated with them. However, costs would be associated with the I/E activities.

In refining the implementation plan to establish your overall financial and technical assistance needs, you should develop a more detailed estimate of the annualized cost of your actions. Table 12-2 provides annualized cost estimates for selected management practices from Chesapeake Bay installations.

Monitoring Program Costs

The cost of your monitoring program will depend on many factors, including the program design, the number and locations of sampling stations, the types and number of samples collected, the variables measured, staff and equipment required, local conditions, and others. Because these factors vary so much from watershed to watershed, it is impossible to establish general unit costs for monitoring activities. In building a monitoring budget for your program (or in putting together a grant application to support monitoring), you should consider costs in several common categories, which are described below.

Staffing

Consider how much staff time you'll need to carry out the activities necessary to conduct monitoring, including

1. Researching and selecting sampling sites
2. Installing and maintaining structures or instruments
3. Collecting samples and other field data
4. Delivering samples to the laboratory
5. Maintaining field data and other records

Table 12-2. Annualized Cost Estimates for Selected Management Practices from Chesapeake Bay[a]

Practice	Practice Life Span (Years)	Median Annual Cost[b] (EAC[c]) ($/ac/yr) (1990 dollars)	Median Annual Cost (EAC[c]) ($/ac/yr) (2002 dollars)
Terraces	10	84.53	116.35
Diversions	10	52.09	71.70
Sediment retention water control structures	10	89.22	122.81
Grassed filter strips	5	7.31	10.06
Cover crops	1	10.00	13.76
Permanent vegetative cover on critical areas	5	70.70	97.31
Reforestation of crop and pasture[d]	10	46.66	64.22
Grassed waterways[e]	10	1.00/lin ft/yr	1.38
Animal waste system[f]	10	3.76/ton/yr	5.18

[a] Median costs (1990 dollars) obtained from the Chesapeake Bay Program Office management practice tracking database and Chesapeake Bay Agreement Jurisdictions' unit data cost. Costs per acre are for acres benefited by the practice.

[b] Annualized management practice total cost, including operation and maintenance, planning, and technical assistance costs.

[c] EAC = equivalent annual cost: annualized total costs for the life span. Interest rate = 10%.

[d] Government incentive costs.

[e] Annualized unit cost per linear foot of constructed waterway.

[f] Units for animal waste are given as dollars per ton of manure treated.

Source: Camancho 1991.

Note that the relationship between the number of stations or samples and the staff requirement is not always linear; operating 20 stations might cost only 25 percent more in staff time than operating 10 stations. This is especially true if you are hiring full-time staff dedicated to a single project. Consider sharing staff with other activities if possible. Monitoring programs associated with a college or university can take advantage of graduate student efforts to provide some staff support.

Equipment

Sophisticated monitoring instrumentation like autosamplers, electronic flow recorders, and dataloggers can automate much of the monitoring program and offset some staffing resources. This might be a desirable approach in long-term, relatively intensive monitoring programs. However, such equipment is often expensive, has a steep learning curve, and sometimes has a greater risk of failure than manual sampling and measurement. The balance between high-tech, high-initial-expense equipment and more manual, labor-intensive approaches will depend on your available budget and monitoring design. Remember to consider power, shelter, and security requirements for expensive electronic equipment in your budget. If you decide to use electronic equipment, consider renting or purchasing used equipment rather than purchasing new equipment outright, especially for short-term projects.

Combine Forces to Share Costs

Twelve state and local Vermont entities facing Stormwater Phase II requirements formed the Chittenden County Regional Stormwater Education Program (RSEP). The RSEP focused on increasing awareness and changing behaviors through social marketing by hiring a local marketing firm to craft a communications and marketing strategy based on the results of a public stormwater awareness survey. Each entity provided $5,000 toward the development and implementation of the strategy. This approach was cost-effective for each entity and allowed for the development of a consistent message across the state. The RSEP paid $20,500 in message distribution through the media (newspaper, cable TV, and radio broadcasts) in the first year.

For more information, visit the RSEP Web site, **www.smartwaterways.org**.

Supplies

In estimating your monitoring costs, remember to account for sampling supplies like bottles, batteries, chemicals, labels, ice, shipping, and so forth, as well as supplies needed to tabulate and report data collected.

Logistics

Operating and maintaining a sampling network requires logistical support. The cost of travel between the project base and remote sampling locations must be considered. Be sure to include routine maintenance and field checks in mileage estimates, in addition to actual sampling runs. You might also need to factor in some additional costs to deal with difficult weather conditions like harsh winters or major storms.

Consider the sample handling and holding requirements for the variables you're monitoring. The cost of collecting, preserving, and transporting a sample for analysis of a variable with a 24-hour holding time might far exceed the costs associated with a variable with a 7-day holding time. Factor this into your decision on whether it's really necessary to measure soluble reactive phosphorus or whether total phosphorus analysis will meet your needs. Travel distance and time to deliver samples, as well as the lab's ability to accept certain kinds of samples on certain days, will affect costs, as well as your decisions on where to collect samples and what lab to chose. The lowest quoted per sample price might not adequately represent the total cost to your monitoring budget.

Laboratory

Analytical costs are relatively straightforward to estimate using direct price quotes from one or more laboratories. Be sure to discuss sample numbers and schedules at the start so that the lab can give you its best price. Remember to include your own field quality control samples in your estimates of total sample numbers for the lab.

Training

Your monitoring staff might need training in specialized monitoring techniques such as stream morphologic assessment or collection and identification of stream biota. Determine the costs (both tuition and travel) for any such training your staff will require in carrying out your monitoring program. Remember to budget for training for staff turnover that is likely to occur over the course of the monitoring program.

Data management

Hardware, software, or programming costs might be associated with storing and manipulating monitoring data. Budget for anticipated costs for statistical analysis or other data reporting that might be contracted out.

I/E Program Costs

Just as for other parts of the watershed plan implementation, you should determine roughly how much funding you'll need to implement your I/E program. I/E program costs are almost always higher than you expect, especially if you plan to use mass media formats like TV or radio PSAs. When planning your I/E budget, don't forget to include travel expenses, supplies (e.g., display booths, paper, storm drain stencil kits), giveaways, and vendor services such as printing and Web site registration. Also consider costs related to obtaining technical information to include in any educational materials developed. You might also incur costs associated with researching ways that your audience can protect water quality or consulting with professionals to obtain this information. You can keep costs down by teaming with universities, local civic organizations, or area businesses. You might also team with other localities or watershed organizations that face the same issues.

12.7.4 Identify Technical Assistance Needs

Technical assistance can take many forms. At the beginning stages of your watershed planning process, it might be collecting or compiling data on the watershed. Later it might involve the work of selecting an appropriate model to work on your watershed's particular issues (e.g., lake-based pollution, sediments) and then actually running the model. After specific practices have been selected, technical assistance in siting chosen practices or selecting among several different management practices for cost-effectiveness might be necessary. Technical assistance can also include advice on the best combination of practices and tools to apply to a particular site based on previous similar work and experience.

The process of delivering technical assistance can include working one-on-one with a landowner to share technical design specifications and similar site experiences; developing engineering plans for a property; showing a demonstration site; presenting drawings, plans, and documents that can be used as a technical record to go along with a watershed plan; or simply providing oversight.

Technical assistance is offered by many agencies and organizations, including local conservation districts, state natural resources agencies, universities, and federal agencies.

> **Common Sources of Technical Assistance for Agricultural Activities**
>
> ***Federal***
>
> In addition to the in-house technical support that USDA provides through Natural Resources Conservation Service, Farm Service Agency, and conservation districts, the Department has expanded the availability of technical assistance to landowners by encouraging the use of technical service providers (TSPs). TSPs are independent of USDA but are certified in delivering conservation technical services to landowners. Keep in mind that TSPs are private professional consultants that provide services to landowners at a cost, unlike the extension agents, Soil and Water Conservation District technicians, and NRCS field staff, whose services are free to the landowner. USDA has developed a registry of TSPs to enable landowners to locate and choose TSPs in their service area. Go to **http://techreg.usda.gov**.
>
> ***State***
>
> USDA's Cooperative State Research, Education, and Extension Service partially sponsors its state partners through Extension Service programs based in land-grant universities. Frequently, state Cooperative Extension Services have a research and education focus that results in their being able to provide cutting-edge technical expertise at a regional scale. Go to **www.csrees.usda.gov/qlinks/partners/state_partners.html**.

12.7.5 Identify the Relevant Authorities Needed for Implementation

In addition to the required technical assistance you might need, it's critical to identify any relevant authorities or legislation that specifically allows, prohibits, or requires an activity. For example, if you're planning a streambank restoration project that involves working in the stream channel, a section 404 dredge and fill permit might be required. You should also identify the available authorities that can help you to implement your plan. For example, you might identify stream buffer ordinances, nutrient management plans, or animal feeding operation (AFO) regulations. In chapter 3 you identified other local, state, tribal, and federal planning efforts that you wanted to coordinate with, and these same programs can help you identify any relevant authorities that you might have missed. Close communication with the local agency staff and state agency personnel can help ensure that you have considered the relevant statutes and authorities needed for implementation.

12.8 Develop the Implementation Plan Basics

The implementation plan is a guide for turning your management strategies from paper into reality and for determining how you're going to measure progress toward meeting your goals. Putting the implementation pieces together involves laying out the detailed tasks that need to be done, identifying who will do them, identifying the funding and technical assistance needed, and setting up a process to measure the effectiveness of the program. The implementation plan, or action plan, is a subset of the overall watershed plan.

If you've followed the approach of this handbook, you've already defined the scope of your plan (chapter 4); estimated pollutant loads and set goals for load reductions (chapters 8 and 9); and identified, evaluated, and selected a management strategy (chapters 10 and 11). From information developed in those steps, you should have a reasonable idea of what, where, and when practices need to be implemented in the watershed to achieve your goals. Although the level and source of resources necessary to complete implementation might not be completely known at this point in time, the procedures recommended in this section will help identify responsible parties, costs, sources of funds, and ways to track progress that will improve the likelihood of assembling the pieces necessary to successfully implement your plan. A good implementation plan that is part of a good overall watershed plan can be very helpful in securing funds for implementation.

To provide a clear guide for stakeholders implementing the watershed plan, it is recommended that you compile basic information into several matrices. For each selected management option or related management options, work with your stakeholders to outline the following:

- Actions that need to be taken (including any special coordination, education, or public outreach needed to improve the chances of implementation)
- The responsible party(ies) for the action/education
- Time frame for implementing the actions
- Time frame for operation and maintenance requirements
- Estimated total cost and annual cost for each action
- Funding mechanism(s) for each action
- Measures or tracking indicators

Your implementation plan should include all activities, including I/E activities and monitoring requirements. Once all the elements of the plan are laid out in matrices, you'll be able to identify gaps or areas that you did not address.

Developing implementation plan matrices can also help to increase the likelihood of completing actions on time and within budget, as well as facilitating the development of annual work plans. The challenge, however, is to generate implementation information that is accurate and acceptable to the stakeholders responsible for carrying out the recommended actions. Meeting that challenge requires research by each responsible party (and consensus-building discussions where multiple parties are involved) regarding feasibility, constraints, possible funding sources, and timeline confirmation for each primary action to be taken. It's important to identify areas of uncertainty and constraints so they can be addressed or planned for where possible. Where funding resources among stakeholders appear to be falling short of projected needs, place emphasis on identifying other potential sources of funding or technical assistance from outside watershed partners. Worksheet 12-1 is an example of an implementation matrix, based on the blank worksheet provided in appendix B.

Worksheet 12-1 Sample Implementation Plan Matrix

Watershed Goals
Goal 1: Restore water quality to meet designated uses for fishing
Objective 1: Reduce sedimentation by 20 percent

Tasks for G1/O1	Respon. Party	Total Costs	Funding Mechanism	Indicators	Milestones			
					Short < 1 yr	Med < 3 yr	Long < 7 yr	Remaining
Task 1 Seek donation of conservation easements from property owners along Baron Creek	Local land trust	$0		# acres donated	2	7	10	10
I/E Activities Task 1 Hold informational workshop with property owners Develop brochures on how to donate easements	Local land trust	$3,000	Section 319 funding	# workshops held # participants # requests for assistance	3 40 2	3 45 4		0
Task 2 Purchase greenway alongside Baron Creek	County park district	$2,000/ mile	County general funds	# miles purchased	2	4	7	5
I/E Activities Task 2 None								
Task 3 Develop ordinance requiring a 150-ft easement for new construction in floodplain of Baron Creek	Local municipalities	$0		# ordinances adopted	1	2	4	0
I/E Activities Task 3 Run articles in local newspapers on benefits of ordinances	Watershed Committee	$0		# articles	2	5	8	0
Task 4 Install 300 ft of riparian buffer along Baron Creek	County dept. of natural resources	$2,500	EQIP, CREP	# ft of buffers	100			
Monitoring Activities for Task 1/2/3								
Monitor sediment load before and after implementation	State DEP	$5,000/ yr	Section 319 funding, state funds	Annual TSS load (kg/yr)	2,500	2,250	2,000	
Evaluate substrate habitat	State DEP & Watershed Committee	$3,000/ yr	Section 319 funding, local volunteers	% embeddedness % sand	12 10	6 5	3 2	

Worksheet 12-2 Developing Criteria to Measure Progress in Meeting Water Quality Goals

[Note: Complete one worksheet for each management objective identified.]

Management Objective: Reduce nutrient inputs into Cane Creek by 20 percent				
Indicators to Measure Progress	**Target Value or Goal**	**Interim Targets**		
		Short-term	**Medium-term**	**Long-term**
P load	44 t/yr	52 t/yr	49 t/yr	44 t/yr
# of nuisance algae blooms	0	2	1	0
transparency	5.5 m	4.1 m	4.9 m	5.5 m
frequency of taste and odor problems in water supply	0	1	1	0
hypolimnetic DO	5.0 mg/L	2.5 mg/L	4.0 mg/L	5.0 mg/L

As a companion matrix to the implementation of your management practices, I/E activities, and monitoring program, you should document how you will measure progress toward reducing pollutant loads and meeting your goals. The criteria you select should correspond to the management objectives in the previous table. A blank Worksheet 12-2 is provided in appendix B.

12.9 Develop an Evaluation Framework

There are two primary reasons to evaluate your watershed program. First, you want to be able to prove, or demonstrate, that by implementing the management measures, you are achieving your water quality and other environmental goals. Second, you want to be able to continually improve your program in terms of efficiency and quality. This adaptive management process should be built into your program before implementation so that you ask the right questions and use the answers to strengthen your program. Collecting information does no good if you don't use the information to improve your watershed program.

You should develop an evaluation framework to use once you begin to implement your watershed plan. The framework should be developed before implementation so that you can effectively identify what measures you want to evaluate and determine how you will obtain the information. You should recognize that you'll continue to build on the initial characterization, filling information gaps and refining the connections between sources, pollutants, and load reductions. You'll adapt your implementation efforts on the basis of new information collected, changes in the operational structure of your partnership, emerging technologies, and monitoring results.

12.9.1 What Parts of Your Program Should You Evaluate?

In general, you'll evaluate three major parts of your watershed implementation program to be able to demonstrate progress and make improvements in your program. You need to structure your evaluation framework to consider all three components and develop indicators that will measure each. The components are inputs, outputs, and outcomes. When filling in these components, you'll work backward, starting with your desired outcomes (goals) and working toward identifying the specific inputs needed to achieve those outcomes.

1. **Inputs**: *the process used to implement your program*. Inputs to your program include resources of time and technical expertise, organizational structure and management, and stakeholder participation.

Sample evaluation questions:

- Are the human and monetary resources allocated sufficient to carry out the tasks?
- Did stakeholders feel they were well represented in the process? (appendix B, Worksheet 13-1)

2. **Outputs**: *the tasks conducted and the products developed*. These include the implementation activities, such as installing management practices, developing brochures, holding workshops, and preparing fact sheets.

Sample evaluation questions:

- Are we meeting our implementation schedule?
- Are we meeting our milestones?
- Did we meet our milestones sooner than expected?
- Did we reach the appropriate target audiences with our I/E materials?

3. **Outcomes**: *the results or outcomes seen from implementation efforts*. These include increased awareness and behavior changes among the watershed community, as well as environmental improvements like water quality, habitat, and physical changes. Outcomes can be further broken down into short-term outcomes and long-term outcomes.

Sample evaluation questions:

- Did the target audience increase its awareness of watershed issues?
- Did the behaviors of the target audience change as a result of implementing the watershed plan?
- Are we meeting our interim targets for pollutant load reductions?
- Are pollutant loads being reduced?

Once you've determined the questions you want to answer, you can set up the framework to collect the necessary information. One approach to setting up an evaluation framework is to use a logic model.

12.9.2 Using a Logic Model to Develop an Evaluation Framework

Many programs use a logic model (figure 12-1) to set up and evaluate their programs. The model is an important tool in the adaptive management process because it allows you to better document the results you find and helps you determine what worked and why. Logic models have been used for years in social programs and are now being used in the context of watershed management.

Basically, a logic model is a picture or visual representation of your program, showing the inputs needed to implement your program, the expected outputs to be performed, and the

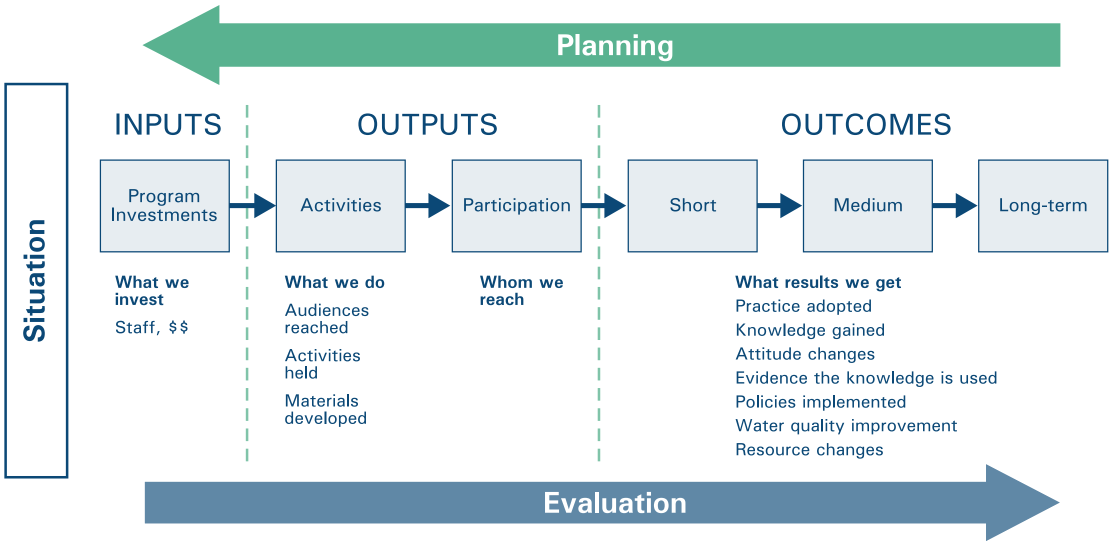


Figure 12-1. Logic Model Components

anticipated outcomes from implementing those activities. Using a logic model can help you to better document the outcomes, discover what works and why, and continually make changes to your program based on your evaluation results.

Using a logic model has several benefits. First, the model puts all the information about your program in one place and can summarize a complex program in a simple picture. This is particularly helpful when communicating key activities to stakeholders. A logic model also shows the connections that link the inputs to results so that you can readily identify any gaps in the sequence. Finally, a logic model provides a "to do" list for evaluation, signaling what needs to be evaluated and when.

The basic structure of a logic model includes stating your situation or problem, recording the inputs or resources needed, listing anticipated outputs, and ultimately outlining the expected outcomes from the program. As you move from the inputs through the outputs and to the outcomes, there should be a direct link between the steps. These links are called "if...then" relationships. For example, if you invest the required staff time and resources (inputs), you'll be able to conduct the outlined activities (outputs). If you conduct those activities, you'll see the expected results (outcomes). Setting up a logic model this way can help you to identify gaps and revise some of the parameters. See figure 12-2 for an example logic model for water quality improvements.

The resources listed in appendix A provide more information on how to develop and use logic models to evaluate your program.

12.9.3 Evaluation Methods

To evaluate your watershed program, you'll use various methods and tools, such as baseline surveys, focus groups, direct measurements, and stakeholder interviews. The important point is to determine what methods you will use *before* you implement your program. Identifying these methods will help make sure you are collecting information that will directly relate to your program. For example, if you wish to do any before-and-after comparisons, you should have baseline information with which you can compare the final results. The methods

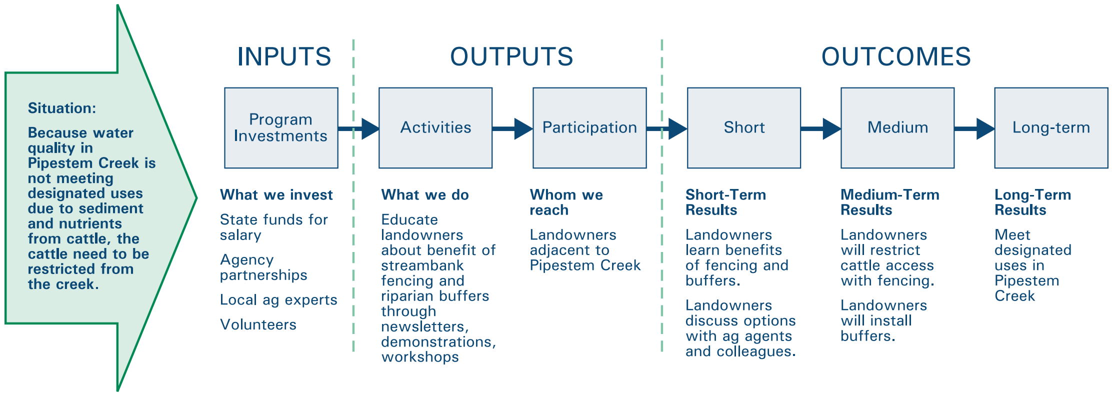


Figure 12-2. Logic Model Example

will be used to measure the indicators you have selected. For each indicator selected, you will identify the method for measuring the indicator. See appendix A for resources for evaluation approaches.

12.9.4 Timing of Evaluation

Once you know what you want to evaluate and how you'll collect the information, you'll develop a timeline for evaluation. Typically, you'll evaluate your watershed management program four times. The first is once you've completed the plan but have not yet begun to implement it. The second is during the implementation of project activities; the purpose of this evaluation is to provide feedback on the activities so that changes can be made if needed to increase their effectiveness. The third time is after the project activities have been completed; the purpose of this evaluation is to provide some measures of project effectiveness. Finally, you will continue to evaluate after the project has been completed to observe its effects. This is the most difficult aspect of the evaluation to complete because of lack of long-term funding. You have the greatest chance of following through on this if you have built your partnership into a sustaining organization to maintain continuity and stability through the years. Chapter 13 provides more information on conducting evaluations during the implementation phase and shows how to use the information collected to make changes in your program.

12.10 Devise a Method for Tracking Progress

Whether you track your implementation program by using index cards or create a computer database tracking system, you should identify how you'll track your program before you begin to implement it. Specifically, you want to set up a system that makes it as easy as possible to perform subsequent evaluations of your watershed plan's effectiveness.

First, examine the types of data that you'll collect to perform the evaluations and match them to the appropriate formats. For example, if you want to perform periodic statistical analysis to answer one or more types of evaluation questions, store data in a spreadsheet (or a more powerful database program if you have large amounts of data for numerous indicators) that can be linked to the analysis. If you plan to conduct spatial analysis and present results in map form, storing information in a GIS database will be appropriate. You might also be using a complex simulation model from your assessment on an ongoing basis and will need to update and maintain it with new information. Whatever your plans for evaluation of

Illinois Conservation Practices Tracking System

The Illinois Department of Natural Resources and the University of Illinois Extension, in cooperation with the USDA's Farm Service Agency, initiated a pilot program to develop a GIS-based information system to track conservation practices being implemented in Illinois and, in particular, the Illinois River Basin.

The project goals are (1) to provide baseline data to assess the efficacy of conservation practices and management techniques in improving water quality and habitat in the Illinois River Basin and (2) to create a tool that will aid state and federal partner agencies in planning and implementing watershed management activities within the Illinois River Basin, as well as visualizing the individual and cumulative impact of programs.

To date, conservation easement data for approximately 123,000 acres have been entered and mapped for all active Illinois Conservation Reserve Enhancement Program (CREP), Conservation Reserve Program (CRP), and Environmental Quality Incentives Program (EQIP) contracts in a six-county area of the Middle Illinois River Basin.

The initiative will continue to expand programmatically and geographically, with the eventual goal of creating a statewide system that tracks all conservation management activities of agencies in Illinois.

the implementation program, be sure you consider the types and uses of the data when setting up the tracking system.

You should also consider how you plan to communicate results to stakeholders and other parties and determine your needs for that process. Examine the format of the results—are you communicating progress in improvement of your indicators, costs of management measures, a schedule of progress? Also consider your method of communication—are you sending e-mails and do you need to maintain an e-mail list, or do you need a list server (a program for distributing e-mail to a large number of recipients)? Are you sending newsletters through the Postal Service and do you need to maintain a database of names and addresses? If you are planning to maintain a Web site, have you arranged for access to a Web server, and do you know the Web site address? Be sure to plan for all of your data management needs as they pertain to stakeholder communication.

Next, think about staff experience, training, and ease of use. For instance, if you need to input and track a large amount of water quality monitoring data and are using a database, you might need to train others to use the database system. Alternatively, you could have a database administrator develop data input forms that are easy to use and require little training. Web site design and maintenance require a certain level of expertise, depending on your expectations about the quality and complexity of the Web site. A number of boxed programs that make Web site design and maintenance relatively easy are available for purchase.

There are several administrative issues to consider as well. Be sure to plan for the following:

1. **Process** and **ownership**. *Process* refers to the procedures you set up to ensure that tasks are performed and completed. *Ownership* refers to the specific person responsible for carrying out each process. It's helpful to have processes written out in detail and easily accessible by staff. This helps staff reference how to perform procedures that occur infrequently, and it facilitates transferring responsibilities when someone is out of the office or leaves a position. Ownership is critical to ensuring that tasks are completed on time.

2. **Maintenance schedule**. This is an important component of defining processes. You should determine a set timetable for various activities, such as data entry, Web site updates, and database maintenance.

3. **Quality assurance/quality control**. Be sure to have procedures for QA/QC. For example, you might want to have a manager responsible for examining data before they are entered into a database to make sure the data are reasonable. You might want to have a third party look over data that have just been entered. For correspondence or reports, you should have someone else do proofreading.

4. **Version history**. In some cases it's important to maintain a file history. This is important in tracking down errors and preventing important information from being overwritten. You might also want to refer back to previous versions to detect changes or report on long-term progress. For files, you might find it helpful to insert the date and version number into the filename itself (e.g., "Progress Report 3-25-05 V2.wpd"). For simulation models, you might want to create a new directory each time you do a model run. GIS files might also need a version history.

5. **Metadata**. Metadata means "data about data," and it communicates the *who*, *what*, *when*, *where*, *why*, and *how* about data. You might want to maintain metadata about certain aspects of project areas. For instance, a database could have metadata describing its contents, who maintains it, the period it covers, sources of information, and so forth. You should give special consideration to metadata for GIS files that you generate. In fact, some state or federal agencies might require that you maintain GIS metadata in a specific format if you're working under contract for them. You should document sources of data, processing steps, definitions of database fields and their values, projection information, and the like. Several scripts and plug-ins for ArcView help with metadata generation and tracking, and ArcGIS has built-in functionality for this.

Remember that the high-quality work is key to maintaining credibility with your stakeholders and with regulators. Through careful planning, attention to detail, and high standards for accuracy, you will retain the respect of those that benefit from your work.

12.11 Putting It All Together

There is more than one way to assemble your watershed plan, but most plans follow a similar sequence of organization. An example table of contents from the White Oak Creek, Ohio, watershed plan is provided (figure 12-3). ↳ To download a complete copy of this watershed plan, go to **http://brownswcd.org/action_plan.htm**.

12.11.1 The Final Review

9 Once you've assembled your watershed plan, take a few minutes to review the sections. Ensure that you have included the recommended elements for a watershed plan, which will help to ensure that you have identified measurable goals that will lead to measurable results. Use the following checklist (✎ Worksheet 12-3) as a guide. ↳ A blank worksheet is provided in appendix B. In addition, some states have developed checklists to help groups submit watershed plans that meet the nine elements. ↳ Worksheets from Michigan and Missouri are included in appendix B (✎ Worksheets 12-4 and 12-5).

12.11.2 Make the Plan Accessible to Various Audiences

Your plan provides an exceptional opportunity to educate the watershed community about the key watershed issues, goals, and planned implementation activities. Consider developing a reader-friendly summary version of the watershed plan, a short executive summary, or a list of frequently asked questions that you can distribute to various audiences. Distribution mechanisms could include mass mailings, handouts at community events, or articles in local papers. A press release could also be used to communicate the availability of your watershed plan for public comment or review. Press releases should be clear, straightforward, and free

White Oak Creek Watershed Plan

Figure 12-3. Table of Contents from White Oak Creek, Ohio, Watershed Plan

Worksheet 12-3 *Basic Components of a Watershed Plan*

Key watershed planning components	Chapter	Done?	Comments
Include the geographic extent of the watershed covered by the plan.	4		
Identify the measurable water quality goals, including the appropriate water quality standards and designated uses.	4, 5, 8, 9		
Identify the causes and sources or groups of similar sources that need to be controlled to achieve the water quality standards.	4, 5, 6		
Break down the sources to the subcategory level.	7		
Estimate the pollutant loads entering the waterbody.	8		
Determine the pollutant load reductions needed to meet the water quality goals.	9		
Identify critical areas in which management measures are needed.	7, 9, 10		
Identify the management measures that need to be implemented to achieve the load reductions.	10, 11		
Prepare an I/E component that identifies the education and outreach activities needed for implementing the watershed management plan.	12		
Develop a schedule for implementing the plan.	12		
Develop interim, measurable milestones for determining whether management measures are being implemented.	12		
Develop a set of criteria to determine whether loading reductions are being achieved and progress is being made toward attaining (or maintaining) water quality standards, and specify what measures will be taken if progress has not been demonstrated.	12		
Develop a monitoring component to determine whether the plan is being implemented appropriately and whether progress toward attainment or maintenance of applicable water quality standards is being achieved.	6, 12		
Estimate the costs to implement the plan, including management measures, I/E activities, and monitoring.	12		
Identify the sources and amounts of financial and technical assistance and associated authorities available to implement the management measures.	12 Appx C		
Develop an evaluation framework.	12		

of unnecessary words or details. The goal of a press release is to arouse the curiosity of reporters and furnish information they can use in developing new stories to publicize your plan.

You should also consider posting the watershed plan on the Internet. With a Web-based format, readers can view the document at their leisure and you can easily update the plan as necessary. In addition, you should provide background information on the Web site that describes how the plan was developed, who was involved in developing it, and how citizens can get in involved in implementing it. Keep in mind that the downloading capabilities and processing speeds of computers vary widely, so you should allow readers to choose which format they would like to view or download, depending on their computer capabilities. The Upper Neuse River Basin Association posted the Upper Neuse Watershed Management Plan on its Web site (**www.unrba.org/projact.htm#mgmtplan**) in May 2003. Since the plan was posted, it has been downloaded more than 850 times.

When it comes to publicizing your watershed plan, be creative. Team with local schools to build watershed lessons into science curricula. Develop a slide presentation on the watershed plan and present it at Master Gardeners or Kiwanis Club meetings. Try to piggyback on the efforts of other organizations to help spread the word about the watershed plan. Finally, be inclusive in your efforts to get the plan out. Be sure to develop written communication in all languages relevant to your community and across various education levels.

General Outline of a Watershed Plan

1. **Executive Summary**
2. **Introduction**
    - 2.1. Document Overview
    - 2.2. Planning Purpose and Process
        - 2.2.1. Watershed Management Team
        - 2.2.2. Public Participation Approach
3. **Watershed Description**
    - 3.1. Physical and Natural Features
        - 3.1.1. Watershed Boundaries
        - 3.1.2. General Hydrology
        - 3.1.3. Climate/Precipitation
        - 3.1.4. Wetlands (NWI) Data
        - 3.1.5. Surface Water
        - 3.1.6. Ground Water Resources
        - 3.1.7. Floodplain Information
        - 3.1.8. Dams in the Watershed
        - 3.1.9. Navigation Channels/Ports/Harbors
        - 3.1.10. Topography/Elevation Data
        - 3.1.11. Geology and Soils
        - 3.1.12. Vegetation
        - 3.1.13. Exotic/Invasive Species
        - 3.1.14. Wildlife
        - 3.1.15. Endangered Species
        - 3.1.16. Sensitive Areas
        - 3.1.17. Cultural Resources
    - 3.2. Land Use and Land Cover
        - 3.2.1. Open Space
        - 3.2.2. Forested Areas
        - 3.2.3. Agricultural Practices
        - 3.2.4. Mining Activities
        - 3.2.5. Fisheries
        - 3.2.6. Developed Areas
        - 3.2.7. Political Boundaries
        - 3.2.8. Relevant Authorities
        - 3.2.9. Future Land Use Expectations
    - 3.3. Demographic Characteristics
        - 3.3.1. Population
        - 3.3.2. Economics
        - 3.3.3. Languages
4. **Watershed Conditions**
    - 4.1. Water Quality Standards
        - 4.1.1. Designated and Desired Uses
        - 4.1.2. Numeric Criteria/ State Standards
        - 4.1.3. Antidegradation Policies/Procedures
    - 4.2. Available Monitoring / Resource Data
        - 4.2.1. Water Quality Data (Impairments/Threats)
        - 4.2.2. Flow Data
        - 4.2.3. Biological Data
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        - 5.1.2. Wildlife
        - 5.1.3. Septic Systems
        - 5.1.4. Silviculture
        - 5.1.5. Urban/ Suburban Runoff
        - 5.1.6. Streambank Erosion
        - 5.1.7. Atmospheric Deposition
    - 5.2. Point Sources
        - 5.2.1. NPDES Permitted Facilities
        - 5.2.2. Wastewater Treatment Plants
        - 5.2.3. Phase I and II Stormwater Permits
        - 5.2.4. CAFO Permits
    - 5.3. Hazardous Waste Sites
        - 5.3.1. CERCLA Sites
        - 5.3.2. RCRA Sites
        - 5.3.3. Brownfields
        - 5.3.4. Underground Storage Tanks
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        - 8.1.1. Structural Controls
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    - 9.1. Management Strategies Overview
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    - 9.7. Monitoring Approach
    - 9.8. Evaluation Framework
10. **Watershed Plan Implementation Updates**

Appendices

13. Implement Watershed Plan and Measure Progress

Chapter Highlights

- Creating an organizational structure
- Implementing activities
- Preparing work plans
- Sharing results
- Evaluating your program
- Making adjustments

Read this chapter if...

- You want to know what to do after you've developed the watershed plan
- You want to get organized for implementation
- You're ready to implement activities
- You want to prepare work plans that will outline implementation activities over time
- You'd like to share the results of your effort
- You want to evaluate your program
- You need to make adjustments to your watershed plan

13.1 What Do I Do Once I've Developed My Watershed Plan?

Although you've expended a tremendous effort to develop your watershed plan, remember that it is nothing if you don't implement it. Although many watershed planning handbooks end with development of the plan, the plan is just the starting point. The next step is to implement the plan in your watershed. Implementation can begin with an information/education (I/E) component or with on-the-ground management measures. Remember that implementation activities should follow the road map developed in your plan.

When implementation begins, the dynamic of your watershed group, as well as stakeholders' level of participation, might change. This is the time when most members of your watershed group are really excited that something more than a written plan will come out of the planning efforts. This chapter offers tips and suggestions on measuring implementation progress, determining when you need to make changes to your current plan, and sharing the results of your efforts with the rest of the community.

13.2 Create an Organizational Structure for Implementation

After the plan is completed, you need to determine how you want to continue to operate. Don't just assume that you'll proceed with the same group that helped to develop the plan. Take a hard look at the planning team and ask the team members if they want to continue to be involved in implementing the plan. It's useful to ask the stakeholders to evaluate the process used to prepare the watershed plan so that you can improve on the process during implementation. Use Worksheet 13-1 to ask your stakeholders for input. A blank copy of the worksheet is provided in appendix B.

Identify any gaps in skills or resources, and try to find some new faces with skills, energy, and enthusiasm to move the ball forward. Consider creating a watershed implementation team made up of key partners, whose responsibilities include making sure tasks are being implemented, reviewing monitoring information, identifying or taking advantage of new funding sources, and sharing results.

Make sure, however, that new players that join the team are committed to the plan and its goals. Seek a balance between bringing in new ideas and energy and allegiance to following through on your hard-won plan.

To help ensure that you can continue to implement your watershed plan for many years, consider "institutionalizing" your watershed team. Try to create several positions that are funded by outside sources to provide continuity and stability. These positions might reside in other organizations but are tasked with administering the watershed plan. For example, the county might fund a part-time watershed coordinator out of the environmental planning department to assist with implementing your watershed plan.

If you want to make your partnership official, many guides explain how to create a nonprofit organization such as a 501(c)3. Having this designation is often useful in applying for funding from foundations. Go to **www.501c3.org** for information on how to set up a nonprofit organization.

Worksheet 13-1 Sample Watershed Stakeholder Committee Evaluation

Possible Evaluation Questions for Participants

Purpose: To determine how the level of participation in the Watershed Stakeholder Committee has changed over the past 2 years and why, and to assess the usefulness of the Committee.

Name/Affiliation: ____

Participation

1. How many Watershed Stakeholder Committee meetings have you participated in over the past 2 years?

2. If you have not participated in all the meetings, what factors would have increased your participation?

❑ Hosting the meeting closer to where I live.

❑ Hosting the meeting at a time that was more convenient for me, such as ________________________ .

❑ Providing more advance notice of where and when the meeting was to be held.

❑ Including topics for discussion that were more relevant to my interests.

❑ Other:

Group Structure

1. Do you feel the size of the group was adequate? Please explain.

2. Do you feel the composition of the group was representative of the watershed community? Please explain.

Group Input

1. Do you feel the meetings were held to optimize participation from the attendees? Please explain.

2. Do you feel that your input was incorporated into the watershed management planning process? Please explain.

Overall Recommendations

1. What do you think are the most useful aspects of the Watershed Stakeholder Committee?

2. What do you think can make the Watershed Stakeholder Committee more useful?

3. Would you like to be involved in future watershed protection efforts?

13.3 Implement Activities

Implementing the watershed management plan involves a variety of expertise and skills, including project management, technical expertise, group facilitation, data analysis, communication, and public relations. Your watershed plan implementation team should include members that can bring these skills to the table. The management measures you selected, schedules and milestones you set, financial and technical resources you identified, and I/E programs you developed in the course of assembling your plan provide a road map for implementation. Follow it. Take advantage of the partnerships you formed during plan development to work toward efficient implementation of the plan.

Key implementation activities include the following:

- Ensuring technical assistance in the design and installation of management measures
- Providing training and follow-up support to landowners and other responsible parties in operating and maintaining the management measures

- Managing the funding mechanisms and tracking expenditures for each action and for the project as a whole
- Conducting the land treatment and water quality monitoring activities and interpreting and reporting the data
- Measuring progress against schedules and milestones
- Communicating status and results to stakeholders and the public
- Coordinating implementation activities among stakeholders, among multiple jurisdictions, and within the implementation team

To keep the implementation team energized, consider periodic field trips and site visits to document implementation activities in addition to the necessary regular team meetings.

13.4 Prepare Work Plans

You'll use your overall watershed plan as the foundation for preparing work plans, which will outline the implementation activities in 2- to 3-year time frames. Think of your watershed plan as a strategic plan for long-term success; annual work plans are the specific to-do lists to achieve that vision. Work plans can be useful templates for preparing grant applications to fund implementation activities. Depending on the time frame associated with your funding source, your work plan might need to be prepared annually with quarterly reporting. It's also possible to update work plans and make some changes, within the original scope of the work plan, as needed. However, completely changing the focus of the work plan after receiving funding is unacceptable to most funding sources. Table 13-1 presents similarities and differences in the scope and breadth of a hypothetical watershed plan with a hypothetical 319 grant application/work plan for the same area. A written work plan would go beyond this tabular format and explain each parameter in much greater detail.

There are two other key pieces of information to include in your work plans. To help keep track of what will need to be done in the future, it's important to document what will *not* be done in your proposed work plan that relates to the overall watershed plan. This approach helps to provide continuity from year to year. In addition, you should indicate other activities that will be conducted using other funds, as well as activities conducted by other cooperating groups as part of the watershed plan implementation.

13.5 Share Results

As part of the I/E program developed in chapter 12, you should have included opportunities to publicize the plan to increase awareness of the steps being taken during implementation. Continuous communication is essential to building the credibility of and support for the watershed implementation process. Lack of communication can impede participation and reduce the likelihood of successful implementation. This is especially critical if you're using a stakeholder-driven process. Transparency of the process builds trust and confidence in the outcome. Regular communication also helps to strengthen accountability among watershed partners by keeping them actively engaged. Such communication might also stimulate more stakeholders to

Table 13-1. Comparison of Example Parameters in a Hypothetical Watershed Plan and 319 Work Plan

Parameter	Lake Fraser Watershed Management Plan	319 Work Plan #1
Period	2003–2013	2003–2006
Geographic scope	180,000 acres	24,000 acres
Critical areas	52,000 acres	7,000 acres
Goal statement	Improve watershed conditions to support sustainable fisheries	Reduce sediment loadings from priority subwatershed X
Example objectives and key elements	• Increase the Index of Biotic Integrity (IBI) from 30 to 75 • Identify causes and sources of sediment • Identify load reduction expected • Identify management practices needed • Identify critical areas	• Treat 5,000 acres of cropland with crop residue management (CRM) practices • Install six terraces to treat 1,200 acres • Establish five buffer strips for a total of 8,000 feet
Implementation	• CRM: 2,000 acres of row crop/year into CRM • Terraces: 4 fields/year, 40 fields total • Buffers: restore 1 to 1.5 miles of riparian area/year, 8 miles total • Field buffers: 100 fields total	• Develop training materials on CRM in year 1 • Hold two workshops each in years 2 and 3 • 2 terraces/year • One buffer strip in first year and two each in years 2 and 3
Costs	$4.02 million over 10 years • $800,000 for information and education (I/E) • $600,000 for monitoring and reporting • $1,980,000 for buffers (18,000 acres at $110/acre) • $140,000 for 40 terraces • $500,000 for CRM	$250,000 over 3 years • $50,000 to prepare training materials and give five workshops on CRM • $160,000 for management practice cost-sharing • $40,000 for monitoring and reporting
Schedule	• Begin slowly and accelerate (build on successes) • Establish interim milestones – Cropland: 2008 – reduce soil erosion by 80,000 tons/year – Streambanks: 2006 – stabilize 10,000 feet of eroding streambanks – 2010 – stabilize 30,000 feet of eroding streambanks • Push I/E early and complete by year 6 • Prepare annual reports that track progress • Coordinate with partners	• See above • Annual progress reports
Monitoring	• Environmental – water quality, IBI, acres treated, tons of soil erosion reduced, feet of streambank stabilized • Administrative – contracts approved, funds expended, and funds obligated • Social – landowners contacted • Changes in public understanding resulting from I/E	• Attendance at CRM training workshops • Acres of cropland using CRM • Feet of stream buffers established • Feet of field buffers established • Number of terraces • Environmental: reduction in sediment loads • Administrative: contracts approved and funds expended • Social: landowners contacted

get involved in the effort and offer new ideas or suggestions. Sharing results can also help to ensure more consistent watershed approaches across subwatersheds.

> More ideas regarding sharing success are provided in the Section 319 Nonpoint Source Success Stories at **www.epa.gov/owow/nps/Success319**

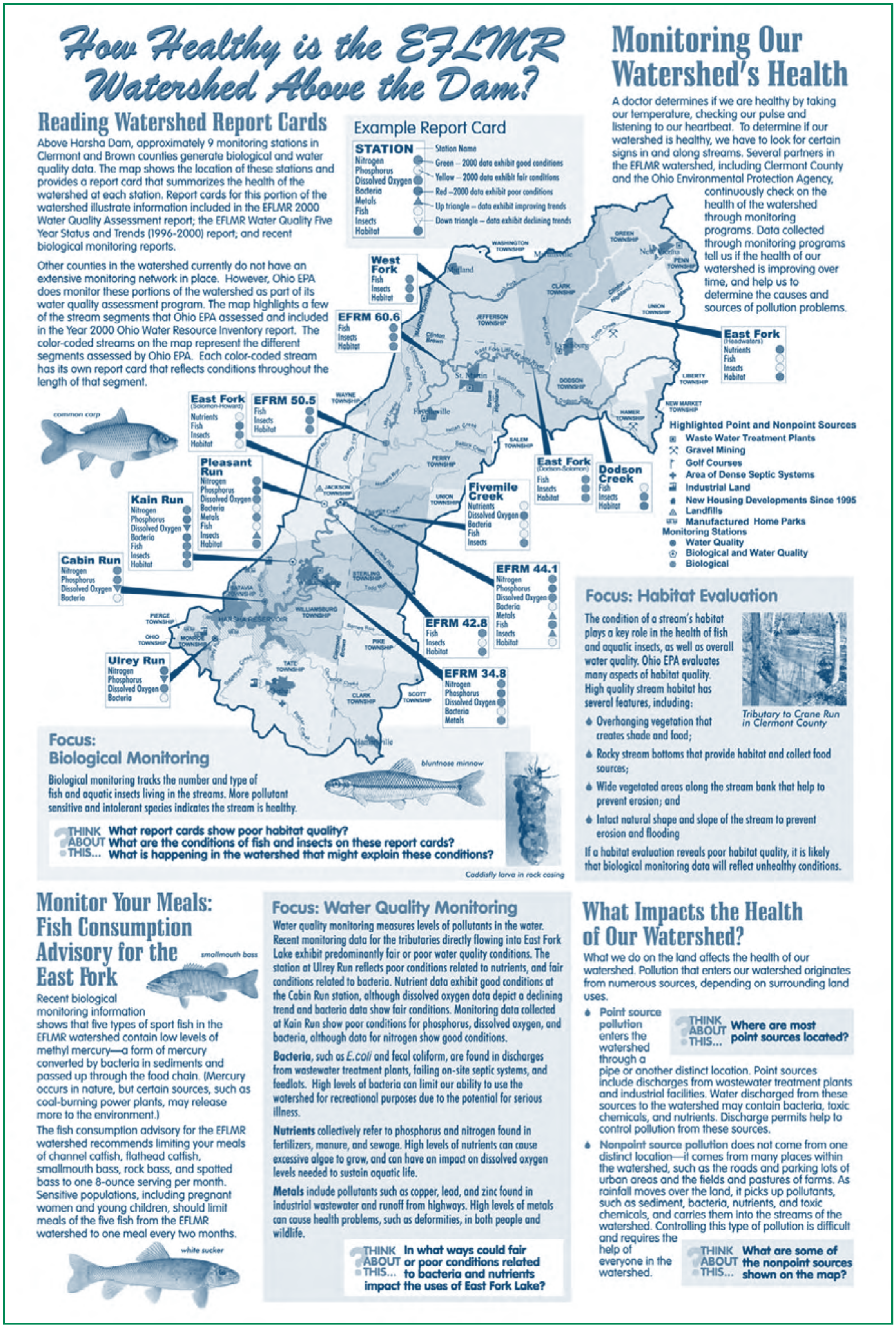
The many stakeholders that have invested time and money in the watershed plan will want to know if the plan is making a difference. They're also likely to want to know what resources have been used to make that difference and what resource gaps remain. You can be accountable to stakeholders by regularly reporting information. You should provide information on interim results and report the ways in which the plan is working and how you plan to address the deficiencies. Encourage stakeholders to contribute ideas on how to make improvements.

Progress and implementation results can be shared through various media formats, such as press releases, ads in local newspapers, television or radio public service announcements, or presentations at community meetings such as those of homeowner associations and local civic organizations, PTA meetings, or other gatherings of members of the watershed community. You could secure time on the local cable access station to discuss the watershed plan and share monitoring results with the public. You might also consider hosting a press conference with local officials and the stakeholders as a way to thank them for their participation and to inform the larger community about the plan's contents and how they can participate in implementing the plan. (See section 12.2.2 on developing an I/E program.)

Remember to publicize the project team's accomplishments to county commissioners, elected local and state officials, watershed residents, and other major stakeholders. The group might wish to issue a watershed "report card" (figure 13-1) or develop a fact sheet, brochure, or annual report to highlight its successes. Report cards let the community know whether water quality conditions are improving overall. They also allow people to compare results across specific areas to see if things are improving, whether some aspects seem to be connected, and whether a change in direction is needed to bring about greater improvements. This is an effective way to build awareness of the watershed issues and the progress of watershed plan implementation. In addition, when people see progress, they'll continue to work toward making the plan a success.

13.6 Evaluate Your Program

Once you've started to implement your watershed plan, you need to monitor both water quality and land treatment to ensure smooth implementation and to measure progress toward meeting goals. The adaptive management approach is not linear but circular, to allow you to integrate results back into your program. You need to create decision points at which you'll review information and then decide whether to make changes in your program or stay the course. Figure 13-2 illustrates how the adaptive management approach feeds back into your program based on information gathered from monitoring and management tracking. As part of your evaluation efforts, you'll periodically review the activities included in your work plan and the monitoring results to determine whether you're making progress toward achieving your goals.



How Healthy is the EFLMR Watershed Above the Dam?

Reading Watershed Report Cards

Above Harsha Dam, approximately 9 monitoring stations in Clermont and Brown counties generate biological and water quality data. The map shows the location of these stations and provides a report card that summarizes the health of the watershed at each station. Report cards for this portion of the watershed illustrate information included in the EFLMR 2000 Water Quality Assessment report; the EFLMR Water Quality Five Year Status and Trends (1996-2000) report; and recent biological monitoring reports.

Other counties in the watershed currently do not have an extensive monitoring network in place. However, Ohio EPA does monitor these portions of the watershed as part of its water quality assessment program. The map highlights a few of the stream segments that Ohio EPA assessed and included in the Year 2000 Ohio Water Resource Inventory report. The color-coded streams on the map represent the different segments assessed by Ohio EPA. Each color-coded stream has its own report card that reflects conditions throughout the length of that segment.

Example Report Card

STATION — Station Name
Nitrogen, Phosphorus, Dissolved Oxygen, Bacteria, Metals, Fish, Insects, Habitat

- Green – 2000 data exhibit good conditions
- Yellow – 2000 data exhibit fair conditions
- Red – 2000 data exhibit poor conditions
- Up triangle – data exhibit improving trends
- Down triangle – data exhibit declining trends

Monitoring Our Watershed's Health

A doctor determines if we are healthy by taking our temperature, checking our pulse and listening to our heartbeat. To determine if our watershed is healthy, we have to look for certain signs in and along streams. Several partners in the EFLMR watershed, including Clermont County and the Ohio Environmental Protection Agency, continuously check on the health of the watershed through monitoring programs. Data collected through monitoring programs tell us if the health of our watershed is improving over time, and help us to determine the causes and sources of pollution problems.

Highlighted Point and Nonpoint Sources
- Waste Water Treatment Plants
- Gravel Mining
- Golf Courses
- Area of Dense Septic Systems
- Industrial Land
- New Housing Developments Since 1995
- Landfills
- Manufactured Home Parks

Monitoring Stations
- Water Quality
- Biological and Water Quality
- Biological

Focus: Habitat Evaluation

The condition of a stream's habitat plays a key role in the health of fish and aquatic insects, as well as overall water quality. Ohio EPA evaluates many aspects of habitat quality. High quality stream habitat has several features, including:

Tributary to Crane Run in Clermont County

- Overhanging vegetation that creates shade and food;
- Rocky stream bottoms that provide habitat and collect food sources;
- Wide vegetated areas along the stream bank that help to prevent erosion; and
- Intact natural shape and slope of the stream to prevent erosion and flooding

If a habitat evaluation reveals poor habitat quality, it is likely that biological monitoring data will reflect unhealthy conditions.

Focus: Biological Monitoring

Biological monitoring tracks the number and type of fish and aquatic insects living in the streams. More pollutant sensitive and intolerant species indicates the stream is healthy.

bluntnose minnow

THINK ABOUT THIS... What report cards show poor habitat quality? What are the conditions of fish and insects on these report cards? What is happening in the watershed that might explain these conditions?

Caddisfly larva in rock casing

Monitor Your Meals: Fish Consumption Advisory for the East Fork

smallmouth bass

Recent biological monitoring information shows that five types of sport fish in the EFLMR watershed contain low levels of methyl mercury—a form of mercury converted by bacteria in sediments and passed up through the food chain. (Mercury occurs in nature, but certain sources, such as coal-burning power plants, may release more to the environment.)

The fish consumption advisory for the EFLMR watershed recommends limiting your meals of channel catfish, flathead catfish, smallmouth bass, rock bass, and spotted bass to one 8-ounce serving per month. Sensitive populations, including pregnant women and young children, should limit meals of the five fish from the EFLMR watershed to one meal every two months.

white sucker

Focus: Water Quality Monitoring

Water quality monitoring measures levels of pollutants in the water. Recent monitoring data for the tributaries directly flowing into East Fork Lake exhibit predominantly fair or poor water quality conditions. The station at Ulrey Run reflects poor conditions related to nutrients, and fair conditions related to bacteria. Nutrient data exhibit good conditions at the Cabin Run station, although dissolved oxygen data depict a declining trend and bacteria data show fair conditions. Monitoring data collected at Kain Run show poor conditions for phosphorus, dissolved oxygen, and bacteria, although data for nitrogen show good conditions.

Bacteria, such as *E.coli* and fecal coliform, are found in discharges from wastewater treatment plants, failing on-site septic systems, and feedlots. High levels of bacteria can limit our ability to use the watershed for recreational purposes due to the potential for serious illness.

Nutrients collectively refer to phosphorus and nitrogen found in fertilizers, manure, and sewage. High levels of nutrients can cause excessive algae to grow, and can have an impact on dissolved oxygen levels needed to sustain aquatic life.

Metals include pollutants such as copper, lead, and zinc found in industrial wastewater and runoff from highways. High levels of metals can cause health problems, such as deformities, in both people and wildlife.

THINK ABOUT THIS... In what ways could fair or poor conditions related to bacteria and nutrients impact the uses of East Fork Lake?

What Impacts the Health of Our Watershed?

What we do on the land affects the health of our watershed. Pollution that enters our watershed originates from numerous sources, depending on surrounding land uses.

- Point source pollution enters the watershed through a pipe or another distinct location. Point sources include discharges from wastewater treatment plants and industrial facilities. Water discharged from these sources to the watershed may contain bacteria, toxic chemicals, and nutrients. Discharge permits help to control pollution from these sources.

  THINK ABOUT THIS... Where are most point sources located?

- Nonpoint source pollution does not come from one distinct location—it comes from many places within the watershed, such as the roads and parking lots of urban areas and the fields and pastures of farms. As rainfall moves over the land, it picks up pollutants, such as sediment, bacteria, nutrients, and toxic chemicals, and carries them into the streams of the watershed. Controlling this type of pollution is difficult and requires the help of everyone in the watershed.

  THINK ABOUT THIS... What are some of the nonpoint sources shown on the map?

Figure 13-1. Watershed Report Card for Clermont County, Ohio

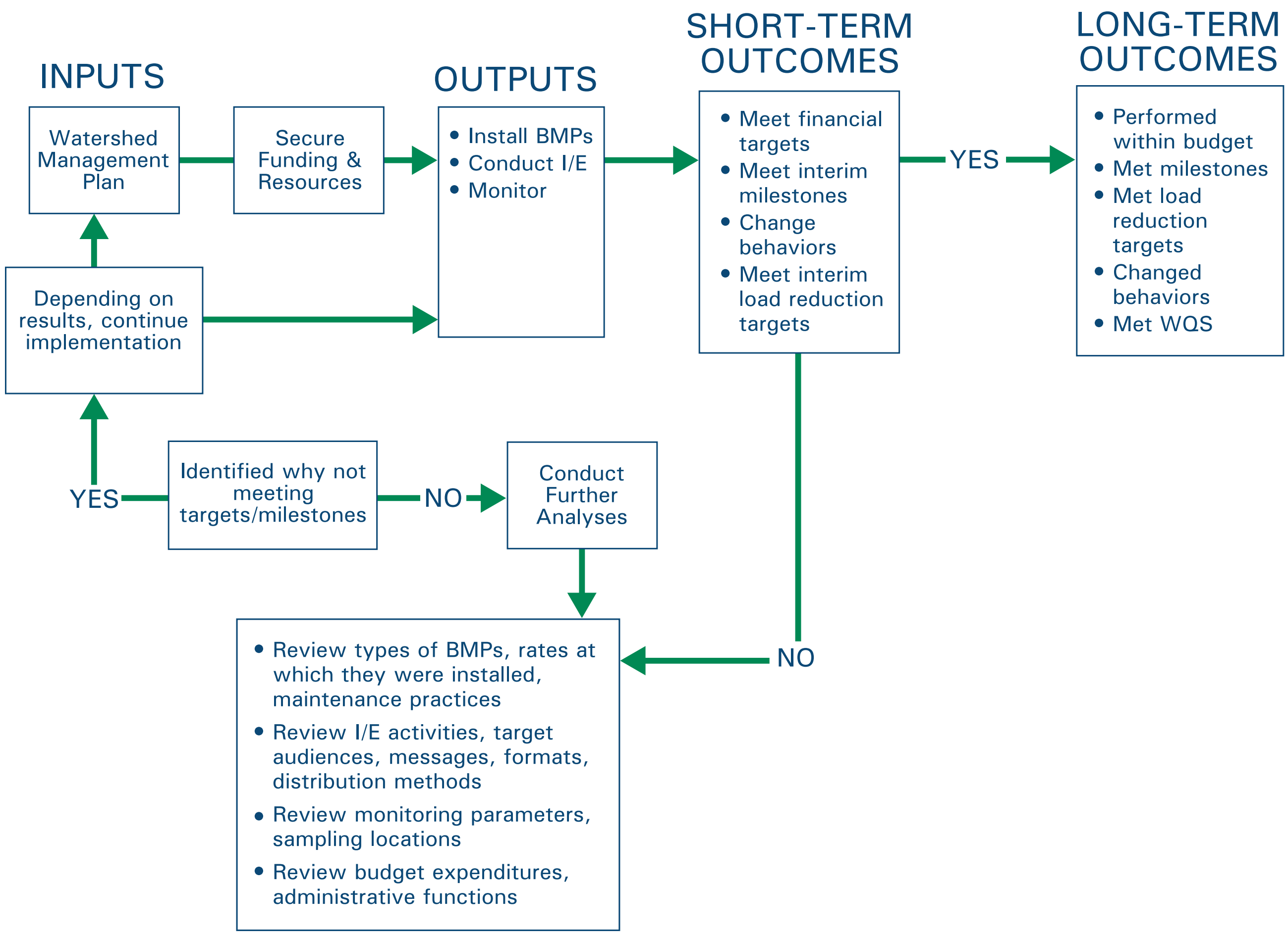


Figure 13-2. Example Adaptive Management Approach Using a Logic Model

13.6.1 Track Progress Against Your Work Plans

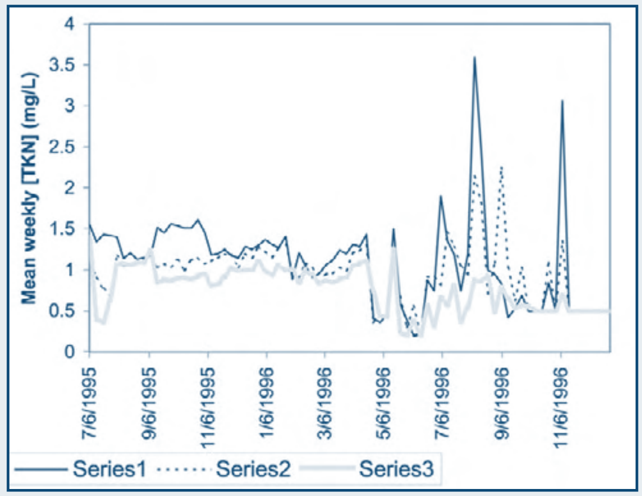
As part of developing your implementation plan, you devised a method for tracking progress (↳ section 12.10). Using that tracking system, you should review the implementation activities outlined in your work plan, compare results with your interim milestones, provide feedback to stakeholders, and determine whether you want to make any corrections. These reviews should address several key areas:

- *The process being used to implement your program*. This process includes the administrative and technical procedures used to secure agreements with landowners, develop specifications, engage contractors, and the like.
- *Progress on your work plan*. Check off items in your annual work plan that have been completed.
- *Implementation results*. Report on where and when practices have been installed and have become operational.
- *Feedback from landowners and other stakeholders*. Review information on the stakeholders' experience with the implementation process and with operation and maintenance of the practices.

Schedule reviews regularly and formalize the routine procedures. A simple way to gather this information is to provide worksheets to the project team at their regularly scheduled meetings. Use Worksheet 13-2 to check in with the group and evaluate how things are going. A copy of the worksheet with detailed questions is provided in appendix B. Maintain agendas, minutes, and other records so that important issues and decisions are well documented. Consider tying each meeting to a simple progress report so that all team members stay up-to-date. Above all, involve *all* team members, not just those directly involved in the specific items outlined above. Communication and sharing of knowledge among team members are essential ingredients for success.

Evaluate Your Data Routinely

This time series plot of total Kjeldahl nitrogen (TKN) data collected in three Vermont watersheds illustrates the importance of frequent data evaluation. Obviously, something happened around May 1996 that caused a major shift in TKN concentrations in all three streams. In addition, it is clear that after October, no values less than 0.5 mg/L were recorded. In this case, the shift was not the result of some activity in the watersheds but an artifact of a faulty laboratory instrument, followed by the establishment of a detection limit of 0.50 mg/L. Discovery of this fault, although it invalidated a considerable amount of prior data, led to correction of the problem in the lab and saved the project major headaches down the road.



13.6.2 Analyze Monitoring Data

As part of the monitoring component developed in section 12.6, you have determined how and where the data are stored, how frequently they are compiled and analyzed, the types of analyses that will be performed, and how results will be interpreted. Two types of analyses should be considered during the implementation phase: (1) routine summary analysis that tracks progress, assesses the quality of data relative to measurement quality objectives (i.e., whether the data are of adequate quality to answer the monitoring question), and provides early feedback on trends, changes, and problems in the watershed and (2) intensive analysis to determine status, changes, trends, or other issues that measure the response to the implementation of the watershed plan.

Routine summary analysis should examine both water quality and land treatment monitoring data fairly frequently. Simple, basic data analysis should be done at least quarterly as part of the regular review process. Progress reports (self-imposed, not necessarily reports to funding agencies or the public) and regular team meetings are effective ways to accomplish this. Even though the process might seem demanding, early suggestion of trends or problems

Worksheet 13-2 Sample Topics to Discuss at Quarterly Review of Watershed Management Plan

- Administrative and management activities
- I/E activities
- Monitoring activities
- Additional issues

> **Review Your Land-Treatment Tracking Data**
>
> ***Inventory of practices/measures implemented***
>
> Where and when were measures implemented? Consider locating implementation as points or areas in a geographic information system (GIS) and developing standard maps.
>
> ***Status of practices/measures implemented***
>
> How were structural measures built or maintained? Are landowners following management practices? For practices that "grow in" such as riparian buffers, report on growth of vegetation.
>
> ***Index of effects of implementation***
>
> What is the magnitude of implementation? What are the estimated effects? In agricultural watersheds, for example, the number or proportion of acres treated or animal populations under management practices in the critical areas can be useful indices of how much treatment has been implemented. Where land treatment tracking data allow, report estimates of changes in nitrogen and phosphorus application under nutrient management. If possible, estimate changes in soil loss using tools like the Revised Universal Soil Loss Equation (RUSLE).

can prevent major headaches down the road by detecting changes or problems early. Feedback from monitoring can be invaluable in tracking the effectiveness of your plan and making small adjustments. To promote consistency and continuity, consider appointing a single team member as the primary gatekeeper for routine data analysis.

Routine data analysis in this context does not have to be complex or sophisticated. Your primary goals are to make sure that your monitoring effort is on track and that you get a general sense of what's going on in your watershed.

Because many watershed activities can affect nonpoint source loads, you should pay attention to broad watershed land use patterns such as overall land use change (e.g., abandonment of agricultural land, timber harvest, large urban development); changes in agriculture, such as acres under cultivation or animal populations; and changes in watershed population, wastewater treatment, stormwater management, and so forth. An annual look at watershed land use is probably enough in most cases.

Types of Data Analyses

In general, intensive data analysis should be conducted at least annually in a multiyear watershed plan. The types of data analyses you perform on the monitoring data depend on the overall goals and objectives, the management approach, and the nature of the monitoring program; several types of analyses might be appropriate depending on the monitoring questions. For example, an assessment of the Clinch River watershed in Virginia used a variety of statistical analyses to relate land use/land cover data and biological or stream habitat indices. Some of these analyses involved relatively simple procedures, such as correlations between percent urban area and fish Indices of Biotic Integrity (IBIs). Other analyses were more complex, involving multivariate procedures such as clustering, multiple regression, or factor analysis to tease out the stressors most responsible for fish community impairments in the watershed. Where analysis and evaluation of management practices are the focus of monitoring, it might be feasible to use relatively simpler analyses, such as t-tests comparing indicator levels before and after implementation, levels above and below implementation sites, or levels in areas where management options were implemented and areas where they were not. Where adequate pre-implementation data are not available, trend analysis can be used to look for gradual changes in response to your implementation program. In some cases, more sophisticated statistical techniques like analysis of covariance might be required to control for the effects of variations in weather, streamflow, or other factors.

Determine Who Should Review the Data

Monitoring data might need to be reviewed by several types of personnel depending on the complexity of the data. For large watershed projects, it's often necessary to enlist the help of an expert in GIS applications because maps and land use relationships are usually critical to the analyses. A statistician is often required to review the data and help design appropriate analyses. Note that even the most capable statistician cannot completely compensate for a weak monitoring design. Consult a statistician during the development of your monitoring design (↳ section 12.6). Additional specialists might be necessary depending on the types of data reported. For example, a toxicologist should review toxicity data and a biologist should review bioassessment data. Finally, the watershed coordinator should review the results of analyses to ensure that they are on track and to help determine whether midcourse changes are needed.

Run Models to Compare Actual Results with Predicted Results

Under some circumstances, models might be useful to evaluate the progress of implementing your plan. You can, for example, compare the predictions of a model that has been validated for your watershed against actual monitoring data. Such a comparison can confirm that you are on track toward your load reduction goals or can tell you that something is amiss. If data do not match predictions, you might be able to track down possible reasons. The failure of a treatment measure to reduce pollutant load as expected, for example, could be due to problems in installation or management that can be corrected.

Models are also useful when you need to extrapolate monitoring data to the watershed scale. For example, you can't monitor every inch of stream and runoff from every square inch of land. In fact, often you'll be lucky if there are monitoring stations (or more than a couple) in your watershed. With modeling techniques, you can sometimes extrapolate data from monitoring stations to other locations to check instream flows, concentrations, loads, or other parameters.

However, always use models with caution. You should not use models as the sole means of assessing progress or evaluating the effectiveness of your efforts. Models incorporate many assumptions about how management practices perform, and without good monitoring data, model predictions can overstate or misstate changes in water quality. In the Chesapeake Bay, for example, model results have suggested major reductions in pollutant loads that are not borne out by monitoring data, leading to a great deal of controversy and uncertainty over the status and direction of the Bay restoration plan. Always remember that you're working to reduce pollutant loads to a real waterbody and that is where you should look to evaluate the effectiveness of your plan.

Review Water Quality Data

Evaluate data collection effectiveness and data quality

Are all planned samples and measurements being collected? If not, why not? Are there technical, logistical, laboratory, or financial issues? Are measurement quality objectives being met? Is the laboratory meeting the stated detection limits and quality control standards?

Screen data

Are the data reasonable? Are there major outliers that suggest sampling or analytical errors that require attention or something going on in the field that needs investigation?

Conduct exploratory data analysis

What can the data tell you? Characterize the data with simple descriptive statistics like mean, median, and standard deviation. Plot the data as a time series that is added to each quarter. This approach allows the team to visualize seasonal patterns, compare data from different locations, and compare current data with data from previous years.

Look at supporting data

What other data are available to support your monitoring? Weather data from the local National Weather Service station, for example, are often key to explaining patterns in your data and putting the data in context. Was this year unusually wet or dry? Did a 100-year storm occur in part of the watershed?

13.7 Make Adjustments

If you've determined that you are not meeting the implementation milestones or interim targets that you set for load reductions and other goals, what should you do? There are several possible explanations for why you haven't met your interim milestones or why pollutant loads aren't being reduced. Sometimes it takes much longer to see results in the waterbody than anticipated. Sometimes management practices have been installed but are not being used or maintained properly so they have lost their effectiveness. Before making any modifications to your watershed plan, ↳ ask yourself the questions in sections 13.7.1 and 13.7.2.

13.7.1 Not Meeting Implementation Milestones

Did weather-related causes postpone implementation?

Installation of many management practices depends on favorable weather conditions. If you were unable to install these practices because of weather conditions, you might want to stay the course, assuming you'll be able to install them in the near future.

Was there a shortfall in anticipated funding for implementing management measures?

You might have identified funding sources to implement several of the management measures. For example, the availability of crop subsidies or funding for cost-share (e.g., USDA Environmental Quality Incentives Program [EQIP]) can affect the installation and maintenance of management practices. If these sources were insufficient or became unavailable, you need to determine whether the management practices can still be installed and adjust new targets for the milestones.

Was there a shortage of technical assistance?

Many management practices require technical assistance (e.g., Natural Resources Conservation Service [NRCS] engineers, Extension personnel, or private crop management consultants) in design and construction or in management. Lack of such assistance can slow implementation. You should consult with NRCS and other sources of technical assistance to determine future availability and possibly adjust your timetable accordingly.

Did we misjudge the amount of time needed to install some of the practices?

Installation of structural practices, growth of vegetative measures, or adoption of management or behavioral changes might take longer than predicted. You might want to adjust your timetable to reflect this new reality.

Did we fail to account for cultural barriers to adoption?

Cultural or social barriers to the adoption of some practices exist. Some stakeholder groups might avoid participation in government programs. Traditional aesthetic preferences might conflict with development of riparian buffers. If such factors become evident, you might need to increase incentives to landowners or undertake additional I/E efforts.

13.7.2 Not Making Progress Toward Reducing Pollutant Loads

Are we implementing and using the management measures correctly?

Are structural practices being installed, operated, and maintained correctly? Remember that the existence of an animal waste storage structure does not itself guarantee effective animal waste management. Are management changes being followed? Don't assume that phosphorus inputs are automatically reduced by a set amount for each acre of nutrient management implemented. Changes in phosphorus applications following nutrient management must be documented. This is one big reason for the land treatment monitoring discussed earlier. If you have instituted erosion and sediment control regulations in portions of the watershed but the sediment loads are not decreasing, determine whether the regulations are being followed, with the proper setbacks, installation of silt fences, and so forth. If management measures are not being implemented or followed correctly, more education or technical assistance might be needed.

Has the weather been unusual?

Extended wet periods or storm events of unusual magnitude or unfortunate timing can increase nonpoint source loads. Furthermore, many management practices have a finite capacity to control nonpoint source loads, and this capacity might be exceeded during extreme weather events. Before concluding that your implementation program needs to be revised, check to see if unusual weather events might have contributed to the failure to reach milestones.

Have there been unusual events or surprises in the watershed?

One purpose of land treatment and land use monitoring is to identify factors other than the implementation program that might affect water quality. Are there new sources of pollutants that you did not consider? Before setting off to revise your implementation program, check to see that no surprises, disasters, or bad actors have created problems in the watershed that affect your progress or mask the progress that your plan implementation has made elsewhere.

Are we doing the right things?

If all your measures are being implemented according to specifications and there has been no unusual weather or other unusual events, you might need to examine the specifications themselves. If erosion and sediment control regulations have not reduced sedimentation problems enough, you might need to extend the setback or increase the inspections of construction sites for those areas. If your nutrient management practice is nitrogen-based but phosphorus loads remain high, you might need to move to phosphorus-based nutrient management. Alternatively, you might need to expand the level of implementation so that more watershed area comes under improved management.

Are our targets reasonable?

If load reductions were predicted on the basis of models, plot studies, or idealized systems, the milestones set for load reductions could be overly optimistic. For most management practices, reports of effectiveness vary widely, depending on the pollutant inputs, climate, and monitoring regime. Riparian buffers, for example, might perform well in plot studies when runoff occurs as sheet flow, but in the real world concentrated overland flow might bypass the treatment processes. You might need to revisit your assumptions about expected load reductions.

Are we monitoring the right parameters?

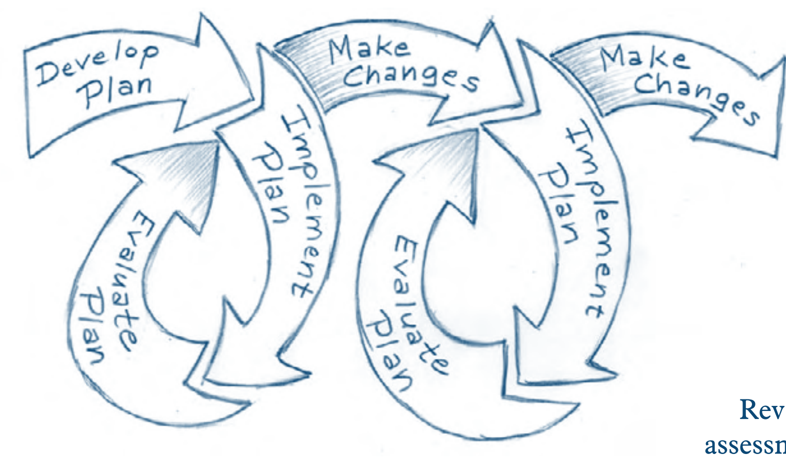
Despite your best efforts to develop a monitoring program that's targeted to measuring progress, review the parameters you selected to ensure that they truly will tell you if load reductions are occurring. Data on turbidity, for example, might not tell the whole story on the success of erosion control measures if high turbidity results from fine clay particles that are not controlled effectively by your management practices.

Do we need to wait longer before we can reasonably expect to see results?

The nonpoint source problems might have taken time to develop, and it might take time to clean them up. Pollutants like phosphorus might have accumulated in soils or aquatic sediments for decades. Sediment could continue to move through drainage networks even after upland erosion has been reduced. It might be a mistake to expect an immediate response to your implementation program. You might want to rethink your targets or timetable for some pollutants.

Revisit the watershed plan

If you've ruled out all the above possibilities, you need to consider whether your plan has called for the right management measures. It's possible that the identification of the causes and sources of pollutants earlier in the planning process was not completely correct or that the situation has changed. For example, from 1978 to 1982, the New York Model Implementation Project attempted to reduce phosphorus loads to the Cannonsville Reservoir by implementing improved management of dairy barnyards and barnyard runoff. This approach was based on an assessment that had identified barnyards as the main source of the excessive phosphorus load. When the phosphorus load reduction targets were not met, the project team determined that winter spreading of dairy manure, not barnyard runoff, was the actual culprit (Brown et al. 1989). In such a case, no amount of barnyard management would address the fundamental problem.



Revisiting the plan and reexamining earlier assessments of the sources of pollutant loads might be the only answer at this point. The good news is that the land treatment and water quality monitoring data you've collected during this process can contribute to a better understanding of your watershed. The watershed team can change any of the elements on the schedule of activities, especially a management measure or responsible party. It can also change priorities and shift resources to achieve a high-priority milestone.

13.8 A Final Word

Volumes have been written on watershed management, and not all the permutations and combinations that you might encounter in your watershed planning effort could be included in this handbook. However, the authors have tried to provide a framework to help you develop a scientifically defensible plan that will lead to measurable results and an overall improvement in the water quality and watershed conditions that are important in your community.

Handbook Road Map

Appendices

Highlights

- Appendix A: Resources
- Appendix B: Worksheets
- Appendix C: List of State Nonpoint Source and Watershed Planning Contacts

Appendix A: Resources

General Watershed Planning Information

The Indiana Watershed Planning Guide
This guide was developed by the Indiana Department of Environmental Management to assist local groups in developing successful watershed plans and to establish a common approach for watershed planning throughout Indiana. It helps users answer the following watershed planning questions: Where are we now? Where do we want to be? How are we going to get there? How will we know when we've arrived? The guide is available at
www.in.gov/idem/catalog/documents/water/iwpg.pdf.

Michigan's Developing a Watershed Management Plan for Water Quality: An Introductory Guide
This guide was developed to help local units of government, nonprofit organizations, and citizens develop watershed management plans. It outlines a process for gathering people, information, and resources to protect and improve Michigan's water resources. The guide is available for download at **www.deq.state.mi.us/documents/deq-swq-nps-Watershe.pdf**.

Ohio EPA's A Guide to Developing Local Watershed Action Plans in Ohio
This guide helps users develop local watershed plans. It provides background information about watershed planning, including the watershed approach, what a watershed plan is and why it is important to develop one, why the plan needs to be locally based, who should participate in planning, when to prepare the plan, and limitations to the approach. The guide also provides guidelines to help users get started with the planning process, inventory the watershed, define the problem, develop solutions and set goals, and implement the action plan. The guide is available for download at **www.epa.state.oh.us/dsw/nps/wsguide.pdf**.

Pennsylvania's Watershed Stewardship—A Planning and Resource Guide
This guide, developed by the Pennsylvania Department of Environmental Protection, consists of six toolboxes designed to give grassroots watershed groups and local governments guidance and a framework for developing comprehensive watershed plans that address local goals, are compatible with regional and state-scale planning efforts, and are based on the most current information available. The guide focuses on six components—watershed organization development and sustainability, securing financial and human resources, watershed assessments, developing the watershed management plan, implementation, and monitoring for success. The guide is available on CD or hard copy by contacting the Watershed Protection Division at 717-772 5807 or **emcdonald@state.pa.us**. The guide may also be downloaded at **http://164.156.71.80/WXLogin.aspx?dp=%2fWXOD.aspx%3ffs%3d2087d8407c0e00008000047a0000047a%26ft%3d1%26watershedmgmtNav%3d%7c37942%7c**.

The California Watershed Assessment Manual
The *California Watershed Assessment Manual* (CWAM) provides guidance for conducting a watershed assessment in California. It is intended to support the planning and technical needs primarily of watershed groups, but also local and state agencies, academic scientists, consultants, and individuals involved in developing and conducting a watershed assessment. The manual includes guidance on planning and operational principles and steps that are useful for assessment processes anywhere in the state. The topics addressed cover the primary natural and human processes in rural watersheds of northern and central California. The optimal organizational and geographic scale for use of the manual is watershed groups conducting

assessments in 10,000-acre to 1 million-acre watersheds. The guide is available for download at ↳ **http://cwam.ucdavis.edu**.

The Watershed Project Management Guide
This book presents a four-phase approach to watershed management that is based on a collaborative process that responds to common needs and goals. Chapters in the book focus on watershed importance, the watershed management process, partnership development and operation, the assessment and problem identification phase, plan development, the watershed management plan, implementation, evaluation, monitoring, models, and social building capacity. The book is available for purchase at ↳ **www.enviroscapes.com/watershed_management.htm**.

The Clean Water Act: An Owner's Manual
This manual was written by River Network to make the Clean Water Act comprehensible and usable for every American working to protect or restore a watershed. *An Owner's Manual* provides citizen activists with clear descriptions of the provisions of the act that enhance citizen involvement. The document is available for purchase at ↳ **www.rivernetwork.org/marketplace/product_details.php?item_id=55334**.

The Urban Subwatershed Restoration Manual Series
This series from the Center for Watershed Protection includes 11 manuals on techniques for restoring small urban watersheds. The entire series of manuals was written to organize the enormous amount of information needed to restore small urban watersheds in a format that watershed groups, municipal staff, environmental consultants, and other users can access easily. The manuals are organized by the following topics: an integrated approach to restore small urban watersheds, methods for developing restoration plans for small urban watersheds, stormwater retrofit practices, stream repair and restoration practices, riparian management practices, discharge prevention techniques, pervious area management practices, pollution source control practices, municipal practices and programs, a user's manual for Unified Stream Assessment (USA), and a user's manual for Unified Subwatershed and Site Reconnaissance (USSR). The manuals are available from the Center for Watershed Protection at ↳ **www.cwp.org/USRM_verify.htm**.

Colorado Nonpoint Source Forum
The Colorado Nonpoint Source Forum, which is held each year, provides tools for watershed planning. The 2004 Forum was a day-long presentation about the nuts and bolts of preparing a watershed plan. A discussion of the nine critical elements of watershed-based nonpoint source pollution control plans was also provided. Additional information about the 2004 Colorado Nonpoint Source Forum is available at ↳ **www.ourwater.org/econnection/connection15/npsforum.html**. Information about the Colorado Nonpoint Source Program is available at ↳ **www.npscolorado.com**.

Comprehensive Conservation and Management Plans
EPA's National Estuary Program (NEP) was established to improve the quality of estuaries of national importance. Clean Water Act section 320 directs EPA to develop plans for attaining or maintaining water quality in an estuary. This includes protection of public water supplies; protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife; allowance of recreational activities, in and on water; and required control of point and nonpoint sources of pollution to supplement existing controls of pollution. Each NEP establishes a Comprehensive Conservation and Management Plan (CCMP) to meet the goals of

section 320. Program-specific CCMPs are available at **www.epa.gov/owow/estuaries/ccmp/index.htm**. Additional information about the NEP is available at **www.epa.gov/nep**.

Community-Based Watershed Management: Lessons from the National Estuary Program
This document (EPA 842-B-05-003) describes the highly successful approaches to watershed management implemented by NEPs throughout the United States. The principles and lessons learned contained in the document are relevant not only to the NEPs, but also to other watershed organizations that are working to implement watershed protection and restoration efforts. To obtain a copy, contact the National Service Center for Environmental Publications (NSCEP) at 800-490-9198 or **www.epa.gov/ncepihom**.

A Guide for Local Governments: Wetlands and Watershed Management
This guidebook (by Dr. Jon Kusler, Institute for Wetland Science and Public Policy of the Association of State Wetland Managers) was written to help local governments integrate water resources management and wetland ecosystem protection efforts. The guidebook was written for engineers, biologists, botanists, planners, not-for-profit staff, legislators, and others. It makes recommendations for integrating wetlands into broad watershed management efforts and more specific water programs, including floodplain management, stormwater management, source water protection, point source pollution control, and nonpoint source pollution control programs. Case study examples are provided from throughout the nation. The guidebook is available for download at **www.aswm.org/propub/pubs/aswm/wetlandswatershed.pdf**.

Planning As Process: A Community Guide to Watershed Planning
Some of the most successful efforts at solving environmental problems have happened through local watershed planning projects. Because most environmental problems originate as local land use issues, it makes sense that local efforts should be the primary means of determining ways to control land use-generated pollution. This guide, developed by the Washington State Department of Ecology, adapts those efforts and presents a watershed planning process that has been used throughout Washington State by local entities that have successfully battled water quality problems. However, the guide can be applied to most environmental problems that require local involvement. Developing a general process that can be converted into the various applications is the idea behind this guide, which is available for download at **www.ecy.wa.gov/pubs/9901.pdf**.

Protecting the Source: Land Conservation and the Future of America's Drinking Water
The Trust for Public Land and the American Water Works Association prepared this report in 2004. The report identifies five best practices for city planners, government officials, and water suppliers involved in developing and implementing a source protection plan. The practices are (1) understanding the watershed, (2) using maps and models to prioritize protection, (3) building strong partnerships and working watershed-wide, (4) creating a comprehensive source protection plan, and (5) developing and implementing a "funding quilt." The best practices outlined in this document offer a guide to success for local communities. This report is available at **www.tpl.org/tier3_cd.cfm?content_item_id=14288&folder_id=175**.

Source Protection Handbook: Using Land Conservation to Protect Drinking Water Supplies
This handbook, prepared by Trust for Public Land and American Water Works Association in 2005, provides information about implementing the policy recommendations in Protecting the Source (2004; see above). The handbook provides resources to help a community make the case for land conservation and implement land conservation measures. The handbook has a land conservation "how-to" section, which includes lessons learned and best practices for protecting

drinking water sources, as well as nine case studies. The goal of this handbook is to strengthen the ability of water suppliers, local governments, and communities to develop protection strategies that address the threats posed by development to drinking water sources. It was produced with funding from EPA's Office of Ground Water and Drinking Water and is available at ↳ **www.tpl.org/tier3_cd.cfm?content_item_id=18298&folder_id=175**.

Path to Protection: Ten Strategies for Successful Source Water Protection
This booklet was prepared by the Trust for Public Land in 2005. It summarizes findings based on the experiences of five source water demonstration projects and proposes 10 strategies that will help put more state and local governments on the path to protection. The pilot projects were implemented around the country by five national nonprofit organizations and were funded by EPA's Office of Groundwater and Drinking Water. The purpose of the projects was to build on state Source Water Assessment Programs to move communities from planning to implementing protection for drinking water sources. The Trust for Public Land led a joint review of the five demonstration projects to glean lessons learned and identify best practices. The booklet is available at ↳ **www.tpl.org/tier3_cd.cfm?content_item_id=19077&folder_id=175**.

NRCS Watershed Resources
The Natural Resources Conservation Service provides a wide range of watershed-related guidance documents, manuals, handbooks, reports, and technical notes. They include planning tools, stream and wetlands restoration documents, information on nutrient and pest management, and information on conservation buffers. All are available at ↳ **www.nrcs.usda.gov/technical/water.html**.

County Water Quality Issue Brief: Using GIS Tools To Link Land Use Decisions to Water Resource Protection
This issue brief provides a list of commonly used GIS tools available to help county leaders link land use decisions to water resource protection. In addition, five county case studies are profiled and a new tools assessment section evaluates some commonly available tools. The document is available for download at ↳ **www.naco.org/Template.cfm?Section=New_Technical_Assistance&template=/ContentManagement/ContentDisplay.cfm&ContentID=23928**.

Smart Watershed Benchmarking Tool
Using lessons learned from around the country, the Center for Watershed Protection developed this self-assessment tool to help local program managers make better decisions on watershed restoration priorities to maximize the performance of staff and financial resources. Local watershed groups can also use this tool by determining how their community compares to others and work with their local governments to encourage adoption of practices that would improve scores. The document is available for download at ↳ **http://cwp.org.master.com/texis/master/search/+/form/Smart_Watershed.html**.

Water Quality Trading Toolkit for Permit Writers
The *Water Quality Trading Toolkit for Permit Writers* is EPA's first "how-to" manual on designing and implementing water quality trading programs. The Toolkit helps National Pollutant Discharge Elimination System (NPDES) permitting authorities incorporate trading provisions into permits. It discusses in detail the fundamental concepts of designing and implementing trading programs, which include the relevant geographic scope, effluent limitations, and other factors involved in defining a credit. The Toolkit also includes five basic trading scenarios that walk the permit writers through the components of a permit where trading

provisions can be incorporated. To download the Toolkit, ↬ go to **www.epa.gov/owow/watershed/trading/WQTToolkit.html**.

Integrating Water and Waste Programs to Restore Watersheds: A Guide for Federal and State Project Managers
This manual is targeted primarily to federal and state project managers in water and waste programs who are working on assessment or cleanup projects in watersheds contaminated by hazardous materials or waste. The manual is also a helpful reference document for stakeholders involved in watershed cleanup efforts. The goal of the manual is to enhance coordination across EPA and state waste and water programs by identifying opportunities for streamlining requirements, leveraging resources, and implementing restoration activities more efficiently. This manual provides valuable guidance and information to enable effective use of water and waste program authorities and resources to restore and protect watersheds. The manual is available at ↬ **www.epa.gov/superfund/resources/integrating.htm**.

Water Quality Trading Assessment Handbook
Water quality trading has gained increasing attention as an innovative approach for achieving water quality goals at lower cost. This handbook is intended to help you determine when and where trading is the right tool and if training will work in your watershed. It provides an analytical framework to assess the conditions and water quality problem(s) in a watershed and determine whether trading could be effectively used to meet the water quality standards. The framework is illustrated through the use of example trades in a hypothetical river basin which will familiarize the reader with the requisites and potential benefits of specific trading scenarios. To download the handbook, ↬ go to **www.epa.gov/owow/watershed/trading/handbook**.

A User's Guide to Watershed Planning in Maryland
This guide presents a common watershed planning framework for Maryland communities, assembles planning resources into one place, integrates regulatory drivers, and presents the methods necessary for completing a local watershed plan. Local government staff are the primary audience for this guide. It incorporates a review of more than 47 local watershed planning surveys; a review of existing watershed management planning guides; and research on Maryland GIS mapping, monitoring, modeling, and financial resources available to watershed planners. The methods in the guide are organized into four broad categories: desktop analysis, field assessment, stakeholder involvement, and management methods. ↬ The guide can be downloaded at **www.dnr.state.md.us/watersheds/pubs/userguide.htm**l.

The Community Watershed Assessment Handbook
This handbook is a simple watershed assessment tool that is intended to direct community groups and local governments in conducting a comprehensive environmental assessment. The purpose of the handbook is to outline a basic process for assessing your community's current and anticipated future watershed conditions. In addition, the handbook offers guidance for using the resulting assessment information as a foundation for future watershed management planning. Local governments and community organizations interested in addressing watershed-wide water quality, water supply and habitat concerns will find this handbook particularly useful. ↬ Call (800)-YOUR-BAY for a copy.

National Association of Counties (NACO) Water Program
NACo's water program is designed to help counties improve water quality and water resource management. With support from EPA and the National Oceanic and Atmospheric

Administration, NACo offers a range of services to help county officials protect water resources on the local level. NACo's water program offers financial and technical assistance to counties on stormwater, wastewater, watershed Planning and TMDLs, GIS Decision Support System Tools, wetlands, coastal habitat, and community-based wetland and habitat restoration grant programs. For more information on NACo's water quality services, visit their Web site at **www.naco.org** and click on Training and Technical Assistance, and then scroll down to Water Resource Management.

Example Watershed Plans

Mill Creek Subwatershed Management Plan, Michigan:
www.hrwc.org/program/mid.htm#plan

White Oak Creek Watershed Action Plan, Ohio:
http://brownswcd.org/action_plan.htm

Upper Neuse Watershed Management Plan, North Carolina:
www.unrba.org/projact.htm

Mill Creek Watershed Implementation Plan, Lancaster County, Pennsylvania:
www.depweb.state.pa.us/watershedmgmt/lib/watershedmgmt/nonpoint_source/implementation/mill_creek_plan.pdf

Beaver and Little Creek TMDL Implementation Plans, Washington County and City of Bristol, Virginia:
www.deq.virginia.gov/export/sites/default/tmdl/implans/bvrltlip.pdf

Clean Water Act Information

Section 319 Nonpoint Source Management Program
Congress amended the Clean Water Act in 1987 to establish the section 319 Nonpoint Source Management Program. Under section 319, states, territories, and American Indian tribes receive grant money to support a wide variety of activities, including technical assistance, financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific nonpoint source management projects. Go to **www.epa.gov/owow/nps/cwact.html**.

Nonpoint Source Program and Grants Guidelines for States and Territories
EPA has developed guidelines for state implementation of nonpoint source management programs under section 319 and for awarding of section 319 grants to states to implement those programs. The guidelines are available, under "EPA Guidance," at **www.epa.gov/owow/nps/cwact.html**.

National Pollutant Discharge Elimination System
All facilities that discharge *pollutants* from any *point source* into *waters of the United States* are required to obtain an NPDES permit. These facilities include sewage treatment plants, industrial wastewater facilities, large concentrated animal feeding operations, stormwater runoff from certain urban areas, and other facilities that discharge pollutants from a point source into surface waters regulated under the Clean Water Act. More information on the NPDES permitting program can be found at **http://cfpub.epa.gov/npdes/home.cfm?program_id=45**.

Other Federal Watershed Management Resources

Digest of Federal Resource Laws
The U.S. Fish and Wildlife Service publishes an online digest of federal resource laws of interest to water quality managers. The digest provides a comprehensive list and descriptions of all federal laws under which agencies like the Fish and Wildlife Service functions, including administrative laws, treaties, executive orders, interstate compacts, and memoranda of agreement. For more information, go to ↳ **www.fws.gov/laws/lawsdigest.htm**.

Multi-State River Compacts
Beginning with the Colorado River Compact of 1922, Congress approved about two dozen water allocation compacts in an attempt to equitably allocate and manage the waters of interstate rivers. The allocation formulas and management objectives in the river compacts vary, but for the most part they seek to protect existing uses and water rights. River compacts can provide a good framework for coordinating multiple watershed plans in large river basins. For more information on river compacts, visit ↳ **www.fws.gov/laws/lawsdigest/interstatecompacts.htm**.

Stream Corridor Restoration: Principles, Processes, and Practices
Stream corridors are increasingly recognized as critical ecosystems that support interdependent uses and values. A group of 15 federal agencies in the United States partnered in the development of a comprehensive stream restoration guide that contains extensive information on assessment, restoration practices, monitoring, and other issues. For more information, go to ↳ **www.nrcs.usda.gov/technical/stream_restoration/**.

Public Outreach and Stakeholder Involvement

Community Culture and the Environment: A Guide to Understanding a Sense of Place
This guide addresses the social and cultural aspects of community-based environmental protection. To obtain a copy, contact the National Service Center for Environmental Publications (NSCEP) at 800-490-9198 or ↳ **www.epa.gov/ncepihom**. The guide is also available at ↳ **www.epa.gov/CARE/library/community_culture.pdf**.

Getting In Step: Engaging and Involving Stakeholders in Your Watershed
This guide provide tips and tools to identify stakeholders, make decisions using consensus, build a stakeholder group, maintain momentum in the watershed planning process, and resolve conflict. The guide is available only in pdf format at ↳ **www.epa.gov/owow/watershed/outreach/documents/stakeholderguide.pdf**.

Getting In Step: A Guide for Conducting Watershed Outreach Campaigns
This guide provides detailed information on developing and conducting effective watershed outreach campaigns. You can download a pdf version at ↳ **www.epa.gov/owow/watershed/outreach/documents/getnstep.pdf**.

Know Your Watershed
The Center for Technology Information Center (CTIC) has developed a series of documents to help you to know your watershed. This information clearinghouse for watershed coordinators helps ensure measurable progress toward local goals. The clearinghouse is available at ↳ **www2.ctic.purdue.edu/kyw**.

Model Ordinance Language

Stormwater Manager's Resource Center
Located at the Center for Watershed Protection, this center provides technical assistance for stormwater management. The Center for Watershed Protection also provides a checklist to evaluate community needs and model ordinances. Go to **www.stormwatercenter.net**.

EPA's Web site for stormwater control operation and maintenance
This site provides model ordinance language, example ordinances, and supporting materials. Go to **www.epa.gov/owow/nps/ordinance/stormwater.htm**.

The Metropolitan North Georgia Water Planning District
The District provides a model stormwater management ordinance. Go to **www.northgeorgiawater.com/html/86.htm**.

Almanac of Enforceable State Laws to Control Nonpoint Source Water Pollution
This report provides a state-by-state summary, including Puerto Rico and the District of Columbia, of enforcement-based laws that are potentially applicable to nonpoint source water pollution. Go to **www.elistore.org/reports_detail.asp?ID=432**.

Putting the Water Quality Plan into Action: Tools for Local Governments
The Southeast Michigan Council of Governments provides specific actions local communities can implement to protect their water resources, including ordinances. Go to **www.semcog.org**.

Evaluation Tools

Logic Model Development Guide: Using Logic Models to Bring Together Planning, Evaluation, and Action
This guide provides a step-by-step approach for using logic models to effectively evaluate programs. It's available in pdf on the Web site at **http://wkkf.org/Default.aspx?LanguageID=0**.

Logic Model Worksheets
The University of Wisconsin Cooperative Extension has done quite a bit of research on logic models and provides online courses and worksheets that you can download at **www.uwex.edu/ces/pdande/evaluation/evallogicmodel.html**.

Seeking Signs of Success: A Guided Approach to More Effective Watershed Programs
This guide includes a step-by-step process and worksheets to conduct meaningful evaluations of watershed programs. Available for $19.95 at **www.rivercare.org**.

Establishing Watershed Benchmarks—Tools for Gauging Progress (River Network. Volume 8, Number 3)
This issue of River Voices focuses on establishing watershed benchmarks, including watershed health, organizational health, and watershed activities. Available for $2 at **www.rivernetwork.org**.

Monitoring Program Design and Implementation

Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls
This EPA manual gives an overview of nonpoint source pollution and covers the development of a monitoring plan, data analysis, quality assurance/quality control, and biological monitoring. To obtain a copy, contact the National Service Center for Environmental Publications (NSCEP) at 800-490-9198 or **www.epa.gov/ncepi**.

EPA's Monitoring and Assessment Web Site
This site includes a wealth of information on assessment and reporting guidelines, databases and mapping capabilities, biological assessment, and volunteer monitoring. Go to **www.epa.gov/owow/monitoring**.

Elements of a State Water Monitoring and Assessment Program
This guidance recommends 10 basic elements of a holistic, comprehensive monitoring program that serves all water quality management needs and addresses all waterbody types. It describes a process in which states develop a monitoring program strategy to implement these basic components over a period of up to 10 years. Go to **www.epa.gov/owow/monitoring/elements**.

DQOs, MQOs, and Performance Characteristics

The Methods and Data Comparability Board
This board, a work group of the National Water Quality Monitoring Council, has developed data and method quality objectives tools. Go to **http://wi.water.usgs.gov/methods/tools/dqomqo/index.htm**.

Consolidated Assessment and Listing Methodology (CALM), Appendix C
Appendix C provides information on statistical considerations for data quality objectives and data quality assessments in water quality attainment studies. Go to **www.epa.gov/owow/monitoring/calm/calm_appc.pdf**.

Quality Assurance Project Plans
Quality assurance project plans document the planning, implementation, and assessment procedures for a particular project, as well as any specific quality assurance and quality control activities. They integrate all the technical and quality aspects of the project to provide a "blueprint" for obtaining the type and quality of environmental data and information needed for a specific decision or use. For more information, go to **http://epa.gov/quality/qapps.html.**

Sampling Design

Biological Criteria: Technical Guidance for Survey Design and Statistical Evaluation of Biosurvey Data
This guidance provides methods to help managers interpret and gauge the confidence with which biological criteria can be used to make resource management decisions. Go to **www.epa.gov/bioiweb1/html/biolstat.html**.

Sampling and Analysis Plans (SAPs)
For more information on SAPs, check out the U.S. Army Corps of Engineers' publication titled *Engineering and Design—Requirements for the Preparation of Sampling and Analysis Plans* (specifically chapter 3, Sampling and Analysis Plan: Format and Contents, and Appendix J,

Sampling and Analysis Plan Review Checklist). Go to **www.usace.army.mil/publications/eng-manuals/em200-1-3**.

Visual Stream Assessment Tools

Izaak Walton League Save Our Streams Program
The Save Our Streams (SOS) program is a national watershed education and outreach tool to provide innovative educational programs for groups and individuals. SOS has educated and motivated citizens to clean up stream corridors, monitor stream health, restore degraded streambanks, and protect dwindling wetland acreage through biological and other assessments, education, and training. Go to **www.iwla.org/sos**.

Rapid Stream Assessment Technique (RSTAT)
RSAT is a methodology for visually evaluating a stream to assess the stream quality and to identify potential pollutant sources. RSAT was developed for Montgomery County, Maryland, to provide a simple, rapid, reconnaissance-level assessment of stream quality conditions. Go to **www.stormwatercenter.net/monitoring%20and%20assessment/rsat/smrc%20rsat.pdf**.

Stream Visual Assessment Protocol (SVAP)
SVAP is designed as an introductory, screening-level assessment method for people unfamiliar with stream assessments. The SVAP measures a maximum of 15 elements and is based on visual inspection of the physical and biological characteristics of instream and riparian environments. To download a copy of an SVAP document, go to **www.nrcs.usda.gov/technical/ECS/aquatic/svapfnl.pdf**.

Unified Subwatershed and Site Reconnaissance (USSR)
USSR is designed to assess upland areas for behaviors that can potentially influence water quality and to identify promising restoration project opportunities. Go to **www.cwp.org**.

Biological Assessment

Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, 2nd edition
This document describes refined and revised methods for conducting cost-effective biological assessments of streams and small rivers. It focuses on periphyton, benthic macroinvertebrates, and fish assemblages and on assessing the quality of the physical habitat. Go to **www.epa.gov/owow/monitoring/rbp**.

Stressor Identification Guidance Document
This guidance leads water resource managers through a rigorous process to identify stressors that cause biological impairment in aquatic ecosystems and to assemble cogent scientific evidence that supports conclusions about potential causes. Go to **www.epa.gov/waterscience/biocriteria/stressors/stressorid.html**.

Summary of Assessment Programs and Biocriteria Development for States, Tribes, Territories, Interstate Commissions: Streams and Wadeable Rivers
This EPA document includes an overview of biological assessment programs and protocols used at the state level. Go to **www.epa.gov/bioindicators**.

Modeling Tools

Compendium of Tools for Watershed Assessment and TMDL Development

The Compendium supports the watershed approach by summarizing available techniques and models that assess and predict physical, chemical, and biological conditions in waterbodies. Go to **www.epa.gov/OWOW/tmdl/comptool.html**; for more technical resources, visit **www.epa.gov/owow/tmdl/techsupp.html**.

The Council on Regulatory Environmental Modeling

The CREM promotes consistency and consensus within the Agency on mathematical modeling issues, including model guidance, development, and application, and it enhances internal and external communications on modeling activities. CREM is the Agency's central point for addressing modeling issues. It has a comprehensive online database that provides links to model reviews and resources. Go to **http://cfpub.epa.gov/crem**.

Management Measures

Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters

This 1992 EPA document describes management measures and associated management practices for all six nonpoint source categories. The document includes extensive cost and effectiveness information, as well as examples and detailed descriptions of management practices. EPA has updated and expanded several chapters of the 1992 guidance. Updated sections are available for agriculture, forestry, marinas and recreational boating, and urban areas. All the chapters can be downloaded at **www.epa.gov/owow/nps/pubs.html**.

International Stormwater Best Management Practices Database

This database is operated by the Urban Water Resources Research Council of the American Society of Civil Engineers under a cooperative agreement with EPA. The database provides technical documents, software, and tools to evaluate the effectiveness of stormwater runoff BMPs. The tools include standardized BMP monitoring and reporting protocols, a stormwater BMP database, BMP performance evaluation protocols, and BMP monitoring guidance. Go to **www.bmpdatabase.org**.

National Handbook of Conservation Practices

Written in 1977 by the Natural Resources Conservation Service, this handbook is updated annually. It provides details on nationally accepted management practices and is available in hard copy and electronically at **www.nrcs.usda.gov/technical/standards/nhcp.html**.

National Menu of BMPs for Storm Water Phase II

EPA developed this compliance assistance tool to help small communities develop stormwater management programs and select management practices to control pollutants in runoff. It includes descriptions, cost and effectiveness data, and case study examples for more than 100 management practices. Go to **http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm**.

Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures

Three documents provide information on the techniques used to track, evaluate, and report on the implementation of nonpoint source control measures. Each document focuses on a different measure—agriculture, forestry, and urban areas. Go to **www.epa.gov/owow/nps/pubs.html**.

National Management Measures to Control Nonpoint Source Pollution from Urban Areas
This guidance provides information on polluted runoff sources, impacts, and management measures for all urban and urbanizing areas, including those covered by the NPDES stormwater program. The introduction includes specific comparisons of the nonpoint source management measures described in this guidance with the six minimum control measures to be addressed for the NPDES Phase II permit program. Go to **www.epa.gov/owow/nps/urbanmm/index.html**.

Onsite and Clustered (Decentralized or Distributed) Wastewater Management
EPA has developed several tools designed to help local communities manage decentralized (distributed) wastewater treatment systems. These include a handbook for developing or improving existing management programs, a set of guidelines that describe five generalized management models, a design guide, technology fact sheets, case studies of successful programs, a homeowners' guide, and more. To access these tools, visit **http://cfpub.epa.gov/owm/septic/index.cfm**.

BMP Costing Information

A list of currently available cost references is provided below. Most of these references are available for free download, but some might be available only at a university library or by purchase. You should look for local costs before using these references because construction costs and designs vary between states.

USEPA BMP Fact Sheets
This comprehensive list of BMP fact sheets contains information on construction and maintenance costs, as well as other monetary considerations. Information is provided on both structural and nonstructural BMPs. Go to **http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm**.

Environmental Quality Incentives Program
Some state NRCS offices publish cost information on agricultural practices to support the Environmental Quality Incentives Program (EQIP). For an example of this cost information, go to the "cost lists" section of the following Web site: **www.nc.nrcs.usda.gov/programs/EQIP/2005Signup.html**.

Rouge River National Wet Weather Demonstration Project
This demonstration project has produced cost-estimating criteria for both structural and nonstructural management practices. The project continues to publish information on recent BMP projects. The most recent cost-estimating criteria are at **www.rougeriver.com/pdfs/stormwater/sr25.pdf**.

International Stormwater BMP Database
The American Society of Civil Engineers and EPA have developed a stormwater BMP database that contains site-specific BMP information from across the country. Depending on the location and type of BMP, the database might provide BMP cost information. It's available at **www.bmpdatabase.org**.

Low Impact Development Center
Among many LID resources, the Low Impact Development Center offers a series of fact sheets with BMP construction and maintenance cost information at **www.lid-stormwater.net/intro/sitemap.htm**.

RS Means Construction Cost Data
RS Means publishes construction cost data and updates this information annually. RS Means publications usually can be found at university libraries. In addition to construction cost, the RS Means publications contain indices for converting prices between cities and states. Go to **www.rsmeans.com**.

Performance and Whole Life Costs of Best Management Practices and Sustainable Urban Drainage Systems
This 2005 publication provides an extensive review of BMP costing techniques for selected controls, as well as a spreadsheet model to estimate costs. Reviewers include Black & Veatch Corporation; Center for Research in Water Resources, University of Texas; Glenrose Engineering; Urban Water Technology Center, University of Abertay; HR Wallingford Ltd.; and Black & Veatch Consulting Ltd. The document is available from the Water Environment Research Foundation (WERF) at **www.werf.org**.

Funding Resources

List of Watershed Funding Resources
This EPA Web site provides tools, databases, and information about sources of funding that serve to protect watersheds. Go to **www.epa.gov/owow/funding.html**.

List of NPS Funding Opportunities
This EPA site provides links to various federal, state, and private funding sources available to address nonpoint source issues. Go to **www.epa.gov/owow/nps/funding.html**.

Catalog of Federal Funding Opportunities
This interactive EPA Web site helps match project needs with funding sources. It also provides administrative guidelines and applicability for each source. Go to **www.epa.gov/watershedfunding**.

Grassroots Fundraising Journal
The Grassroots Fundraising Journal helps nonprofit organizations learn how to raise more money to support their goals. It offers practical how-to instructions on implementing fundraising strategies such as direct mail, special events, major gift campaigns, and phone-a-thons. It also has tools to help you build a board of directors that is willing to raise money, choose a database to track donors, manage your time effectively, and ultimately develop a successful fundraising program. Go to **www.grassrootsfundraising.org/index.html**.

A Guidebook of Financial Tools
EPA's Environmental Financial Advisory Board and the Agency's network of university-based Environmental Finance Centers developed this guidebook as a working tool to enable practitioners in the public and private sectors to find appropriate methods to pay for environmental protection efforts. Go to **www.epa.gov/efinpage/guidebook/guidebooktp.htm**.

Appendix B: Worksheets

Worksheet 3-1 *Identifying Stakeholder Skills and Resources*

Name: ______________________________

Phone: ______________________________

E-mail: ______________________________

Skills/resources	If you possess these skills or have access to these resources	Comments
Skills in Stakeholder Group		
Accounting		
Graphic design		
Computer support		
Fund-raising		
Public relations		
Technical expertise (e.g., geographic information systems, water sampling)		
Facilitation		
Other		
Other		
Resources Available		
Contacts with media		
Access to volunteers		
Access to datasets		
Connections to local organizations		
Access to meeting facilities		
Access to equipment (please describe)		
Access to field trip locations		
Other		
Other		
Other		

Please identify any other skills or resources you bring to the group:

Worksheet 4-1 *What Do We Already Know?*

1. What are the known or perceived impairments and problems in the watershed?

2. Do we already know the causes and sources of any water quality impairments in the watershed? If so, what are they?

3. What information is already available, and what analyses have been performed to support development of a TMDL, watershed plan, or other document?

4. Have the relative contributions from major types of sources of the pollutant or stressor causing impairment been estimated?

5. Are there any historical or ongoing management efforts aimed at controlling the problem pollutants or stressors?

6. Are there any threats to future conditions, such as accelerated development patterns?

7. Have any additional concerns or goals been identified by the stakeholders?

Worksheet 4-2 *What Ecosystem Issues Need to Be Considered?*

1. What are the sensitive habitats and their buffers, both terrestrial and aquatic?

2. Where are these habitats located in the watershed?

3. What condition are these habitats in?

4. Are these habitats facing any of the following problems?

   a. Invasive species

   b. Changes associated with climate warming

   c. Stream fragmentation and/or in-stream flow alterations

   d. Changes in protection status

5. On what scale are these habitats considered? (e.g., regional, watershed, subwatershed, or site-specific)

Worksheet 4-3 Building a Conceptual Model

The conceptual model is essentially made up of three parts—the sources (at the top); the impairments (at the bottom); and the stressors (or the steps/relationships between the sources and impairments (in the middle).

1. Start at the end: Define the impairments

The impairments are the endpoints for the conceptual model. Add the impairments in boxes at the bottom of the next page. Put each impairment in its own box on the worksheet. Be as specific as possible. Keep the impairments on the same sheet (don't make a separate model for each impairment). You might find that the impairments share a common source and are linked in unexpected ways.

2. Go to the top

Start listing the most likely sources of impairment. In general, you will identify many more sources than impairments. List the sources in boxes at the top of the next page.

3. Identify the stressors and impacts that link sources to impairments

These boxes provide the links between the sources and the impairments. Draw in as few or as many stressors and impacts as are needed to show cause and effect between sources, stressors, and impairment.

4. Connect the sources, stressor, impacts, and impairments

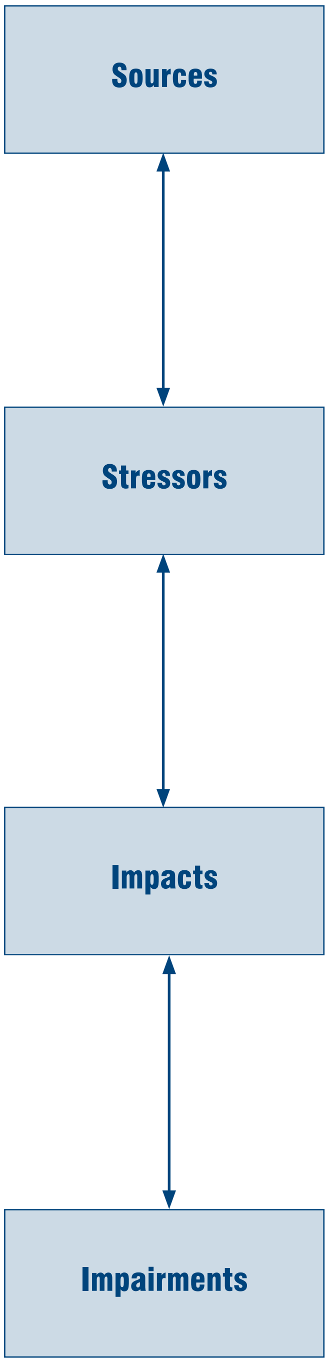
Start drawing arrows between the sources, linkages, and impairments. You might have arrows that go from sources to sources (e.g., between logging and unpaved roads), from sources to linkages, and finally from linkages to the impairments.

Examples

Use the template and examples on the next page as guides to identifying sources, stressors, impacts, and impairments in your watershed.

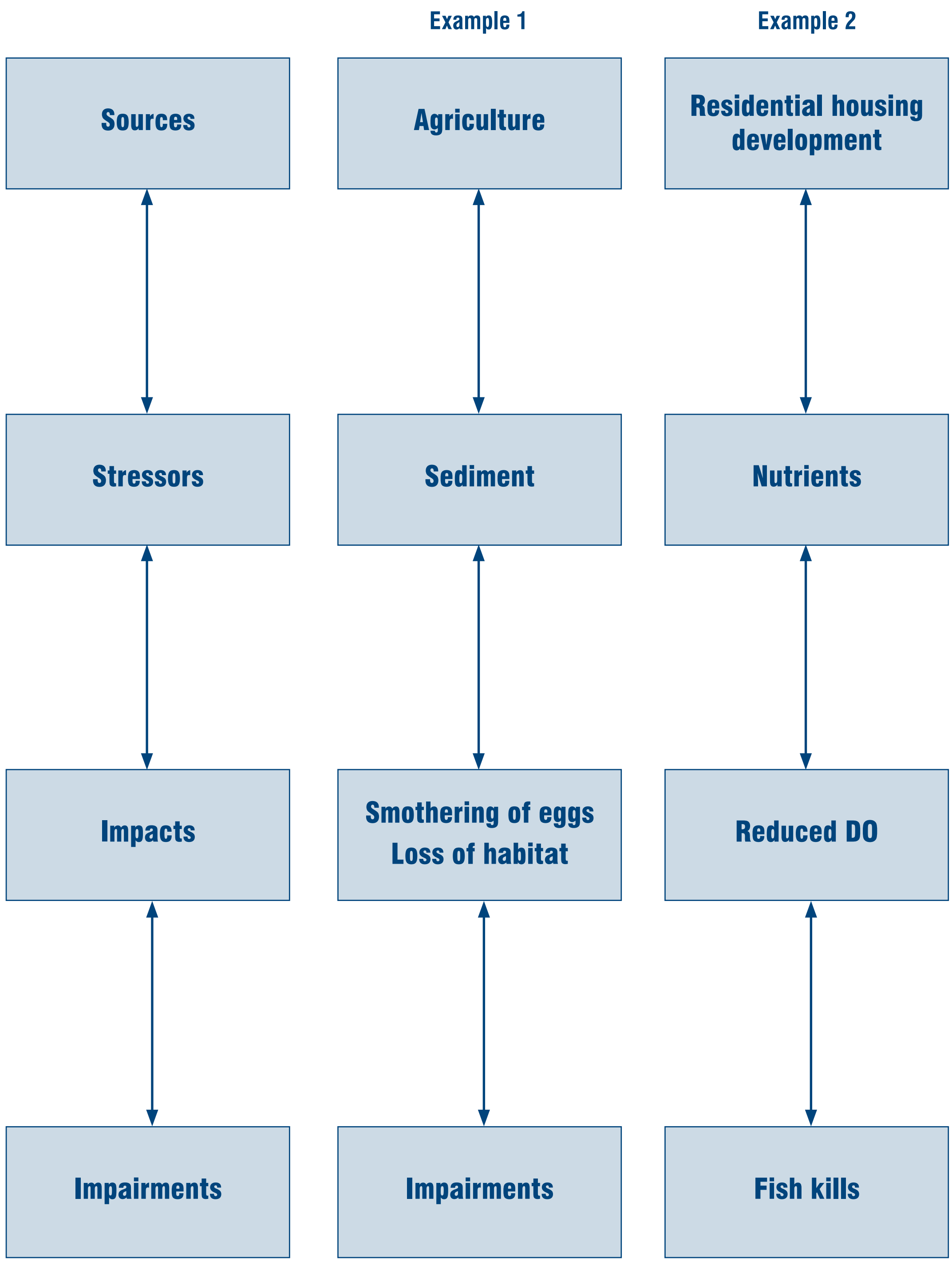
Worksheet 4-3 *Building a Conceptual Model* (continued)

Your sources here



your impairments here

Worksheet 4-3 *Building a Conceptual Model* (continued)



Worksheet 4-4 *Identifying Concerns, Causes, Goals, and Indicators*

What are the problems/ concerns in the watershed?	What do you think caused the problems?	How can we assess current conditions? (Indicators)	What would you like to see for your watershed? (Goals)	How will we measure progress toward meeting those goals? (Indicators)

Worksheet 7-1 What Data Analysis Do We Need to Conduct for Water Quality?

Questions to help determine what kinds of data analyses are needed

Question **Answer**

1. Are water quality standards being met?
   If so, are they maintaining existing levels?
2. Is water quality threatened?
3. Is water quality impaired?
4. Are there known or expected sources causing impairment?
5. Where do impairments occur?
6. When do the impairments occur? Are they affected by seasonal variations?
7. Under what conditions (e.g., flow, weather) are the impairments observed?
8. Do multiple impairments (e.g., nutrients and bacteria) coexist?)
9. Are there other impairments that are not measured by water quality standards?

Questions to answer based on the results of the data analysis:

1. What beneficial uses for the waterbodies are being impaired?
   What pollutants are impairing them?
2. What are the potential sources, nonpoint and point, that contribute to the impairment?
3. When do sources contribute pollutant loads?
4. How do pollutants enter the waterbody (e.g., runoff, point sources, contaminated ground water, land uses, ineffective point source treatment, pipe failures)?
5. What characteristics of the waterbody, the watershed, or both could be affecting the impairment (e.g., current or future growth, increased industrial areas, future NPDES permits, seasonal use of septic systems)?
6. Revisit the conceptual model showing the watershed processes and sources, and revise it if necessary.

Worksheet 7-2 *What Data Analysis Do We Need to Conduct for Habitat Assessment and Protection?*

1. Where are critical habitats (e.g., headwaters, wetlands, forests, springs and seeps) and their buffers located?

2. What is their conservation status?

3. What is their condition?

4. Are they threatened?

5. Are there opportunities to protect or restore buffers or fill a habitat connectivity gap to reduce fragmentation and protect source water?

6. How does spatial hierarchy (e.g., site, subwatershed, watershed, basin, and region) factor into habitat protection and restoration goals?

7. What are the current and future development projections and who will they affect habitats and their buffers?

Worksheet 10-1 Identifying Existing Management Efforts

Wastewater Discharges

(Source of information: state water quality program administering NPDES permits)

1. Where are wastewater discharges located in the watershed?
   If possible, map the locations.

2. What volume of wastewater is being discharged?

3. What are the parameters of concern in the effluent?

4. For each permit, what are the existing requirements?

5. What is the recent (5-year) history of permit compliance? How severe are the violations, and what caused them?

6. Are significant treatment plant upgrades being planned?
   If so, will the future discharge show a net increase or decrease in pollutant loading?

7. Have potential threats to diminishing water supplies been identified in a source water assessment?

On-Site Wastewater Treatment Systems

(Source of information: local health department)

8. Where are on-site systems located? If possible, map the locations.

9. Are there known concentrations of failing on-site systems? If so, where?

10. Is there a homeowners' education program for proper maintenance of on-site systems?
    Is there an inspection program?

11. What is the depth of the water table?

Worksheet 10-1 *Identifying Existing Management Efforts* (continued)

Urban Stormwater Runoff

(Source of information: local government engineering and planning department)

12. Are cities and counties in the watershed covered by an NPDES stormwater permit?
    If so, what are the conditions of the permit?

13. Do local governments in the watershed have stormwater ordinances?
    If so, what are the requirements?

14. Do the regulations address stormwater volume and pollutant loading?

15. Do the stormwater requirements apply to redevelopment of existing developed areas?

16. Does the local government have a public education program for pollution prevention?

17. Does the local government have a stream restoration and BMP retrofit program?
    Are projects being located in your watershed?

18. Are any new ordinances or programs being developed or planned?

Agricultural and Forestry Practices

(Sources of information: local NRCS Conservation District office and Forest Service office, state soil and water district office, and state forestry service office)

19. Are there areas with active farming or logging in the watershed?
    If so, map them if possible.

20. Are management plans in place where these activities are occurring?

Worksheet 10-1 Identifying Existing Management Efforts (continued)

21. What percentage of the area uses management practices for controlling sediment and other pollutants? Are these practices effective? If not, why? Are monitoring data available?

22. For areas not using management practices to control runoff, what have been the obstacles to their use?

23. Are there existing stream side buffers? If so, how wide are they?

Note: Farm*A*Syst is a voluntary, confidential program in each state that helps farmers and ranchers evaluate pollution risks to their property and take preventive action to reduce those risks. Further state program information and Web links can be accessed through www.uwex.edu/farmasyst/index.html. Click on “Resources” and the state of interest. Other programs that have developed from Farm*A*Syst include Forest*A*Syst, Stream*A*Syst, and Cotton*A*Syst. Forest*A*Syst provides a series of questions for landowners on the types of practices conducted on their forestland. Stream*A*Syst is a set of materials that landowners review to determine whether there are stream-related factors to improve with better management practices. Cotton*A*Syst is an assessment tool to measure current levels of integrated pest management (IPM) implementation and help cotton farmers improve management practices.

Wetlands and Critical Habitat Protection

(Sources of information: Association of State Wetlands Managers, Association of State Floodplain Managers, local wetlands partners)

24. Have wetlands been identified and evaluated for the habitat value, water quality benefits, and flood control contributions?

25. To what extent do natural buffers and floodplains remain in the watershed?

26. What projects have created or restored wetlands and wetland formations?

27. To what extent are critical habitats such as headwater streams, seeps, and springs that provide many critical functions (e.g., habitat for aquatic organisms) being protected?

28. Has the natural hydrologic connectivity been mapped? If so, are there management practices in place to restore any fragmentation of stream networks?

Worksheet 10-2 *Documenting Management Measure Opportunities and Constraints*

Sources (e.g., streambanks, urban stormwater, malfunctioning septic systems, livestock in stream)
Causes (e.g., eroding streambanks, unlimited access of livestock, undersized culverts)
Name of management measure or program (NRCS code if applicable)
Data source (i.e., where you obtained your information on the management measure)
Description (what it is and what it does)
Approximate unit cost (including installation and operation and maintenance costs; may be expressed as a range)
Approximate or relative load reduction for each parameter of concern (could be high, moderate, low, or unit reduction per acre per year)
Planning considerations (e.g., project factors such as site size and contributing watershed area; physical factors such as slope, depth of water table, and soil type limitations or considerations; operation and maintenance requirements)
Skill needed to implement the management measures (e.g., engineering, landscape design, construction)
Permitting considerations
Other (e.g., stakeholders' willingness to use the measure)

Worksheet 12-1 Template for Implementation Plan Matrix

Note: prepare one worksheet for each management objective identified.

Watershed Goal:

Management Objective (MO 1):

Implementation Activities						
Management Measures	**Who Needs to Be Involved? (Authorities/ Resp. Party/Other**	**Costs (Annual/ Total Funding Sources)**	**Schedule/Milestones**			
			Short	**Med**	**Long**	**Remaining**
MM 1 Benefits/ estimated load reduction						
MM 2 Benefits/ estimated load reduction						
MM 3 Benefits/ estimated load reduction						

I/E Activities
I/E 1
I/E 2
I/E 3

Monitoring Component

Worksheet 12-2 Developing Criteria to Measure Progress in Meeting Water Quality Goals

[Note: Complete one worksheet for each management objective identified.]

Management Objective: Reduce nutrient inputs into Cane Creek by 20 percent				
Indicators to Measure Progress	**Target Value or Goal**	**Interim Targets**		
		Short-term	**Medium-term**	**Long-term**

Worksheet 12-3 *Basic Components of a Watershed Plan*

Key watershed planning components	Done?	Comments
Include the geographic extent of the watershed covered by the plan.		
Identify the measurable water quality goals, including the appropriate water quality standards and designated uses.		
Identify the causes and sources or groups of similar sources that need to be controlled to achieve the water quality standards.		
Break down the sources to the subcategory level.		
Estimate the pollutant loads entering the waterbody.		
Determine the pollutant load reductions needed to meet the water quality goals.		
Identify critical areas in which management measures are needed.		
Identify the management measures that need to be implemented to achieve the load reductions.		
Prepare an I/E component that identifies the education and outreach activities needed for implementing the watershed management plan.		
Develop a schedule for implementing the plan.		
Develop interim, measurable milestones for determining whether management measures are being implemented.		
Develop a set of criteria to determine whether loading reductions are being achieved and progress is being made toward attaining (or maintaining) water quality standards, and specify what measures will be taken if progress has not been demonstrated.		
Develop a monitoring component to determine whether the plan is being implemented appropriately and whether progress toward attainment or maintenance of applicable water quality standards is being achieved.		
Estimate the costs to implement the plan, including management measures, I/E activities, and monitoring.		
Identify the sources and amounts of financial and technical assistance and associated authorities available to implement the management measures.		
Develop an evaluation framework.		

Worksheet 12-4 Example Checklist for Reviewing Section 319 Work Plans

319 WATERSHED PLANT REVIEW LIST

Watershed:

Plan(s): Document(s) reviewed and dates.

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. Sources that need to be controlled should be identified at the significant subcategory level with estimates of the extent to which they are present in the watershed (e.g., including a rough estimate of the number of cattle per facility, Y acres of row crops needing improved nutrient management or sediment control, or Z linear miles of eroded streambank needing remediation).

- ❑ Plan(s) meets element as demonstrated.
- ❑ Plan(s) **does not** meet element. The following additional information is required:

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). Estimates should be provided at the same level as in item a above (e.g., the total load reduction expected for row crops, or eroded streambanks).

- ❑ Plan(s) meets element as demonstrated.
- ❑ Plan(s) **does not** meet element. The following additional information is required:

c. A description of the BMPs and techniques (nonpoint source management measures) that are expected to be implemented to achieve the load reductions estimated under item 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 (by pollutant or sector) in which those measures will be needed to implement this plan.

- ❑ Plan(s) meets element as demonstrated.
- ❑ Plan(s) **does not** meet element. The following additional information is required:

Worksheet 12-4 Example Checklist for Reviewing Section 319 Work Plans (continued)

d. An estimate of the amounts of technical and financial assistance needed, monitoring and I&E cost, associated administrative costs, and/or the sources and authorities that will be relied on to implement the entire plan (include administrative, I&E, and monitoring costs). Expected sources of funding, states to be used section 319 programs, State Revolving Funds, USDA's Environmental Quality Incentives Program and Conservation Reserve Program, and other relevant federal, state, local, and private funds to assist in implementing this plan.

- ❑ Plan(s) meets element as demonstrated.
- ❑ Plan(s) does **not meet** element. The following additional information is required:

e. An information/education component that will be implemented to enhance public understanding of the project and enable the public's early and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented (cost needs to be included in item d above).

- ❑ Plan(s) meets element as demonstrated.
- ❑ Plan(s) **does not** meet element. The following additional information is required:

f. A schedule for implementing the activities and NPS management measures identified in this plan.

- ❑ Plan(s) meets element as demonstrated.
- ❑ Plan(s) **does not** meet element. The following additional information is required:

g. A description of interim, measurable milestones for determining whether NPS management measures or other control actions are being implemented and what will be done if the project is not meeting its milestones.

- ❑ Plan(s) meets element as demonstrated.
- ❑ Plan(s) **does not** meet element. The following additional information is required:

Worksheet 12-4 Example Checklist for Reviewing Section 319 Work Plans (continued)

h. A set of environmental criteria that will be used to determine whether loading reductions are being achieved over time, and substantial progress is being made toward attaining water quality standards. These criteria provide the basis for determining whether the watershed-based plan needs to be revised or whether the nonpoint source TMDL needs to be revised.

- ❑ Plan(s) meets element as demonstrated.
- ❑ Plan(s) **does not** meet element. The following additional information is required:

i. A monitoring and evaluation component to track progress and evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under items g and h above.

- ❑ Plan(s) meets element as demonstrated.
- ❑ Plan(s) **does not** meet element. The following additional information is required:

Worksheet 12-5 *Missouri's Nine-Element Watershed Management Planning Worksheet*

The attached worksheet provides guidance for the development of watershed management plans that meet the requirements of the Environmental Protection Agency to be eligible for certain grant funding. It is designed to help the user find basic information to begin the development of these watershed management plans, as well as providing information about the nine elements that are required in the plan. The completion of this worksheet does not constitute an approved plan, but it should provide the user with the basic necessary information from which an approved watershed management plan can be developed and ultimately implemented.

Completing the Worksheet:

This worksheet must include the Waterbody Identification Number (WBID) of the impaired waterbody that the planning effort will impact.

If a Total Maximum Daily Load (TMDL) has been written for the watershed, the Watershed Management Plan must be designed to achieve the reduction in pollutant load called for in the NPS Total Daily Maximum Load (TMDL). If a TMDL has not been developed for the waterbody, the plan must include implementation practices to remove the waterbody from the 303(d) list.

Project Name:	**Waterbody Name(s)**	**Waterbody ID Number**
Project Sponsor:		
Address:		
Project Manager:		
Phone:		
E-mail:		

Watershed Identification					
Name of Watershed:					
HUC Codes for all 14-Digit Watersheds in Planning Effort:					
Total Area Encompassed in Planning Effort (Acres):					
Approved TMDLs with nonpoint source impairments (if any) **See Attachment B**	Waterbody	WBID	Size	Pollutant(s)	Source
Does the area encompass a Public Water Supply?	Yes ❑	Name(s):			
	No				

Worksheet 12-5 *Missouri's Nine-Element Watershed Management Planning Worksheet* (continued)

Elements of the Watershed Management Plan (see Attachment C)									
Element A Pollutant(s) Addressed in the Plan:	**Pollutant Category** (see Attachment D) (Mark all that apply)								**Element A** Quantify Sources of Pollutant (e.g., # of cattle, # of acres, miles of stream, etc.)
	Ag CP	**Ag AP**	**Silv.**	**C**	**U/ SW**	**HM**	**LD**	**RE**	
Sediment									
Nutrients									
Pesticides									
Fecal Coliforms									
Dissolved Oxygen									
Metals									
pH									
Other/Unknown									

AgCP-Agriculture Crop Production, **AgAP**-Agriculture Animal Production, **Silv.**-Silviculture, **C**-Construction, **U/SW**-Urban/Stormwater, **HM**-Hydrologic/Habitat Modification, **LD**-Land Disposal, **RE**-Resource Extraction

NPS Management Measures—Element C		
BMP to Be Implemented (For a list of some BMPs, refer to the Natural Resources Conservation Service's (NRCS) Electronic Field Office Technical Guide)	**Total # or Area Unit of Measure**	**Estimate of Pollutant Load Reduction—Element B**

Describe Methods Used to Estimate Pollutant Load Reduction:

Worksheet 12-5 Missouri's Nine-Element Watershed Management Planning Worksheet (continued)

Estimate of Assistance Needed—Element D	
Agency Providing Technical Assistance (For a list of some agencies, refer to appendix J of the Nonpoint Source Management Plan)	**Technical Assistance to be Provided**

Agency Providing Technical Assistance (For a list of some agencies, refer to appendix J of the Nonpoint Source Management Plan)	**Amount of Financial Assistance Provided**

Schedule for BMP Implementation—Element F				
	Anticipated Date of Completion			
BMP to Be Implemented	25% complete	50% complete	75% complete	100% complete

Description of Interim Milestones—Element G	
Describe interim, measurable milestones:	
Method Used to Determine Load Reduction—Element H	**Pollutant Type(s)**
Fixed Station Network	
Intensive Surveys	
Toxics Monitoring Program	
Biological Monitoring Program	
Fish Tissue Analysis	
Volunteer Monitoring Program	
Other(s)	

Worksheet 12-5 *Missouri's Nine-Element Watershed Management Planning Worksheet* (continued)

Monitoring Program—Element 1
Describe monitoring component(s):

Information/Education Component—Element E
Describe information/education component(s):

Worksheet 13-1 *Sample Watershed Stakeholder Committee Evaluation*

Possible Evaluation Questions for Participants

Purpose: To determine how the level of participation in the Watershed Stakeholder Committee has changed over the past 2 years and why, and to assess the usefulness of the Committee.

Name/Affiliation:

Participation

1. How many Watershed Stakeholder Committee meetings have you participated in over the past 2 years?

2. If you have not participated in all the meetings, what factors would have increased your participation?
   - ❑ Hosting the meeting closer to where I live.
   - ❑ Hosting the meeting at a time that was more convenient for me, such as .
   - ❑ Providing more advance notice of where and when the meeting was to be held.
   - ❑ Including topics for discussion that were more relevant to my interests.
   - ❑ Other:

Group Structure

1. Do you feel the size of the group was adequate? Please explain.

2. Do you feel the composition of the group was representative of the watershed community? Please explain.

Group Input

1. Do you feel the meetings were held to optimize participation from the attendees? Please explain.

2. Do you feel that your input was incorporated into the watershed management planning process? Please explain.

Overall Recommendations

1. What do you think are the most useful aspects of the Watershed Stakeholder Committee?

2. What do you think can make the Watershed Stakeholder Committee more useful?

3. Would you like to be involved in future watershed protection efforts?

Worksheet 13-2 Sample Topics to Discuss at Quarterly Review of Watershed Management Plan

Review Administrative and Management Activities

1. Are we on track with resources and expenditures?
2. Do we have any gaps in skills or do we need additional technical assistance?
3. What implementation activities have occurred since the last quarterly meeting?
4. Are we meeting our implementation milestones?
5. What are the next management measures to be implemented?
6. Do we have the resources/skills/authorities to proceed?

Review I/E Activities

7. Are we getting participation at the events?
8. What materials have been produced?
9. How were they distributed?
10. What are the upcoming I/E activities?

Review Monitoring Activities

11. Are we meeting our interim load reduction targets?
12. When is the next round of monitoring?
13. How will we publicize the monitoring results?

Additional Issues

14. Are there any upcoming initiatives or new regulatory requirements of which we need to be aware?
15. Are there any additional issues that we need to discuss?

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Glossary

The following terms are used throughout this handbook. Refer back to this list if you need to determine the meaning of any of these terms. In addition, EPA's Terms of Environment: Glossary, Abbreviations and Acronyms provides definitions for a variety of environmental terms and is available at **www.epa.gov/OCEPAterms**.

Baseline	An initial set of observations or data used for comparison or as a control; a starting point.
Beneficial uses	See Designated uses.
Best management practice (BMP)	A method that has been determined to be the most effective, practical means of preventing or reducing pollution from nonpoint sources.
Biocriteria	The biological characteristics that quantitatively describe a waterbody with a healthy community of fish and associated aquatic organisms. Components of biocriteria include the presence and seasonality of key indicator species; the abundance, diversity, and structure of the aquatic community; and the habitat conditions required for these organisms.
Calibration	Testing and tuning of a model to a set of field data not used in developing the model; also includes minimization of deviations between measured field conditions and output of a model by selecting appropriate model coefficients.
Clinger richness	A metric used to measure the diversity of macroinvertebrates that have the ability to attach to the substrate in flowing water.
Coefficient of skewness (g)	Most commonly used measure of skewness. It is influenced by the presence of outliers because it is calculated using the mean and standard deviation.
Combined sewer overflow (CSO)	Overflow from systems designed to collect runoff, domestic sewage, and industrial wastewater in the same pipe system.
Criteria	Standards that define minimum conditions, pollutant limits, goals, and other requirements that the waterbody must attain or maintain to support its designated use or uses. Criteria describe physical, chemical, and biological attributes or conditions as measurable (e.g., parts per million of a certain chemical) or narrative (e.g., no objectionable odors) water quality components.
CWA section 303(d)	Section of the Clean Water Act under which states, territories, and authorized tribes are required to develop lists of impaired waters.
CWA section 305(b)	Section of the Clean Water Act under which states are required to prepare a report describing the status of their water quality every 2 years.

CWA section 319	Section of the Clean Water Act under which EPA has developed guidelines to help states, territories, and tribes implement nonpoint source pollutant management programs and provide grants to fund the programs.
Delineation	The process of identifying a watershed boundary on the basis of topographic information.
Designated use	Simple narrative description of water quality expectations or water quality goals. A designated use is a legally recognized description of a desired use of the waterbody, such as (1) support of communities of aquatic life, (2) body contact recreation, (3) fish consumption, and (4) public drinking water supply. These are uses that the state or authorized tribe wants the waterbody to be healthy enough to fully support. The Clean Water Act requires that waterbodies attain or maintain the water quality needed to support designated uses.
Discounting	The process of calculating the present value of a project on the basis of the current value of the projected stream of costs throughout the project's lifetime.
Eutrophication	Enrichment of an aquatic ecosystem with nutrients (nitrogen, phosphorus) that accelerate biological productivity (growth of algae and weeds) and an undesirable accumulation of algal biomass.
First-order decay	A reaction in which the concentration decreases exponentially over time.
Geographic information system (GIS)	A tool that links spatial features commonly seen on maps with information from various sources ranging from demographics to pollutant sources.
Hydrologic unit code (HUC)	A unique code, consisting of two to eight digits (based on the four levels of classification in the hydrologic unit system), that identifies each hydrologic unit.
Information/ education (I/E) activities	Public outreach.
Impaired waterbody	A waterbody that does not meet the criteria that support its designated use.
Indicator	Direct or indirect measurements of some valued component or quality in a system. Can be used to measure the current health of the watershed and to provide a way to measure progress toward meeting the watershed goals.
Interquartile range (IQR)	The difference between the 25th and 75th percentile of the data. Because the IQR measures the range of the central 50 percent of the data and is not influenced by the 25 percent on either end, it is less sensitive to extremes or outliers than the sample variance and standard deviation.

Management measure	A group of cost-effective practices implemented cooperatively to achieve more comprehensive goals, such as reducing the loads of sediment form a field to receiving waters.
Management practice	A method that is effective and practical for preventing or reducing pollution from nonpoint sources. Management practices, which are the building blocks of management measures, are similar to best management practices.
Maximum (statistics)	The highest data value recorded during the period of record.
McNeil core	A streambed sample collected with a McNeil core sampler and used to characterize the composition of the substrate.
Mean	The sum of all data values divided by the number of samples. The mean is strongly influenced by "outlier" samples (extremely high or low samples), with one outlier sample possibly shifting the mean significantly higher or lower.
Measure of central tendency	Measure that identifies the general center of a dataset.
Measure of range	Measure that identifies the span of the data from low to high.
Measure of skewness	Measure that shows whether a dataset is asymmetrical around the mean or median and suggests how much the distribution of the data differs from a normal distribution.
Measure of spread	Measure of the variability of the dataset.
Median (P0.50)	The 50th percentile data point; the central value of the dataset when ranked in order of magnitude. The median is more resistant to outliers than the mean and is only minimally affected by single observations.
Mesotrophic	Describes reservoirs and lakes that contain moderate quantities of nutrients and are moderately productive in terms of aquatic animal and plant life.
Minimum (statistics)	The lowest data value recorded during the period of record.
Model	A representation of an environmental system obtained through the use of mathematical equations or relationships.
Model application	The use of a model or models to address defined questions at a specific location.
Modeling system	A computer program or software package that incorporates a model and input and output systems to facilitate application.
Narrative criteria	Nonnumeric descriptions of desirable or undesirable water quality conditions.

National Pollutant Discharge Elimination System (NPDES)	A provision of the Clean Water Act that prohibits the discharge of pollutants into waters of the United States unless a special permit is issued by EPA, a state, or, where delegated, a tribal government on an Indian reservation.
Nine minimum elements	Components that EPA has identified as critical for achieving improvements in water quality. EPA requires that these nine elements be addressed for section 319 funded watershed plans and strongly recommends they be included in all watershed plans that are intended to remediate water quality impairments.
Nonpoint source	Diffuse pollution source; a source without a single point of origin or not introduced into a receiving stream from a specific outlet. The pollutants are generally carried off the land by stormwater. Common nonpoint sources are agriculture, forestry, urban areas, mining, construction, dams, channels, land disposal, saltwater intrusion, and city streets.
Nonstructural practice	A practice that prevents or reduces runoff problems in receiving waters by reducing the generation of pollutants and managing runoff at the source. This type of practice may be included in a regulation or may involve voluntary pollution prevention practices.
Numeric criteria	Criteria or limits for many common pollutants that are based on laboratory and other studies that test or otherwise examine the effects of pollutants on live organisms of different species.
Point source	A stationary location or fixed facility from which pollutants are discharged; any single identifiable source of pollution, such as a pipe, ditch, ship, ore pit, or factory smokestack.
Pollutant	A contaminant in a concentration or amount that adversely alters the physical, chemical, or biological properties of the natural environment.
Pollutant load	The amount of pollutants entering a waterbody. Loads are usually expressed in terms of a weight and a time frame, such as pounds per day (lb/d).
Probabilistic sampling	Sampling in which sites are randomly chosen to represent a larger sampling population for the purpose of trying to answer broad-scale (e.g., watershed-wide) questions.
Quality assurance project plan (QAPP)	A project-specific document that specifies the data quality and quantity requirements of a study, as well as the procedures that will be used to collect, analyze, and report the data.
Quartile skew coefficient (qs)	Measure of the difference in the distances of the upper and lower quartiles (upper and lower 25 percent of data) from the median. The qs is more resistant to outliers because, like the IQR, it uses the central 50 percent of the data.

Reach file	A series of national hydrologic databases that uniquely identify and interconnect the stream segments or “reaches” that compose the country’s surface water drainage system.
Remote sensing	The collection of data and information about the physical world by detecting and measuring radiation, particles, and fields associated with objects located beyond the immediate vicinity of the sensor device(s).
Sample variance (s2) and its square root standard deviation (s)	The most common measures of the spread (dispersion) of a set of data. These statistics are computed using the squares of the difference between each data value and the mean, so that outliers influence their magnitudes dramatically. In datasets with major outliers, the variance and standard deviation might suggest much greater spread than exists for the majority of the data.
SCS curve number	Number used to determine runoff, as a result of rainfall, for a specific land area based on the area’s hydrologic condition, land use, soil, and treatment.
Stakeholder	Individual or organization that has a stake in the outcome of the watershed plan.
Sanitary sewer overflow (SSO)	An occasional unintentional discharge of raw sewage from a municipal sanitary sewer.
Structural practice	A practice, such as a stormwater basin or streambank fence, that requires construction, installation, and maintenance.
Targeted sampling	Sampling in which sites are allocated to specific locations of concern (e.g., below discharges, in areas of particular land use, at stream junctions to isolate subwatersheds) for the purpose of trying to answer site-specific questions.
Threatened waterbody	A waterbody that is meeting standards but exhibits a declining trend in water quality such that it will likely exceed standards.
Total Maximum Daily Load (TMDL)	The amount, or load, of a specific pollutant that a waterbody can assimilate and still meet the water quality standard for its designated use. For impaired waters the TMDL reduces the overall load by allocating the load among current pollutant loads (from point and nonpoint sources), background or natural loads, a margin of safety, and sometimes an allocation for future growth.
Universal Soil Loss Equation (USLE)	An equation used to predict the average rate of erosion of an area on the basis of the rainfall, soil type, topography, and management measures of the area.
Validation	Subsequent testing of a precalibrated model to additional field data, usually under different external conditions, to further examine the model’s ability to predict future conditions. Same as verification.

Water quality standards	Standards that set the goals, pollution limits, and protection requirements for each waterbody. These standards are composed of designated (beneficial) uses, numeric and narrative criteria, and antidegradation policies and procedures.
Watershed	Land area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ultimately the ocean.
Watershed approach	A flexible framework for managing water resource quality and quantity within specified drainage area, or watershed. This approach includes stakeholder involvement and management actions supported by sound science and appropriate technology.
Watershed plan	A document that provides assessment and management information for a geographically defined watershed, including the analyses, actions, participants, and resources related to development and implementation of the plan.

Bibliography

Arnold, J.G., and J.R. Williams. 1987. Validation of SWRRB—Simulation for Water Resources in Rural Basins. J. *Water Res. Plan. Man*. 13:243-256.

Arnold, J.G., J.R. Williams, A.D. Nicks, and N.B. Sammons. 1990. *SWRRB: A Basin Scale Simulation Model for Soil and Water Resources Management*. Texas A&M University Press, College Station, TX.

ASCE (American Society of Civil Engineers). 1993. *Criteria for Evaluation of Watershed Models*. American Society of Civil Engineers, Task Committee of the Watershed Management Committee.

Athayde, D.N., P.E. Shelley, E.D. Driscoll, D. Gaboury, and G.B. Boyd. 1983. *Results of the Nationwide Urban Runoff Program: Final Report*. U.S. Environmental Protection Agency, Water Planning Division, Washington, DC.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish*. 2nd ed. EPA 841 B 99 002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

Barfield, B. J., J. C. Hayes, K. F. Holbrook, B. Bates, J. Gillespie, and J. Fersner. 2002. *IDEAL Model User Manual*. J. C. Hayes and Associates, Clemson, SC.

Beasley, D.B., L.F. Huggins, and E.J. Monke. 1980. ANSWERS: A model for watershed planning. *Trans. ASAE* 23:938-944.

Beaulac, M.N., and K.H. Reckhow. 1982. An examination of land use-nutrient export relationships. *Water Resources Bulletin* 18(6): 1013 1024.

Beck, M.B. 1987. Water quality modeling: A review of the analysis of uncertainty. *Water Res. Research* 23(8):1393-1442.

Beyer, A.S., C.K. Contant, and M.J. Donahue. 2001. *Seeking Signs of Success: A Guided Approach to More Effective Watershed Programs*. Harbor House Publishers, Michigan.

Bingner, R.L., C.E. Murphree, and C.K. Mutchler. 1987. *Comparison of Sediment Yield Models on Various Watersheds in Mississippi*. ASAE paper 87-2008. American Society of Agricultural Engineers, St. Joseph, MI.

Bosch, D.D., R.L. Bingner, F.D. Theurer, G. Felton, and I. Chaubey. *Evaluation of the AnnAGNPS Water Quality Model*. Presented at the 1998 ASAE Annual International Meeting, July 12-16, 1998, Orlando, Florida. Paper no. 982195. American Society of Agricultural Engineers, St. Joseph, MI.

British Columbia Ministry of Forests. 1999. *Forest Practices Code of British Columbia: Coastal Watershed Assessment Procedure Guidebook (CWAP), Interior Watershed Assessment Procedure Guidebook*. 2nd ed. British Columbia Ministry of Forests.

Brown, E., A. Peterson, R. Kline-Robach, K. Smith, and L. Wolfson. 2000. *Developing a Watershed Management Plan for Water Quality: An Introductory Guide*. Michigan Department of Environmental Quality.
<**www.michigan.gov/documents/deq/ess-nps-watershed-planning_210637_7.pdf**>.

Brown, M.P., P. Longabucco, M.R. Rafferty, P.D. Robillard, M.F. Walter, and D.A. Haith. 1989. Effects of animal waste control practices on nonpoint source phosphorus loading in the West Branch of the Delaware River watershed. *J. Soil Water Cons*. 44(1):67-70.

California SWRCB (State Water Resources Control Board). 2003. A Process for Addressing Impaired Waters in California. Draft. California State Water Resources Control Board, CA.

Camacho, R. 1991. Financial Cost Effectiveness of Point and Nonpoint Source Nutrient Reduction Technologies in the Chesapeake Bay Basin. Unpublished draft. Interstate Commission on the Potomac River Basin, Rockville, MD.

Caraco, D., R. Claytor, P. Hinkle, H.Y. Kwon, T. Schueler, C. Swann, S. Vysotsky, and J. Zielinski. 1998. *Rapid Watershed Planning Handbook*. Center for Watershed Protection, Ellicott City, MD.

Cassell, E.A. and J.C. Clausen. 1993. Dynamic simulation modeling for evaluating water quality response to agricultural BMP implementation. *Water Sci. & Technol*. 28(3 5): 635-648.

CCRS (Canada Centre for Remote Sensing). 2005. *Fundamentals of Remote Sensing.* <**http://ccrs.nrcan.gc.ca/resource/tutor/fundam/index_e.php**>.

Clausen, J.C. and J. Spooner. 1993. *Paired Watershed Study Design*. Office of Water, U.S. Environmental Protection Agency, Washington, DC. EPA 841-F-93-009. 8 p.

Claytor, R.A., and W.E. Brown. 1996. *Environmental Indicators to Assess Stormwater Control Programs and Practices*. Center for Watershed Protection, Ellicott City, MD.

Cleland, B. 2002. *TMDL Development from the "Bottom Up."* Part II. Using Duration Curves to Connect the Pieces. America's Clean Water Foundation, Washington, DC.

Cohn, T.A., and E.J. Gilroy. 1991. *Estimating Loads from Periodic Records*. U.S. Geological Survey Branch of Systems Analysis Technical Memo 91.01.

Cronshey, R.G., and F.D. Theurer. 1998. AnnAGNPS—Nonpoint Pollutant Loading Model. In *Proceedings of First Federal Interagency Hydrologic Modeling Conference*, April 19-23, 1998, Las Vegas, NV.

CTIC (Center for Technology Information Center). *Know Your Watershed Kits*. <**www2.ctic.purdue.edu/kyw/kyw.html**>.

CWP (Center for Watershed Protection). 1996. Crafting better urban watershed protection plans. *Watershed Protect*. Techn. 2(2): 329-337.

CWP. 2004. *Unified Subwatershed and Site Reconnaissance: A User's Manual, Version 1.0*. Urban Subwatershed Restoration Manual Series, Manual 11. Center for Watershed Protection, Ellicott City, MD.

Dai, T., R.L. Wetzel, T.R.L. Christensen, and E.A. Lewis. 2000. *BasinSim 1.0: A Windows Based Watershed Modeling Package. User's Guide*. Special Report in Applied Marine Science and Ocean Engineering #362. Virginia Institute of Marine Science, School of Marine Science, College of William & Mary, Gloucester Point, VA.

Davenport, T.E. 2003. *The Watershed Project Management Guide*. Lewis Publishers, Boca Raton, FL. <**www.enviroscapes.com/watershed_management.htm**>. Accessed March 2005.

Deal, J.C., J.W. Gilliam, R.W. Skaggs, and K.D. Konyha. 1986. Prediction of Nitrogen and Phosphorus Losses as Related to Agricultural Drainage System Design. *Ag. Ecosys. and Envir.* 18:37-51.

Donigian, A.S. 1983. Model Predictions vs. Field Observations: The Model Validation/Testing Process. In *Fate of Chemicals in the Environment*, ACS Symposium Series 225, American Chemical Society, Washington, DC, pp.151-171.

Donigian, A.S., and W.C. Huber. 1991. *Modeling of nonpoint source water quality in urban and non-urban areas*. EPA/600/3-91/039. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA.

Edwards, D.R., V.W. Benson, J.R. Williams, T.C. Daniel, J. Lemunyon, and R.G. Gilbert. 1994. Use of the EPIC Model to Predict Runoff Transport of Surface-applied Inorganic Fertilizer and Poultry Manure Constituents. *Trans. ASAE* 37(2):403-409.

Elder, D. 1997. Establishing watershed benchmarks: Tools for gauging success. *River Voices* 8(3).

Evans, B.M., D.W. Lehning, K.J. Corradini, G.W. Petersen, E. Nizeyimana, J.M. Hamlett, P.D. Robillard, and R.L. Day. 2002. A Comprehensive GIS-Based Modeling Approach for Predicting Nutrient Loads in Watersheds. *J. Spatial Hydrology* 2:2.

Flanagan, D.C., and M.A. Nearing, eds. 1995. *USDA-Water Erosion Prediction Project: Hillslope Profile and Watershed Model Documentation*. NSERL Report no. 10. West Lafayette, IN.

Follet, R.F., D.R. Kenney, and R.M. Cruse. 1991. *NLEAP or Nitrogen Leaching and Economic Analysis Package*. Soil Science of America, Inc., Madison, WI.

Foster, M.A., P.D. Robillard, D.W. Lehning, and R. Zhao. 1996. STEWARD, a knowledge-based system for selection, assessment, and design of water quality control practices in agricultural watersheds. *Water Res. Bull*. In review.

GLNPO (Great Lakes National Program Office). 1994. *Assessment and Remediation of Contaminated Sediments (ARCS) Program: Assessment Guidance Document*. EPA 905-B94-002. Great Lakes National Program Office, Chicago, IL.

Grabow, G.L., J. Spooner, L.A. Lombardo, and D.E. Line. 1999a. Detecting water quality changes before and after BMP implementation: Use of SAS for statistical analysis. p. 1-11. In NWQEP notes. *The NCSU Water Quality Group Newsletter.* January 1999. North Carolina State Univ. Coop. Ext., Raleigh.

Grabow, G.L., J. Spooner, L.A. Lombardo, and D.E. Line. 1999b. Detecting water quality changes before and after BMP implementation: Use of SAS for trend analysis. p. 1-8. In NWQEP notes. *The NCSU Water Quality Group Newsletter.* July 1999. North Carolina State Univ. Coop. Ext., Raleigh.

Griffin, M.L., D.B. Beasley, J.I. Fletcher, and G.R. Foster. 1988. Estimating Soil Loss on Topographically Nonuniform Field and Farm Units. *J. Soil Water Cons*. 43:326-331.

Haan, C.T., B. Allred, D.E. Storm, G.J. Sabbagh, and S. Prabhu. 1995. Statistical procedure for evaluating hydrologic/water quality models. *Trans. ASAE* 38(3):725-733.

Haith, D.A. 1985. Variability of pesticide loads to surface waters. *J. WPCF* 57(11):1062 1067.

Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy. 1994. *Stream Channel Reference Sites: An Illustrated Guide to Field Technique*. Gen. Tech. Rep. RM-245. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Heidtke, T.M., and M.T. Auer. 1993. Application of a GIS-based nonpoint source nutrient loading model for assessment of land development scenarios and water quality in Owasco Lake, New York. *Water Sci. Technol*. 28(3 5):595-604.

Helfert, E. 1997. *Techniques of Financial Analysis*. 9th ed. McGraw Hill, New York.

Helsel, D.R., and R.M. Hirsch. 2002. Statistical Methods in Water Resources. Chapter A3 in Book 4, *Hydrologic Analysis and Interpretation of Techniques of Water-Resources Investigations of the United States Geological Survey*.

Howard County SWMD (Stormwater Management Division). 2001. *Quality Assurance Project Plan for Howard County Biological Monitoring and Assessment Program*. Howard County, Department of Public Works, Stormwater Management Division, Columbia, MD.

Huber, W.C. 1992. Experience with the USEPA SWMM Model for analysis and solution of urban drainage problems. *Proceedings, Inundaciones Y Redes De Drenaje Urbano*, ed. J. Dolz, M. Gomez, and J. P. Martin, eds., Colegio de Ingenieros de Caminos, Canales Y Puertos, Universitat Politecnica de Catalunya, Barcelona, Spain, pp. 199-220.

Huber, W.C., and R.E. Dickinson. 1988. *Storm Water Management Model Version 4, User's manual*. EPA 600/3 88/ 001a (NTIS PB88-236641/AS). U.S. Environmental Protection Agency, Athens, GA.

IDEM (Indiana Department of Environmental Management). 2003. *Indiana Watershed Planning Guide*. Indian Department of Environmental Management. <**www.in.gov/idem/catalog/documents/water/iwpg.pdf**>. Accessed March 2005.

IEP, Inc. 1990. *P8 Urban Catchment Model User's Manual, v1.1*. IEP, Inc.

Illinois CREP (Conservation Reserve Enhancement Program). 2002. *Illinois Conservation Practices Tracking System*. Illinois Conservation Reserve Enhancement Program. <**www.ilcrep.org**>.

ITFM (Intergovernmental Task Force on Monitoring Water Quality). 1995. *The Strategy for Improving Water Quality Monitoring in the United States*. Final report of the Intergovernmental Task Force on Monitoring Water Quality. OFR 95-742. U.S. Geological Survey, Office of Water Data Coordination, Reston, VA.

Keith, L.H. 1991. *Environmental Sampling and Analysis: A Practical Guide*. Lewis Publishers, Chelsea, Michigan.

Knisel, W.G., R.A. Leonard, and F.M. Davis. 1991. Water Balance Components in the Georgia Coastal Plain: A GLEAMS Model Validation and Simulation. *J. Soil Water Cons*. 46(6):450-456.

Lauenroth, W.K., G.V., Skogerboe, and M. Flug. 1982. *Developments in Environmental Modeling 5*. Elsevier Scientific Publishing Company.

Lee, E R. 1999. SET-WET: A Wetland Simulation Model to Optimize NPS Pollution Control. Master's thesis, Dept. of Biological Systems Engineering, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Lee, E.R., S. Mostaphimi, and T. M. Wynn. 2002. A model to enhance wetland design and optimize nonpoint source pollution control. *J. AWRA* 8(February):17-32.

Lin, J.P. 2004. *Review of Published Export Coefficient and Event Mean Concentration (EMC) Data*. ERDC TN WRAP 04 03. U.S. Army Corps of Engineers, Engineer Research and Development Center, Vicksburg, MS.

Line, D.E., S.W. Coffey, and D.L. Osmond. 1997. WATERSHEDSS—GRASS AGNPS modeling tool. *Trans. ASAE* 40(4):971-975.

Liu, B.Y., M.A. Nearing, C. Baffault, and J.C. Ascough. 1997. The WEPP Watershed Model: Three Comparisons to Measured Data from Small Watersheds. *Trans. ASAE* 40:945-952.

Lombardo, L.A., G.L. Grabow, J. Spooner, D.E. Line, D.L. Osmond, and G.D. Jennings. 2000. *Section 319 Nonpoint Source National Monitoring Program Successes and Recommendations*. North Carolina State University Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC. <**www.bae.ncsu.edu/programs/extension/wqg/section319/nmp_successes.pdf**>.

Lombardo, L.A., G.L. Grabow, D.E. Line, J. Spooner, and D.L. Osmond. 2004. *2004 Summary Report: Section 319 National Monitoring Program Projects*. National Nonpoint Source Watersheds Project Studies, NCSU Water Quality Group, Biological and Agricultural Engineering Department, North Carolina State University, Raleigh, NC.

MD Tributary Strategy. 1997. *Close to Home: A Focus on Small Watersheds*. <**www.dnr.state.md.us/bay/tribstrat/monitor/ss/small_shed.html**>.

MDEQ (Mississippi Department of Environmental Quality). 2001. *Quality Assurance Project Plan for 303(d) Monitoring and Assessment of Wadeable Streams in Mississippi*. Mississippi Department of Environmental Quality, Office of Pollution, Jackson, MS.

MDEQ. 2003. *Mississippi Gulf Coast Stormwater Toolbox Ranking Report*. Mississippi Department of Environmental Quality, Department of Marine Resources. <**www.dmr.state.ms.us/CoastalEcology/Storm/SECTION-2/Section-2-Text.pdf**>.

Meals, D.W. 1990. *LaPlatte River Watershed Water Quality Monitoring and Analysis Program: Comprehensive Final Report*. Program report no. 12. University of Vermont, Vermont Water Resources Research Center, Burlington, VT.

Meals, D.W. 1992. Relating land use and water quality in the St. Albans Bay Watershed, Vermont. In *The National Rural Clean Water Program Symposium, September 1992, Orlando, FL*, pp. 131-144. EPA/625/R-92/006. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

Meals, D.W. 2001. *Lake Champlain Basin Agricultural Watersheds Section 319 National Monitoring Program Project, Final Project Report: May, 1994–September, 2000*. Vermont Department of Environmental Conservation, Waterbury, VT.

Mill Creek Subwatershed Stakeholder Advisory Group. 2003. *Mill Creek Subwatershed Management Plan*. Available from the Huron River Watershed Council. <**www.hrwc.org**>.

Mullens, J.A., R.F. Carsel, J.E. Scarbrough, and I.A. Ivery. 1993. *PRZM-2, A Model for Predicting Pesticide Fate in the Crop Root and Unsaturated Soil Zones: Users Manual for Release 2.0*. EPA/600/R 93/046. U.S. Environmental Protection Agency, Office of Research and Development, Environmental Research Laboratory, Athens, GA.

Munoz-Carpena, R., and J.E. Parsons. 2003. *VFSMOD-W—Vegetative Filter Strips Hydrology and Sediment Transport Modeling System, Model Documentation and User's Manual*. University of Florida, Agricultural and Biological Engineering.

NASA (National Aeronautics and Space Administration). 2005a. *Remote Sensing: Special Signatures*. <**http://earthobservatory.nasa.gov/Library/RemoteSensing/remote_05.html**>.

NASA. 2005b. Remote Sensing: Remote Sensing Methods. National Aeronautics and Space Administration. <**http://earthobservatory.nasa.gov/Library/RemoteSensing/remote_08.html**>.

NCDENR (North Carolina Department of Environment and Natural Resources). 2003. *North Carolina Nonpoint Source Management Program, Tar-Pamlico Nutrient Strategy*. <**http://h2o.enr.state.nc.us/nps/tarpam.htm**>.

NOAA (National Oceanic and Atmospheric Administration). 2005a. *NOAA's Remote Sensing Activities*. <**www.magazine.noaa.gov/stories/mag13.htm**>.

NOAA. 2005b. *NOAA Uses Remote Sensing Technology to Monitor and Identify Harmful Algal Blooms*. National Oceanic and Atmospheric Administration. <**www.noaanews.noaa.gov/stories/s2096.htm**>.

Novotny, V., and H. Olem. 1994. *Water Quality: Prevention, Identification, and Management of Diffuse Pollution*. Van Nostrand Reinhold, New York.

NRCS (Natural Resources Conservation Service). 1997. *National Handbook of Water Quality Monitoring*. 450-vi-NHWQM. National Water and Climate Center, Portland, Oregon.

NRCS. 2005. *National Conservation Practice Standards*. <**www.nrcs.usda.gov/technical/Standards**>.

NSFC (National Small Flows Clearinghouse). 1993. *National Onsite Wastewater Treatment: Summary of Onsite Systems in the United States*. National Small Flows Clearinghouse, Morgantown, WV.

NWQMC (National Water Quality Monitoring Council). 2005. *Water Quality Data Elements*. <**http://wi.water.usgs.gov/methods/tools/wqde/index.htm**>.

Ohio EPA (Ohio Environmental Protection Agency). 1989. *The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Application*. Ohio, Environmental Protection Agency, Ecological Assessment Section, Division of Water Quality Planning and Assessment. Columbus, OH.

Ohio EPA. 1997. *A Guide to Developing Local Watershed Action Plans in Ohio*. <**www.epa.state.oh.us/dsw/nps/wsguide.pdf**>.

PGDER (Prince George's County Department of Environmental Resources). 1995. *Biological Monitoring and Assessment Program, Prince George's County, Maryland*. Maryland Department of Environmental Resources, Programs and Planning Division, Technical Support Section, Landover, MD.

Prince George's County. 2001. *Low-Impact Development Management Practices Evaluation Computer Module, User's Guide*. Prepared for Prince George's County, Maryland, by Tetra Tech, Inc., Fairfax, VA.

Reckhow, K.H., M.N. Beaulac, and J.T. Simpson. 1980. *Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients*. EPA 440/5-80-011. U.S. Environmental Protection Agency, Washington, DC.

Richards, R.P. 1997. *Estimation of Pollutant Loads in Rivers and Streams: A Guidance Document for NPS Programs*. Draft. Heidelberg College, Water Quality Laboratory, Tiffin, OH.

Ritchie, J.C., and C.M. Cooper. 2001. Remote sensing techniques for determining water quality: Applications to TMDLs. In *TMDL Science Issues Conference, Water Environment Federation, Alexandria, VA*, pp. 367-374. <**www.wef.org/Home**>.

Rosgen, D. 1996. *Applied River Morphology*. Wildland Hydrology, Pagosa Springs, CO.

Schueler, T.R. 1987. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs*. Metropolitan Council of Governments, Washington, DC.

Schueler, T.R. 1995. *Site Planning for Urban Stream Protection*. Center for Watershed Protection, Silver Spring, MD.

Shaffer, M.J. 1985. Simulation Model for Soil Erosion Productivity Relationships. *J. Environ. Qual*. 14(1):144-150.

Shaffer, M.J., and W.E. Larson, eds. 1985. *NTRM: A Soil-Crop Simulation Model for Nitrogen, Tillage, and Crop Residue Management*. U.S. Department of Agriculture, Agricultural Research Service, St. Paul, MN.

Shaffer, M.J., S.C. Gupta, D.R. Linden, J.A.E. Molina, C.E. Clapp, and W.E. Larson. 1986. Simulation of Nitrogen, Tillage, and Residue Management Effects on Soil Fertility. In *Analysis of Ecological Systems: State-of-the-art in Ecological Modelling*, ed. W.K. Lauenroth, G.V.

Sharpley, A.N., and J.R. Williams, eds. 1990. *EPIC—Erosion/Productivity Impact Calculator: 1. Model Documentation*. Bulletin no. 1768. U.S. Department of Agriculture.

Shilling, F., S. Sommarstrom, R. Kattelmann, B. Washburn, J. Florsheim, and R. Henly. 2004. *California Watershed Assessment Manual*. Prepared for the California Resources Agency. <**http://cwam.ucdavis.edu**>.

Skaggs, R.W. 1980. *A Water Management Model for Artificially Drained Soils*. North Carolina Agricultural Research Service technical bulletin 267. North Carolina State University, Raleigh, NC.

Smith, M.C., A.B. Bottcher, K.L. Campbell, and D.L. Thomas. 1991. Field testing and comparison of the PRZM and GLEAMS models. *Trans. ASAE* 34(3):838-847.

Sugden, R., and A. Williams. 1981. *Principles of Practical Cost Benefit Analysis*. Oxford University Press, Oxford, UK.

Sugiharto, T., T.H. McIntosh, R.C. Uhrig, and J.J. Lavdinois. 1994. Modeling alternatives to reduce dairy farm and watershed nonpoint source pollution. *J. Environ. Qual*. 23:18-24.

Tetra Tech, Inc. 2000. *Ecological Data Application System (EDAS): A User's Manual*. Prepared for U.S. Environmental Protection Agency, Office of Water, Office of Wetlands, Oceans and Watersheds, by Tetra Tech, Inc., Owings Mills, MD. (For more information on this report, contact Robert King, USEPA, at 202-566-1177).

Tetra Tech, Inc. 2001. *Greater Battle Creek Area Watershed Management Plan*. Prepared for the City of Springfield.

Tiscareno Lopez, M., V.L. Lopes, J.J. Stone, and L.J. Lane. 1993. Sensitivity analysis of the WEPP watershed model for rangeland applications: I. Hillslope Processes. *Trans. ASAE* 36:1659-1672.

University of Nebraska. 2005. *Development and Implementation of a Comprehensive Lake and Reservoir Strategy for Nebraska as a Model for Agriculturally Dominated Ecosystems*. The Center for Advanced Land Management Information Technologies (CALMIT), University of Nebraska-Lincoln (supported through EPA STAR Grant R828635).
<**http://digitalcommons.unl.edu/geosciencefacpub/21**>.

University of Texas. 2002. *Symposium on Terrain Analysis for Water Resources Applications, December 16 18, 2002*. Center for Research in Water Resources, University of Texas, Austin.
<**www.crwr.utexas.edu/terrainAnalysis/presentations.cfm**>.

USDA (U.S. Department of Agriculture). 1996. *Predicting Soil Erosion by Water: A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE)*. Renard, K.G., G.R. Foster, G.A. Wessies, D.K. McCool, and D.C. Yoder, coordinators. U.S. Department of Agriculture, Agricultural Handbook No. 703. 404 pp.

USDA-ARS (U.S. Department of Agriculture–Agricultural Research Service). No date. *User's Guide for REMM: Riparian Ecosystem Management Model*.
<**http://sacs.cpes.peachnet.edu/remmwww/remm/users.htm**>.

USDA-NRCS (U.S. Department of Agriculture, Natural Resources Conservation Service formerly Soil Conservation Service). 1986. *Urban Hydrology for Small Watersheds*. Technical release no. 55, rev. ed. U.S. Department of Agriculture, Washington, DC.

USEPA (U.S. Environmental Protection Agency). 1980. *Modeling Phosphorus Loading and Lake Response Under Uncertainty: A Manual and Compilation of Export Coefficients*. EPA 440/5-80-011. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1985. *Field Agricultural Runoff Monitoring (FARM) Manual*. EPA/600/3-85/043. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, GA.

USEPA. 1986. *Eastern Lake Survey. Phase 1. Characteristics of Lakes in the Eastern United States: Volume 1. Population Descriptions and Physico Chemical Relationships*. EPA/600/4 86/007a. U.S. Environmental Protection Agency, Office of Acid Deposition, Environmental Monitoring, and Quality Assurance, Office of Research and Development, Washington, DC.

USEPA. 1989. *A Probabilistic Methodology for Analyzing Water Quality Effects of Urban Runoff on Rivers and Streams*. Final report. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1993a. *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*. EPA 840-B-92-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1993b. *Post Audit Verification of the Model AGNPS in Vermont Agricultural Watersheds*. EPA 841-R-93-006. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1997a. *EPA's Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures—Agriculture*. EPA 841-B-97-010. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1997b. BASINS Training Course, December 8 12, 1997. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1997c. *Compendium of Tools for Watershed Assessment and TMDL Development*. EPA 841-B-97-006. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1997d. *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls*. EPA 841-B-96-004. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1998. *Guidelines for Ecological Risk Assessment*. EPA 630-R-095-002F. U.S. Environmental Protection Agency, Risk Assessment Forum, Washington, DC.

USEPA. 1999a. *Protocol for Developing Nutrient TMDLs*. EPA 841-B-99-007. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 1999b. *Protocol for Developing Sediment TMDLs*. EPA 841-B-99-004. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 2000a. *Guidance for the Data Quality Objectives Process*. EPA QA/G-4. EPA/600/R-96/055. U.S. Environmental Protection Agency, Office of Environmental Information, Washington, DC.

USEPA. 2000b. *Stressor Identification Guidance Document*. EPA/822/B-00/025. U.S. Environmental Protection Agency, Office of Water and Office of Research and Development, Washington, DC.

USEPA. 2000c. *Projecting Land Use Change: A Summary of Models for Assessing the Effects of Community Growth and Change on Land Use Patterns*. EPA 600-R-00-098. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.

USEPA. 2001a. *Protocol for Developing Pathogen TMDLs*. 1st ed. EPA 841-R-00-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 2001b. *Getting in Step: Engaging Stakeholders in Your Watershed*. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 2002a. *319 Success Stories, Volume III: The Successful Implementation of the Clean Water Act's Section 319 Nonpoint Source Pollution Program*. EPA 841-S-01-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 2002b. *Community Culture and the Environment: A Guide to Understanding a Sense of Place*. EPA 842-B-01-003. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 2002c. *Water Quality Assessment of the Black Warrior River Basin*. U.S. Environmental Protection Agency, Region 4, Nonpoint Source Branch.

USEPA. 2003a. *National Management Measures to Control Nonpoint Source Pollution from Agriculture*. EPA 841-B-03-004. U.S. Environmental Protection Agency, Office of Water, Washington, DC. <**www.epa.gov/owow/nps/agmm**>.

USEPA. 2003b. *Post Construction Storm Water Management in New Development & Redevelopment*. U.S. Environmental Protection Agency, Office of Wastewater Management. <**http://cfpub.epa.gov/npdes/stormwater/menuofbmps/post.cfm**>.

USEPA. 2003c. *Getting in Step: A Guide for Conducting Watershed Outreach Campaigns*. EPA 841-B-03-002. U.S. Environmental Protection Agency, Office of Water, Washington, DC.

USEPA. 2005. *TMDL Model Evaluation and Research Needs*. EPA/600/R-05/149. U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Cincinnati, OH.
<**www.epa.gov/nrmrl/pubs/600r05149/600r05149.htm**>.

USEPA, Montana Operations Office, Flathead National Forest, and Tetra Tech, Inc. 2004. *Water Quality Assessment and TMDLs for the Flathead River Headwaters Planning Area, Montana*. Prepared for Montana Department of Environmental Quality.

USEPA and USDA. 1998. *Clean Water Action Plan: Restoring and Protecting America's Waters*. U.S. Environmental Protection Agency, Washington, DC, and U.S. Department of Agriculture, Washington, DC.

USGS (U.S. Geological Survey). 2005a. *Remote Sensing*.
<**www.gcmrc.gov/about/programs/isp/dasa/survey/remotesensing.htm**>.

USGS. 2005b. *About Terrestrial Remote Sensing*. <**http://terraweb.wr.usgs.gov/about.html**>.

USGS. 2005c. *LIDAR—Light Detection and Ranging*.
<**http://vulcan.wr.usgs.gov/Monitoring/LIDAR/description_LIDAR.html**>.

USOMB (U.S. Office of Management and Budget). 2005. *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* (Revised), January 2005. Circular no. A-94.
<**www.whitehouse.gov/omb/circulars/a094/a094.html**>.

Van Ness, K., K. Brown, M.S. Haddaway, D. Marshall, and D. Jordahl. 1997. *Montgomery County, Water Quality Monitoring Program, Stream Monitoring Protocols*. Department of Environmental Protection, Watershed Management Division, Rockville, MD.

Walker, W. W. 1985. Empirical Methods for Predicting Eutrophication in Impoundments; Report 3, Phase III: Model Refinements. Technical Report E-81-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Walker, W. W. 1986. Empirical Methods for Predicting Eutrophication in Impoundments; Report 3, Phase III: Applications Manual. Technical Report E-81-9, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Walker, W.W. 1990. *P8 Urban Catchment Model Program Documentation, v1.1.*

Walker, W.W. 1996. *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual*. Chapter 2, FLUX. Instruction Report W. U.S. Army Corps of Engineers, Water Operations Technical Support Program.

Wischmeier, W.H., and D. Smith. 1965. *Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains: Guide for Selection of Practices for Soil and Water Conservation*. USDA-ARS Agriculture Handbook no. 282. U.S. Department of Agriculture, Washington, DC.

Wischmeier, W.H., and D. Smith. 1978. *Predicting Rainfall Erosion Losses: A Guide to Conservation Planning.* USDA ARS Agriculture Handbook no. 537. U.S. Department of Agriculture, Washington, DC.

Wong, T.H.F., Duncan, H.P., Fletcher, T.D. and Jenkins, G.A. 2001. A Unified Approach to Modelling Urban Stormwater Treatment. In *Proceedings of the 2nd South Pacific Stormwater Conference*. Auckland, New Zealand, June 27-29, 2001. pp.319-327.

Wong, T.H.F., J. Coleman, H. Duncan, T. Fletcher, G. Jenkins, L. Siriwardena, A. Taylor, and R. Wootton. 2005. *MUSIC: User Guide*. MUSIC Development Team, Cooperative Research Center for Catchment Hydrology, Australia.

Wright, J.F., D.W. Sutcliffe, and M.T. Furse. 2000. *Assessing the Biological Quality of Fresh Waters: RIVPACS and Other Techniques*. Freshwater Biological Association, Ambleside, Cumbria, UK.

Wylie, B.K., M.J. Shaffer, M.K. Brodohl, D. Dubois, and D.G. Wagner. 1994. Predicting Spatial Distributions of Nitrate Leaching in Northeastern Colorado. *J. Soil Water Cons*. 49:288-293.

Wylie, B.K., M.J. Shaffer, and M.D. Hall. 1995. Regional Assessment of NLEAP NO3-N Leaching Indices. *Water Res. Bull*. 31:399-408.

Young, R.A., C.A. Onstad, D.D. Bosch, and W.P. Anderson. 1994. *Agricultural NonPoint Source Pollution Model, Version 4.03 AGNPS User's Guide*. U.S. Department of Agriculture, Agricultural Research Service, Morris, MN.

Yu, S.L., G.M. Fitch, and T.A. Earles. 1998. *Constructed Wetlands for Stormwater Management*. VTRC 98-R35RB. Virginia Department of Transportation Research Council.

Zacharias, S., C. Heatwole, T. Dillaha, and S. Mostighimi. 1992. *Evaluation of GLEAMS and PRZM for Predicting Pesticide Leaching Under Field Conditions*. ASAE paper 92-2541. American Society of Agricultural Engineers, St. Joseph, MI.

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