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A Framework Incorporating Community Preferences in Use Attainment and Related Water Quality Decision-Making

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NOTICE

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LIST OF ABBREVIATIONS

AI	Adaptive Implementation
AR	Antidegradation reviews
AWQC	Ambient Water Quality Criteria
BCA	Benefit-cost analysis
BOD	Biochemical oxygen demand
BUVD	Beneficial Use Values Database
CCMP	National Estuary Program Comprehensive Conservation and Management Plan
CSO	Combined sewer overflow
CV	Contingent valuation
CWA	Clean Water Act
DELEP	Delaware Estuary Program
DEP	Department of Environmental Protection
DEQ	Wyoming Department of Environmental Quality
DO	Dissolved oxygen
ERA	Ecological risk assessment
EVRI	Environmental Valuation Reference Inventory
FERC	Federal Energy Regulation Commission
FIA	Financial impact analysis
GEAEs	Generic ecological assessment endpoints
GIS	Geographic information systems
HQW	High quality water
NRC	National Research Council
NYDEC	New York Department of Environmental Control
OWRB	Oklahoma Water Resources Board
POTW	Publicly-owned treatment works
ppm	Parts per million
SAR	Santa Ana River
SPDES	State Pollutant Discharge Elimination System

LIST OF ABBREVIATIONS cont.

TDS	Total dissolved solids
TMDL	Total Maximum Daily Load
UAA	Use attainability analysis
WERF	Water Environment Research Foundation
WQS	Water quality standards
WTP	Willingness to pay
WWTP	Waste water treatment plant

PREFACE

Section 303(c) of the Clean Water Act (CWA) requires states and tribes to adopt water quality standards; this includes setting designated uses or goals for their water bodies. In certain cases, use attainment decisions, such as whether or not to change the use of a water body, can be complex because they can lead to gains and losses among health, ecological, institutional, and economic considerations. Estimating the gains from use attainment is not required by the CWA or Water Quality Standards regulation, but evaluating community preferences for water quality against the costs may aid in conducting a balanced analysis. The National Center for Environmental Assessment (NCEA) and RTI International[1] have prepared this report to help water quality officials and the public understand how the assessment of ecological benefits could help support their decisions.

To guarantee a useful product, 20 experts were invited to a workshop held on November 14-15, 2006, in Cincinnati, OH. The objectives of the two-day workshop were to (1) critically examine and develop recommendations for revising an earlier draft of this report (Chapters 1 through 4), (2) employ hypothetical case studies of use attainment problems to evaluate a draft decision process and (3) hold discussions with practitioners and stakeholders to develop recommendations for incorporating community preferences into water quality management decisions. The report has been revised based on the comments from the workshop and it now includes the final chapter developed from the recommendations of the workshop participants. It will be useful for water quality officials, watershed managers, and members of stakeholder groups who are interested in weighing the ecological effects in use attainment decisions.

[1] RTI International is a trade name of Research Triangle Institute.

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EXECUTIVE SUMMARY

ES.1. INTRODUCTION

This report will assist states and authorized tribes—and the associated communities—to understand how the assessment of ecological benefits can help to support their water quality decisions while complying with the provisions of the Clean Water Act (CWA). The report is intended to assist water quality officials, watershed managers, members of stakeholder groups, and other interested individuals in fully evaluating ecological and socioeconomic objectives and the gains and losses that often are involved. Under the CWA, states and tribes adopt water quality standards (WQS). This includes setting designated uses or goals for their water bodies. When natural, man-made, or socioeconomic factors preclude the attainment of a designated use, the CWA recognizes that states and tribes must do an evaluation before changes to a designated use can be made.[2] In certain cases, depending on the factor, the evaluation focuses on the costs and impacts (i.e., losses) of achieving the designated use. However, decisions related to changing or attaining designated uses sometimes involve both gains and losses (or benefits and costs) among health, ecological, institutional, and socioeconomic considerations. Evaluating the gains from continuing to attain the current designated use (rather than degrading water quality) may aid in developing a balanced analysis. An important step in achieving this report's goal is integrating the assessment of ecological quality with the assessment of economic considerations so that the benefits and costs can be understood, communicated, and evaluated in the standard-setting process. Therefore, this approach requires evaluating community preferences and Chapter 1 outlines specific situations where this may occur.

The report incorporates methods from ecological risk assessment, stressor identification, economics, and social science to explain how to incorporate this information into water quality attainment decisions. Specific objectives (by chapter) are as follows:

- provide an introduction to the CWA and WQS regulation and analyses related to setting or changing designated uses (Chapter 2)
- create a basis for understanding the relationship between use-attainment decisions and the effects on ecosystems, ecosystem services, and ecological benefits (Chapter 3)

[2] In some cases, these evaluations could establish that a higher use is attainable.

- serve as a reference for methods that elicit or infer preferences for benefits and costs related to attaining uses (Chapter 4), and
- present a process for incorporating new approaches in water quality decisions (Chapter 5).

Chapter 1 also introduces the general decision framework for addressing WQS and use-attainment issues (Figure ES-1). It describes a series of steps for framing the decision problem and then comparing the advantages and disadvantages of different management options. It also identifies the points in the process where input from the community and the assessment of community preferences can be used to strengthen the decision process. Chapter 1 also describes how Figure ES-1 is used as an organizing framework for this report, and it discusses how each chapter relates to the diagram.

ES.2. UNDERSTANDING THE GROUND RULES: AN INTRODUCTION TO WATER QUALITY STANDARDS, USE ATTAINABILITY ANALYSES, AND ANTIDEGRADATION REVIEWS

Chapter 2 explains how the water quality goals and ecological integrity for a water body, termed its designated uses, are established as part of a WQS program. It discusses the circumstances under which designated uses or water quality goals can be changed, with a focus on the important role of socioeconomic analyses in making better decisions.

The purpose of the WQS program is to protect public health and welfare by supporting the objectives of the CWA, which articulates two overarching goals:

- restore and maintain the chemical, physical and biological integrity of the nation's waters.
- achieve a "fishable/swimmable" level of water quality: one that provides for the protection and propagation of fish, shellfish, and wildlife and for recreation in and on the water, wherever attainable.

To comply with the provisions of the CWA, states and authorized tribes must establish WQS for all water bodies. These standards consist of designated uses, water quality criteria to protect those uses, and an antidegradation policy to maintain high quality waters. General

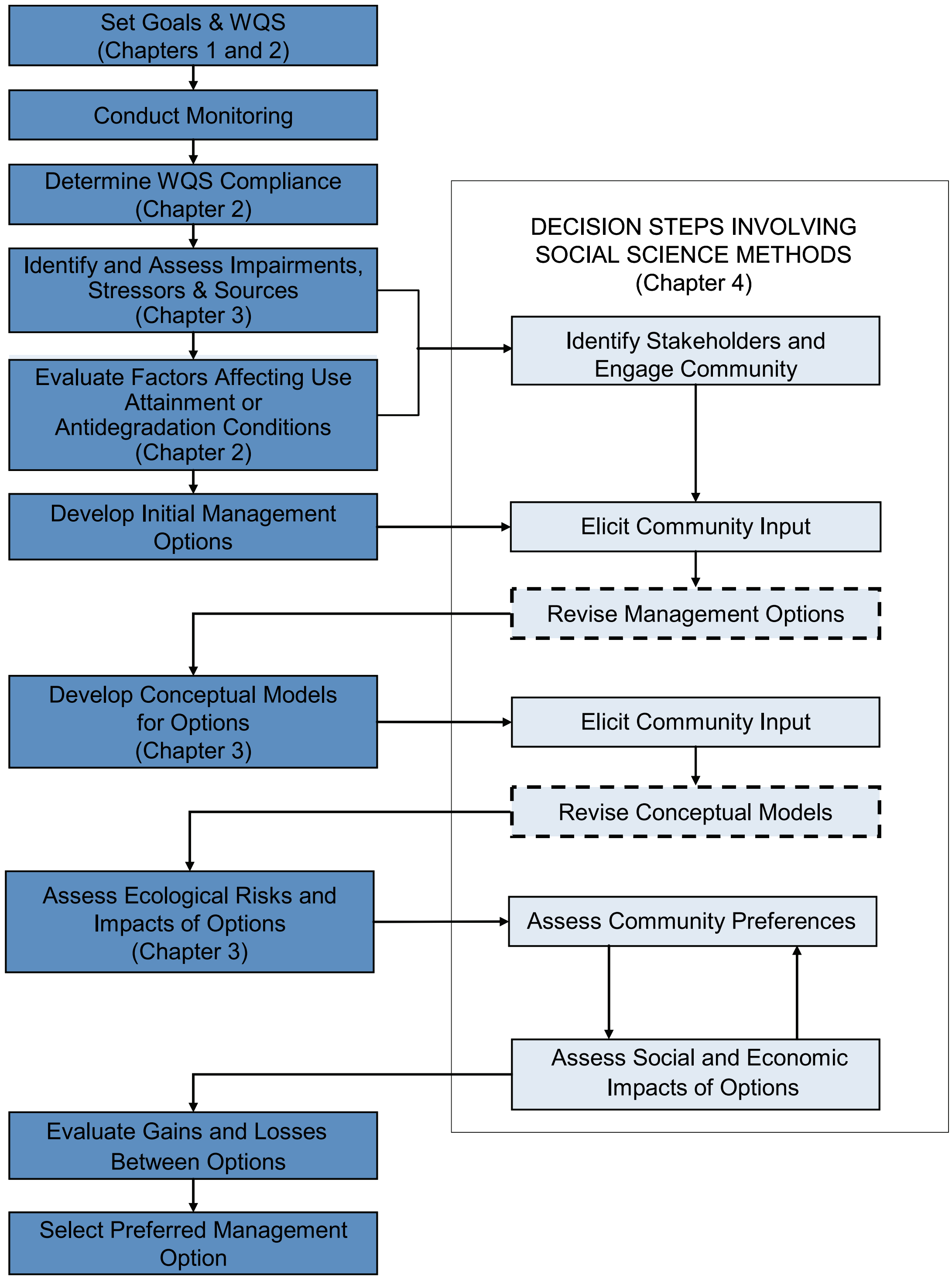

FIGURE ES-1

Framework for Incorporating Community Input and Preferences and Evaluating Ecological and Socioeconomic Gains and Losses in WQS Decisions
(chapter listed provides details of decision step)

provisions, such as variances that temporarily relax a designated use to work toward attainment, may also be included, subject to EPA review and approval.

States and tribes must conduct use attainability analyses (UAAs) to justify specific designated use modifications for water bodies. A UAA is a structured scientific assessment of the factors affecting the attainment of a use. These factors can include a range of naturally occurring, human-caused, physical conditions, or economic and social impacts. The majority of UAAs rely on noneconomic arguments, but economics may play a determining role in some cases. An economic UAA must demonstrate that the controls required to attain the use would result in "substantial and widespread economic and social impact."

In contrast to UAAs, antidegradation reviews tend to place more emphasis on economic considerations. Antidegradation reviews examine whether water quality in "high-quality" waters may be lowered if it is necessary to permit "important economic and social development" as long as existing[3] and "fishable/swimmable" uses are not impaired.

To provide states and tribes with guidance on using economic analysis in UAAs and antidegradation reviews, EPA compiled the *Interim Economic Guidance for Water Quality Standards: Workbook* (U.S. EPA, 1995). To understand the current practices based on the *Interim Economic Guidance*, a literature search was conducted, which identified 13 UAAs and four antidegradation reviews that incorporate economic arguments. One conclusion from the available case studies is that, to the extent that an economic analysis is done, most attention is given to costs data of attaining designated uses or of maintaining high water quality. Very little attention is given to the economic benefits that would be obtained from use attainment or of maintaining high water quality. Therefore, the analyses, while useful for regulatory determinations, may not fully inform affected communities about the benefits and effects of these decisions on their well-being. For example, in the UAA case, a community may ask, what are the benefits of attaining a designated use that is not currently being attained? Or, in the antidegradation review case, the relevant question might be, if we allow the degradation being considered, what are the damages produced? The answers to these questions may lead to a community's reconsideration of whether a use change (and hence, the quality of their water) is needed.

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[3]The WQS regulation defines existing uses as those uses "actually attained in the water body on or after November 28, 1975, whether or not they are actually included in the water quality standards" (40 CFR 131.3 (e)).

ES.3. UNDERSTANDING THE CHOICES: RELATING WATER QUALITY MANAGEMENT DECISIONS TO CHANGES IN ECOSYSTEMS, ECOSYSTEM SERVICES, AND ECOLOGICAL BENEFITS

Although existing WQS guidance for evaluating socioeconomic impacts in UAAs and antidegradation reviews focuses on financial and regional economic impacts, many states, tribes, and communities could take a broader approach in analyzing the effects of selecting different water quality management options. Chapter 3 provides decision-makers with a framework for understanding how these different options can affect ecosystems and human well-being. This framework adapts and extends concepts from ecological risk assessment to show how aquatic ecosystems are linked to and support humans through the provision of “ecosystem services.” It also describes how these services are related to designated uses. The framework is further described through a series of “expanded conceptual models,” which are applied and illustrated in five case studies, focusing on different water quality management decisions.

Figure ES-1 also conveys the relationship of stressor identification and ecological risk assessment to the other components of use-attainment decisions. When designated uses are not attained because WQS are not being met, the water body is said to be impaired. Stressor identification can identify the causes of impairment, allowing management alternatives to be developed (U.S. EPA, 2000). So together, ecological risk assessment, stressor identification, and economic analysis can provide a means to better characterize ecosystem services and compare the management alternatives of use-attainment decisions.

The concept of ecosystem services is fundamental for evaluating how humans are supported by ecological systems and how their well-being is affected by changes in these systems. This report adopts the following definition (U.S. EPA, 2006):

> **Ecosystem services** are outputs of ecological functions or processes that directly or indirectly contribute to social welfare or have the potential to do so in the future. Some may be bought and sold, but most are not marketed.

The definition above highlights the importance of understanding the relationship between ecosystem services and designated uses. In essence, these terms represent two distinct but related ways of characterizing how the quality or conditions of water resources support human well-being. When water quality management decisions result in changes to designated uses, they are also likely to affect the types and levels of ecosystem services that the water resource provides. However, changes in ecosystem services may occur even if use attainment does not change.

Conceptual models expressed as flow diagrams are particularly useful tools for representing relationships within and between ecological and human systems. For example, these diagrams play an integral role in ecological risk assessment by illustrating relationships between sources of stressors (e.g., abandoned mines producing acid mine drainage), ecological entities, and their responses to the stressors. Chapter 3 presents conceptual models to evaluate the broader societal implications and the gains and losses associated with setting or modifying WQS.

Figure ES-2 shows that land uses or human activities and other sources are capable of introducing stressors to aquatic ecosystems. These stressors disrupt the normal functioning of the ecosystem, which can cause reductions in water quality and can impair the ecosystem's ability to provide key services. However, these same sources and land uses are also capable of providing other important goods and services to humans. For example, agricultural land uses may degrade water quality in local streams while at the same time providing valued food crops for consumers.

Figure ES-2 also illustrates how management options considered in a standard-setting process, such as restoring a riparian area, will typically alter the effects of land uses their ability to support or sustain human well-being. Because humans may experience both gains and losses as a result of these options (shown by purple lines), the figure also demonstrates the gains and losses inherent with these types of decisions. By controlling stressors to the aquatic ecosystem (represented by the blue lines), a management option should improve certain ecosystem services, resulting in gains to individuals who value these services. At the same time, however, the costs of controlling stressors impose losses on certain individuals.

It also shows how the attainment of designated uses fits into the conceptual model framework. Use attainment is ultimately determined by comparing observed water quality (or related conditions) in the aquatic ecosystem with the relevant water quality criteria.

Chapter 3 describes specific steps for developing these expanded conceptual models. Using the framework outlined in Figure ES-2, the chapter illustrates the development of expanded conceptual models through five hypothetical "case studies," which address the following types of WQS scenarios:

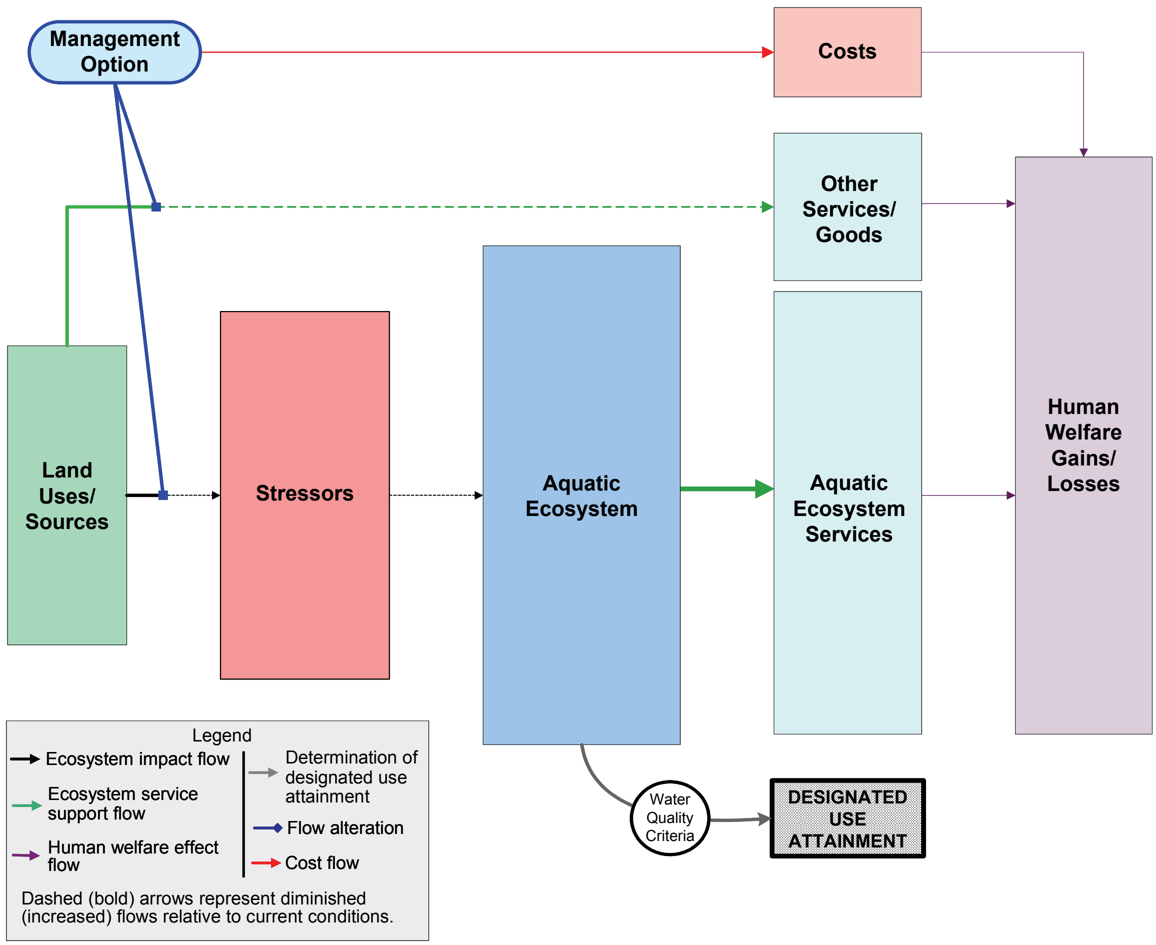

FIGURE ES-2

Effects of Management Options on Aquatic Ecosystem Services and Human Well-Being

- Case Study 1 presents a hypothetical UAA addressing acid mine drainage (AMD) impacts on a tributary stream and a river.
- Case Study 2 presents a hypothetical UAA addressing combined sewer overflows (CSOs) and stormwater impacts on a river system.
- Case Study 3 presents a hypothetical UAA addressing agricultural impacts on an intermittent stream.
- Case Study 4 presents a hypothetical antidegradation review of a proposed retail development complex.
- Case Study 5 presents a hypothetical UAA addressing discharges to an effluent-dominated stream.

ES.4. UNDERSTANDING THE TOOLS: A SUMMARY OF METHODS FOR CHARACTERIZING THE GAINS AND LOSSES

Chapter 4 describes and compares various methods—broadly defined as "social science methods"—that can be used to inform the decision-making process for WQS. A common goal of these methods is to help decision-makers understand the perceptions, attitudes, objectives, and preferences of relevant stakeholders in an affected community and to apply this information to improve policy decisions (e.g., those affecting water quality). The purpose of Chapter 4 is to provide an overview of these methods and a basic understanding of their relative advantages and disadvantages. Rather than providing detailed instructions on how to apply each method, the chapter is intended to help the reader gauge which methods might be applicable to his or her situation on a case-by-case basis.

The overall goal of the proposed decision-making process described previously in Figure ES-1 is to select the management option that meets the highest attainable use of a particular water body or segment and best addresses the needs and priorities of the affected community. Throughout this process, social science methods can be used to address three supporting objectives:

1. involve the community in framing the key elements of the WQS decision,
2. assess community preferences for different management options to meet the highest attainable use and
3. assess the expected social and economic impacts of the different options.

Chapter 4 discusses the types of social science methods that are best suited to addressing each of these objectives. It divides these assessment methods into two main categories: sociocultural and economic methods.

Sociocultural methods provide a number of alternative perspectives and approaches for eliciting, evaluating, and applying community preferences and stakeholder input in the decision-making process. These methods can be broadly categorized as either deliberative or analytic methods (and in some cases both). In deliberative methods, groups of stakeholders are convened to discuss and collectively assess possible decisions (e.g., those related to water quality). In addition to providing structured approaches for eliciting community input on technical matters, deliberative methods can be used to elicit and assess community preferences for management options. They also offer the advantage of encouraging active community involvement throughout the decision-making process. In analytic methods, data on community preferences are analyzed by decision-makers without necessarily engaging in dialogue with stakeholders. These methods have the advantage of providing decision-makers with a rigorous and structured set of responses on which they can base their selection of the final WQS management option. Some researchers have advocated decision-making processes that incorporate both deliberative and analytic components into socioeconomic assessments. Chapter 4 identifies and describes 13 specific sociocultural methods and distinguishes them according to whether they are primarily analytic or deliberative methods (or both).

In contrast to sociocultural methods, economic assessment methods share a common conceptual framework, which guides how preferences are interpreted, quantified (typically in monetary terms), and used to compare and evaluate options (e.g., through benefit-cost or cost-effectiveness comparisons). Chapter 4 identifies and describes nine commonly used economic assessment methods.

Economic analyses of environmental regulations and related policies are geared toward understanding how society's resources, including its natural resources like water, are used or exchanged as a result of policy actions and how human well-being may be affected. Two commonly used criteria in economic analyses for determining whether society is better off as a result of a policy are *efficiency* and *equity*. The main questions underlying the efficiency criterion are whether and to what extent the gains to society (benefits) exceed the losses to society (costs) from a given policy. This criterion is the basis for benefit-cost analysis, which is a widely used economic analysis method that involves identifying, quantifying, and valuing the positive and negative impacts on society's well-being that result from policy changes. The main questions underlying the equity criterion have to do with how the gains and losses are distributed across society. In contrast to the efficiency criterion, there is no generally agreed upon measure or assessment method for gauging equity. Nevertheless, the process of developing and conducting benefit-cost analysis often requires the separate estimation of different types and sources of benefits and costs, which, in turn, can also be useful for informing equity concerns.

One of the main challenges in applying benefit-cost analysis to evaluate environmental policies related to meeting WQS is that it requires methods for expressing human welfare changes in monetary terms. In certain instances, such as adding new pollution control that reduces profit and gets passed on to consumers as price increases, this process is relatively straightforward because the changes are experienced by humans as monetary gains or losses.

In other instances, welfare changes are not directly associated with monetary gains or losses, for example, benefits from improved recreational opportunities at a water body. In these cases, economists and other practitioners of benefit-cost analysis generally regard "willingness to pay" (WTP) as the conceptually correct measure for valuing changes in individuals' welfare.[4] For example, if changes in water quality improve fishing conditions at a lake, the benefit to anglers can be expressed as the maximum amount they would have been willing to pay for the change.

All the methods discussed in Chapter 4 require data collection regarding the affected community. These methods are broadly categorized as either primary or secondary data collection. Primary data collection entails gathering original data directly from community members or stakeholders. Among the more commonly used methods are individual interviews, surveys, group deliberations, and observation. Secondary data collection relies on existing sources of data, many of which can be used to support and conduct socioeconomic assessments. For example, data collected by the Bureau of Census, including information on population, housing, and economic characteristics, can be useful for identifying and characterizing the potentially affected community.

[4] Willingness to accept (WTA) is the minimum amount an individual is willing to accept to forego the change. Both WTA and WTP are correct measures for valuing changes. However, to simplify, we only use WTP in this report. Freeman (1993) provides information on the differences between WTA and WTP and how to choose the appropriate measure.

Chapter 4 compares 22 different social science methods according to the data collection technique most commonly used for the method. Using a 5-point scale from very low to very high, each method is also rated by cost/complexity which refers to the costliness and/or complexity of method, in terms of time, data, and specialized technical skills required to implement the method.

ES.5. WORKING THE PROCESS: BUILDING AN APPROACH FOR COMMUNITIES TO UNDERSTAND THE ECOLOGICAL RISKS, COSTS, AND BENEFITS OF WATER QUALITY MANAGEMENT DECISIONS

The purpose of Chapter 5 is to provide a more detailed description of how the proposed decision process outlined in Figure ES-1 can be implemented in practice. The chapter is organized according to three main phases of the process: (1) framing the WQS decision, (2) comparing the advantages and disadvantages of the different management options, and (3) making the decision (selecting the option). In each case, it describes the main components of the decision process and the techniques that can be used to address each component. It also uses two of the hypothetical case studies described in Chapter 3—the CSO example and the AMD example—to illustrate specifically how the methods and tools described in the previous chapters can be applied to inform and strengthen each stage of the decision-making process.

Framing the WQS decision involves identifying the key water quality impairments, along with the related sources and stressors, and determining the set of feasible options available for addressing the impairment. It also means recognizing and engaging community residents in initial discussions of how they are likely to be affected by both the impaired water and the options available for addressing the impairment. Chapter 5 describes how group deliberative methods can be used in several ways to involve the community in framing the decisions, including (1) identifying community priorities, concerns, and constraints; (2) revising and defining the most practical set of management options and (3) revising and finalizing conceptual models that illustrate the key linkages between environmental conditions and human welfare and the gains and losses involved in the decision-making process. In particular, it describes how deliberative processes could be used to develop conceptual models incrementally and how simplified versions of the models might be used to communicate the decision problem to community residents.

Assessing community preferences entails gathering information to determine how different segments of the affected population regard and value different features of the WQS management options. With this information and with an understanding of the expected ecological impacts of different options (e.g., through ecological risk assessment), it is then possible to estimate the social and economic impacts of the different options. Regardless of how they are organized, the purpose of all these activities—ecological risk assessment, preference assessment, and the assessment of economic and social impacts—is to acquire and organize information that can be used to better evaluate the gains and losses between the options. Chapter 5 describes how social science methods can be used to evaluate gains and losses by collecting both qualitative and quantitative information on preferences and impacts. It also explains how these and other methods can be applied to analyze the equity implications of different management options.

The final step, as defined in Figure ES-1, is for the decision-makers to select the management option that best addresses the need to protect human health and the environment, the communities' needs, and compliance with the CWA and WQS regulation to attain the designated uses. Chapter 5 emphasizes that the purpose of this report is not to suggest the criteria that should be used in making any particular decision, rather to propose methods that could help decision-makers better frame and evaluate the options. None of the individual methods described in the report can determine unequivocally which management option is best suited to address a particular WQS issue. However, they should enable communities and water quality managers to better understand the ecological and socioeconomic gains and losses involved, and therefore, promote better environmental and economic decisions.

ES.6. REFERENCES

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1. INTRODUCTION

1.1. THE PURPOSE AND ROLE OF THIS REPORT

The goal of this report is to help states and authorized tribes—and the associated communities—to understand how the assessment of ecological benefits could inform decisions about their water bodies while complying with the provisions of the Clean Water Act (CWA). Although estimating the gains from these decisions is not required by the CWA and related regulations, understanding community preferences for water quality may aid in conducting a balanced analysis. The report is intended to assist water quality officials, watershed managers, members of stakeholder groups, and other interested individuals in fully evaluating the ecological and socioeconomic gains and losses that often are involved in these decisions. It also provides a framework and suggestions for eliciting input from stakeholders, assessing the preferences of the affected community, and incorporating these insights into the decision-making process.

The CWA includes two main approaches to improving water quality: effluent guidelines and water quality standards (WQS). This report focuses on WQS. Whereas effluent guidelines focus on specific industries and, depending on the available technology, set pollution limits to protect the receiving waters, Section 303(c) of the CWA requires states and tribes to adopt designated uses or goals for their water bodies. Designated uses, which are one component of the WQS program, are designed to protect the natural integrity of the nation's waters and the uses of these waters by people and aquatic organisms. The CWA also recognizes that, in some cases, states or tribes must evaluate changes to a designated use, for example, because naturally occurring, man-made, or socioeconomic factors inhibit its attainment.[1] Decisions related to changing or attaining designated uses sometimes require consideration and balancing of various health, ecological, institutional (e.g., organizational goals), and socioeconomic factors (herein called *gains and losses* or *benefits and costs*). States and tribes are provided limited latitude in adopting or revising designated uses and must balance these gains and losses carefully. For example, a significant reduction in the discharge of pollutants to a stream might restore a blue ribbon trout fishery and make the stream safe for full-contact recreation such as swimming, but it also may require a substantial increase in treatment costs. On the other hand, a modest reduction

[1] In some cases, these evaluations could establish that a higher use is attainable.

with a modest increase in treatment costs may allow the stream to support trout year round yet make the water only safe enough for incidental contact recreation such as fishing and boating.

To change designated uses, states and tribes are first required to conduct **use attainability analyses (UAAs)** or variance analyses. The purpose of these scientific assessments is to determine which designated uses are feasible and appropriate for a water body. A variance analysis, similar to a UAA, is for a temporary relaxation of the WQS. In other cases, states and tribes may consider permitting a reduction of water quality in high-quality waters if the reduced quality will not affect existing[2] or designated uses. Under these conditions, the CWA requires formal **antidegradation reviews (ARs)** to demonstrate that the reduction is necessary to accommodate important economic or social development in the area. Thus, the ultimate determination of water quality goals for a stream, lake, or estuary may require the evaluation of both ecological and socioeconomic objectives. Therefore, in the UAA case, a community may ask, what are the benefits of attaining a use that is not currently being attained? Or, in the AR case, the relevant question might be, if we allow the degradation being considered, what are the damages produced? The answers to these questions may lead to a community's reconsideration of whether a use change (and, in turn, the quality of their water) is needed.

Figures 1-1 through 1-5 outline some of the specific situations this report is intended to address.[3] They include, most importantly, decisions related to UAAs and ARs, but they also extend more broadly to watershed planning decisions. More specifically, the four situations are

1. Deciding whether to change a use in a UAA where there are substantial and widespread economic impacts from retaining existing use,
2. Deciding whether a source of impairment is better left in place because of the environmental damages that might be caused from corrective measures,
3. Deciding whether the damages from allowing the reduction in water quality that is necessary to accommodate important economic and social development (Tier 2: Antidegradation) are acceptable to the community, and
4. Deciding whether a potential watershed planning activity should be pursued.

[2] The WQS regulation defines existing uses as those uses "actually attained in the water body on or after November 28, 1975, whether or not they are actually included in the water quality standards" (40 CFR 131.3 (e)).
[3] The CWA elements and the WQS regulation process are not as distinct as the figures suggest. This simplification, however, is needed to clarify the purpose of the report.

The report describes an approach for integrating assessments of ecological quality with assessments of socioeconomic considerations, so that the relevant benefits and costs can be understood, communicated, and weighed in the standard-setting process. As shown in these figures, in many situations this approach requires evaluating community preferences.

Figure 1-1 depicts the key CWA elements. If a state/tribe determines that a water body is not meeting its WQS, it can place the water body on its listing of impaired waters—the 303(d) list—and develop management strategies and total maximum daily loads (TMDLs).[4] This strategy assumes that the use is attainable. However, if the state believes that attaining the use is not feasible, one alternative is changing the use, contingent on a UAA assessing the physical, chemical, biological, or socioeconomic factors (40 CFR 131.10 (g)). Decision-makers and analysts would have to evaluate conditions in the affected water body, define an initial set of options for addressing the WQS, and evaluate the options following existing guidance for UAAs.

Figure 1-2 illustrates how the socioeconomic factor is used in a UAA and how public preferences can enter the decision-making process. The socioeconomic factor specifically addresses whether the adverse economic and social impacts of actions necessary to eliminate an impairment at a particular site would be both *substantial and widespread*. With this factor, attainability is usually determined using financial impact and economic impact analyses; community preferences for water quality are not likely to play a role in examining this factor. However, following the determination of *substantial and widespread*, community preferences for water quality might be important if the UAA suggests that a designated use should be downgraded, as indicated by the box with the broken outline in Figure 1-2. The community may want to keep the long-term water quality goal even if doing so would have a substantial and widespread economic impact.

Current guidance allows, but does not require, the consideration of benefits in deciding whether to actually remove the designated use (U.S. EPA, 1995). For example, the community could decide to subsidize the pollution control costs. If the current use is removed, then a new

[4] U.S. EPA defines a TMDL as the "calculation of the maximum amount of a pollutant that a water body can receive and still meet WQS, and an allocation of that amount to the pollutant's sources."

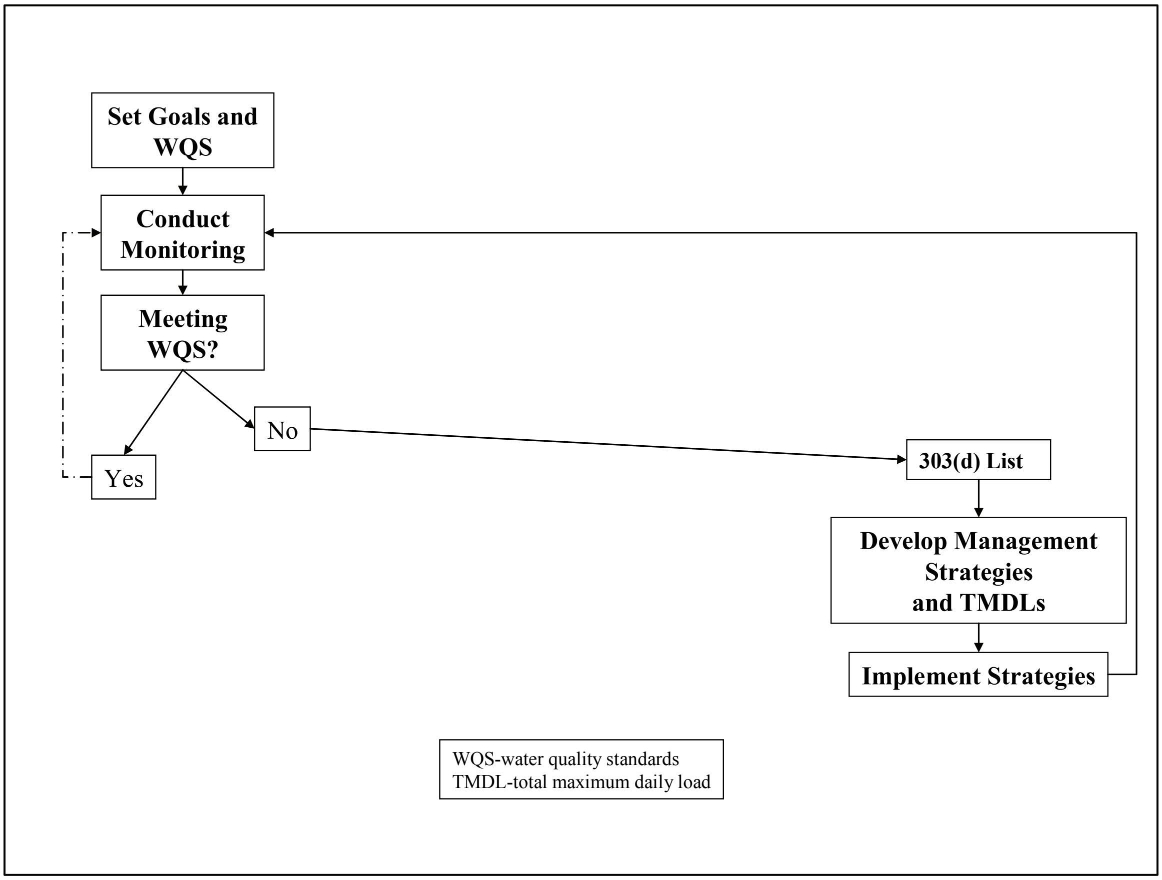

FIGURE 1-1

Key Clean Water Act Elements*

*CWA elements based on slides from: "Watersheds 101: CWA Tools for Watershed Protection. A Training Workshop." Additional information accessed at www.epa.gov/watertrain.

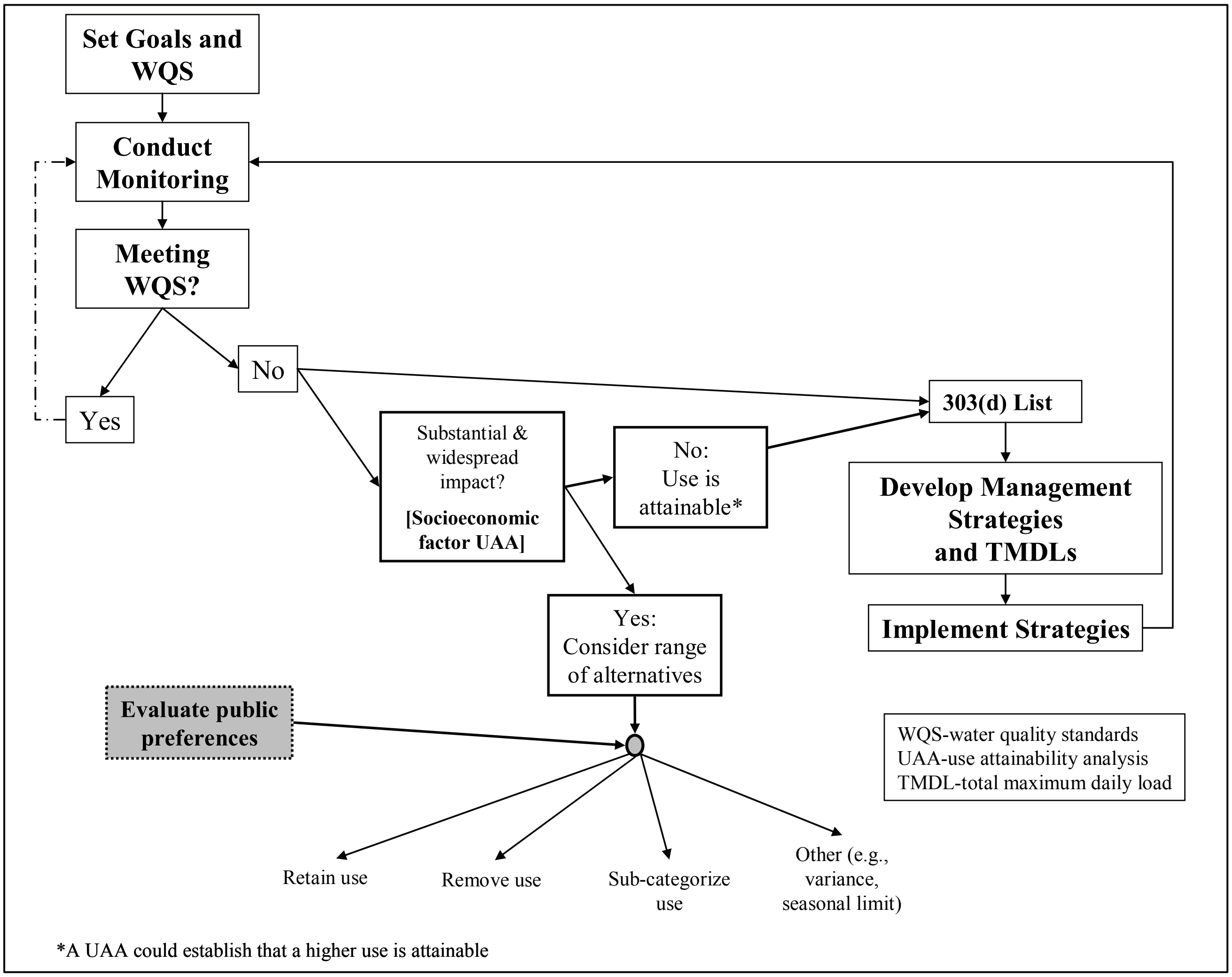

FIGURE 1-2

Use Attainability Analysis Using Socioeconomic Factor use may need to be determined. Community preferences for water quality improvements and the costs of achieving those improvements could play a role in identifying the appropriate new use.[5]

Figure 1-3 illustrates how the human-caused condition factor is used in a UAA and how public preferences can enter the decision-making process in this situation. A UAA may determine that human-caused conditions or sources of pollution prevent the attainment of the designated use and that these impairments cannot be remedied or that corrective measures would cause more environmental damage than leaving the source of impairment in place.[6] For example, in certain circumstances, removing contaminated sediments associated with historical pollution inputs would result in greater downstream environmental damage than leaving the sediments in place.

In these situations, evaluating community preferences may have an appropriate role for weighing the damages vs. the improvement, particularly if the environmental damage to be caused by correcting the human-caused condition differs in kind from the environmental improvement that would result. For example, community preferences may help to weigh the creation of an upland disposal site vs. the alleviation of instream contamination.

Figure 1-4 illustrates the situation where a state is meeting its WQS, but an antidegradation policy is required. The antidegradation policy is a set of procedures for evaluating regulated activities that may affect water quality. It is a three-tier program that sets the minimum level of protection (Tier 1) and protects "high-quality" waters (Tier 2) and outstanding national resource waters (Tier 3).[7] Figure 1-4 specifically illustrates a Tier 2 decision node that could benefit from community input. Tier 2 water quality levels that exceed "fishable/ swimmable" must be protected unless the reduction is deemed necessary to accommodate important economic and social development in the area of the water body (as long as WQS are still met). U.S. Environmental Protection Agency (EPA) guidance suggests that the same analytic tools for the socioeconomic factor UAA be used for AR (U.S. EPA, 1995). Therefore, as

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[5] In this report, obtaining community or public preferences refers to something more than the mere solicitation of public comments. Although public comments can provide important information in the process, here we are discussing the use of preference elicitation or preference revelation methods (see Chapter 4 for more information).
[6] Related to this factor is EPA Region IX's guidance for effluent-dominated waters (U.S. EPA, 1992) describing the "net environmental benefit use attainability analysis." As stated in a Colorado Water Quality Control Division Discussion Paper (2003: p. vi), "[b]ecause a net environmental benefit approach inherently involves trade-offs and value judgments, the appropriate roles for both the states and the EPA in making these judgments need to be defined." This report suggests that public preferences should play a role in the value judgment as well.
[7] Chapter 2 provides more details on the Antidegradation Policy.

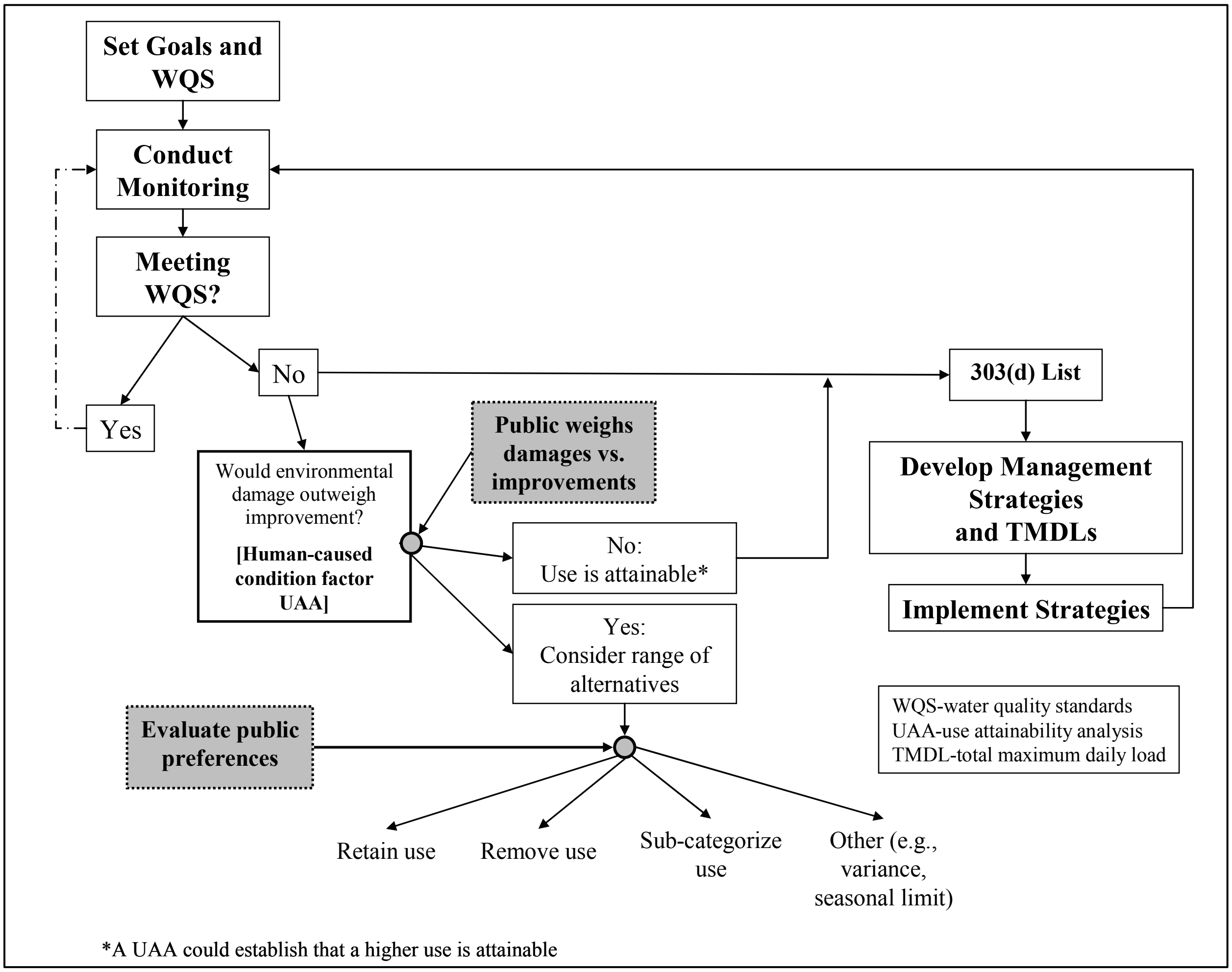

FIGURE 1-3

Use Attainability Analysis Using Human-Caused Condition Factor

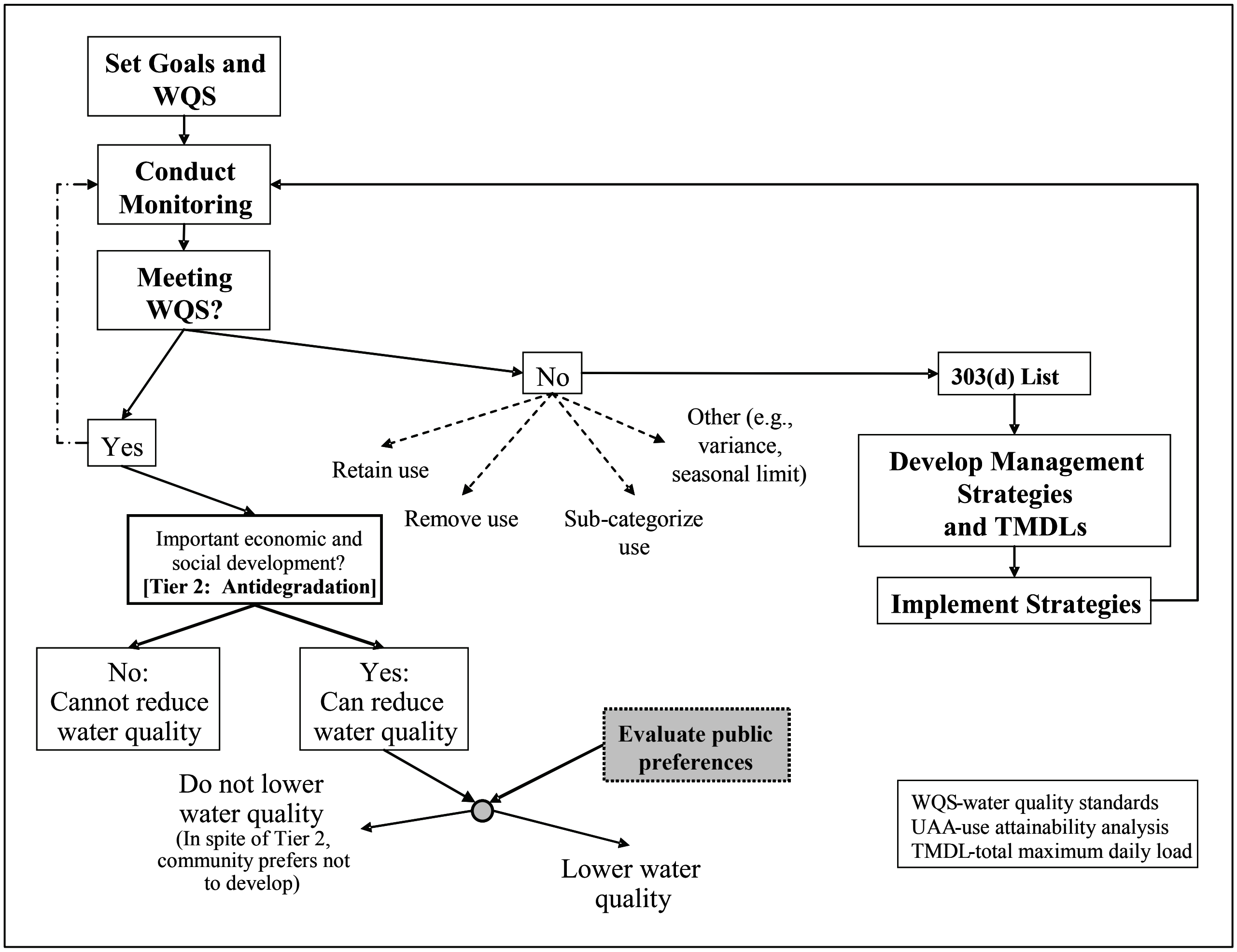

FIGURE 1-4

Antidegradation Review for High-Quality Waters
(exceeds fishable/swimmable goal)

with the socioeconomic factor (Figure 1-2), the fact that a lowering of water quality is allowable does not necessarily mean that the community would prefer it.

Figure 1-5 addresses watershed-wide planning activities that may identify water quality improvement strategies, which include regulatory (e.g., TMDL), nonregulatory (e.g., Section 319 nonpoint source grants), and other, non-CWA mechanisms or authorities. Through these activities, community development or other land management decisions may influence WQS attainment. In this broader context, community preferences play a critical or even determining role. For example, a community group may want to justify spending money to improve downstream water quality or coastal recreational activities.

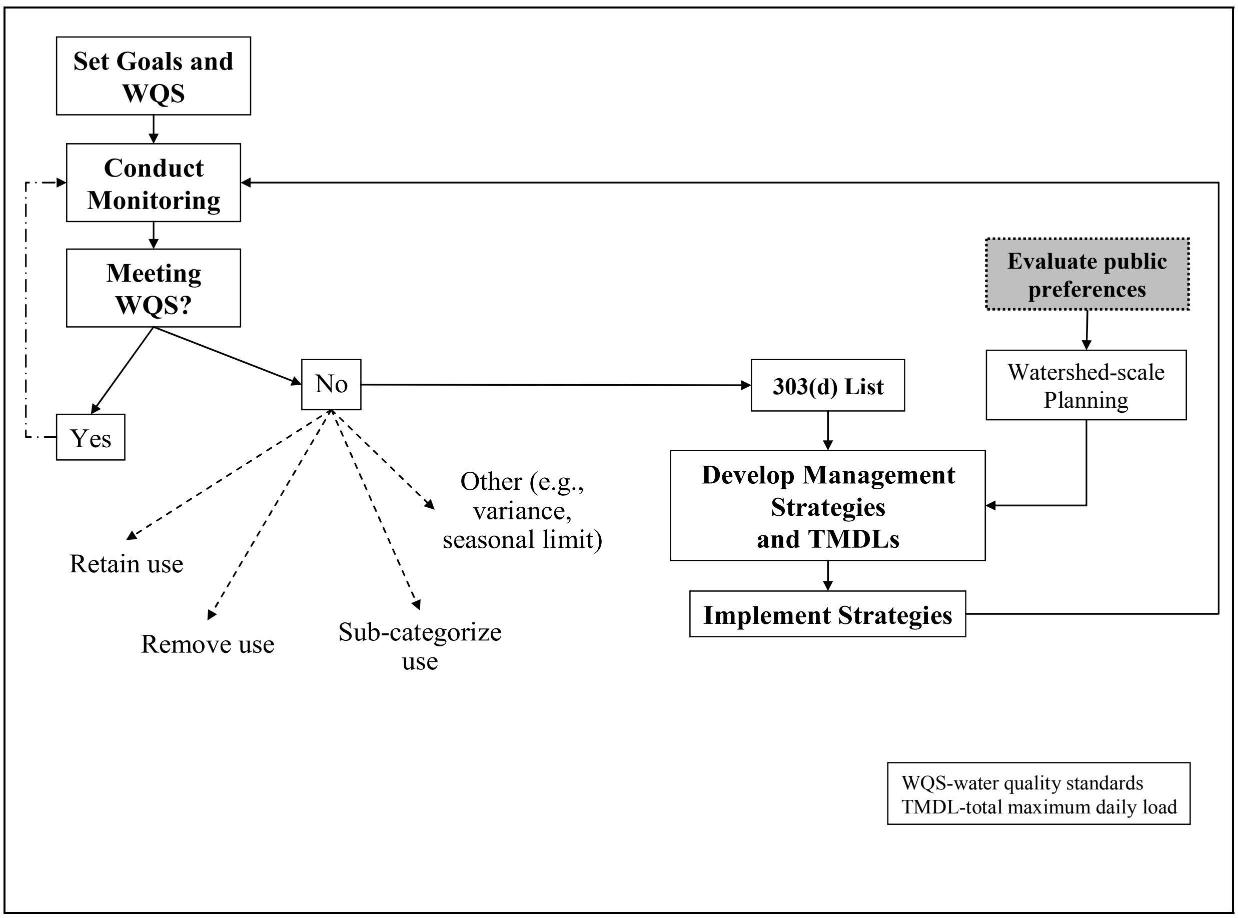

FIGURE 1-5

Watershed Planning Activities

As shown in these five figures, community preferences can contribute to WQS decisions in a number of ways. The main objective of this report is to propose a general decision framework and a corresponding set of methods for incorporating community input and preferences into decisions affecting the quality of local rivers and streams. Although the framework and methods are potentially applicable to a wide range of WQS decisions (e.g., prioritizing restoration activities, establishing variances, conducting watershed planning), the report focuses mainly on UAA and AR decisions. It uses and references methods from ecological risk assessment, causal analysis, economics, and other social sciences to explain how this information can be used in these types of water quality management decisions. More broadly, this document serves as

- an introduction to the CWA, WQS, UAAs, and ARs (Chapter 2);
- a basis for understanding the relationship between use-attainment decisions and the effects on ecosystems, ecosystem services, and ecological benefits (Chapter 3);
- a reference for methods that ascertain preferences related to attaining uses (Chapter 4); and
- a guide for incorporating new approaches in water quality decisions (Chapter 5).

This report should not be misconstrued as a new regulation or setting aside current regulatory requirements. It works within the boundaries set by the CWA and does not supersede any existing regulations or guidance.

Figure 1-6 depicts the general decision framework that this report proposes for addressing WQS and use-attainment issues. It also serves as an organizing structure for the report. The first few elements of the framework—from setting water quality goals and standards to developing initial management options—have already been touched on in this chapter. The next chapter (Chapter 2) expands on these topics by specifying the ground rules for WQS decisions. It defines the goals of the CWA, describes how WQS are used in implementing the CWA, and explains how WQS are established and occasionally modified through UAAs and ARs. It discusses the main factors that are evaluated in UAAs to determine whether use attainment is feasible. It specifically examines the “widespread economic and social impact” factor and describes the alternative economic methods that are or could be used in UAAs and ARs. It also presents examples of actual UAAs and ARs that have included economic analyses.

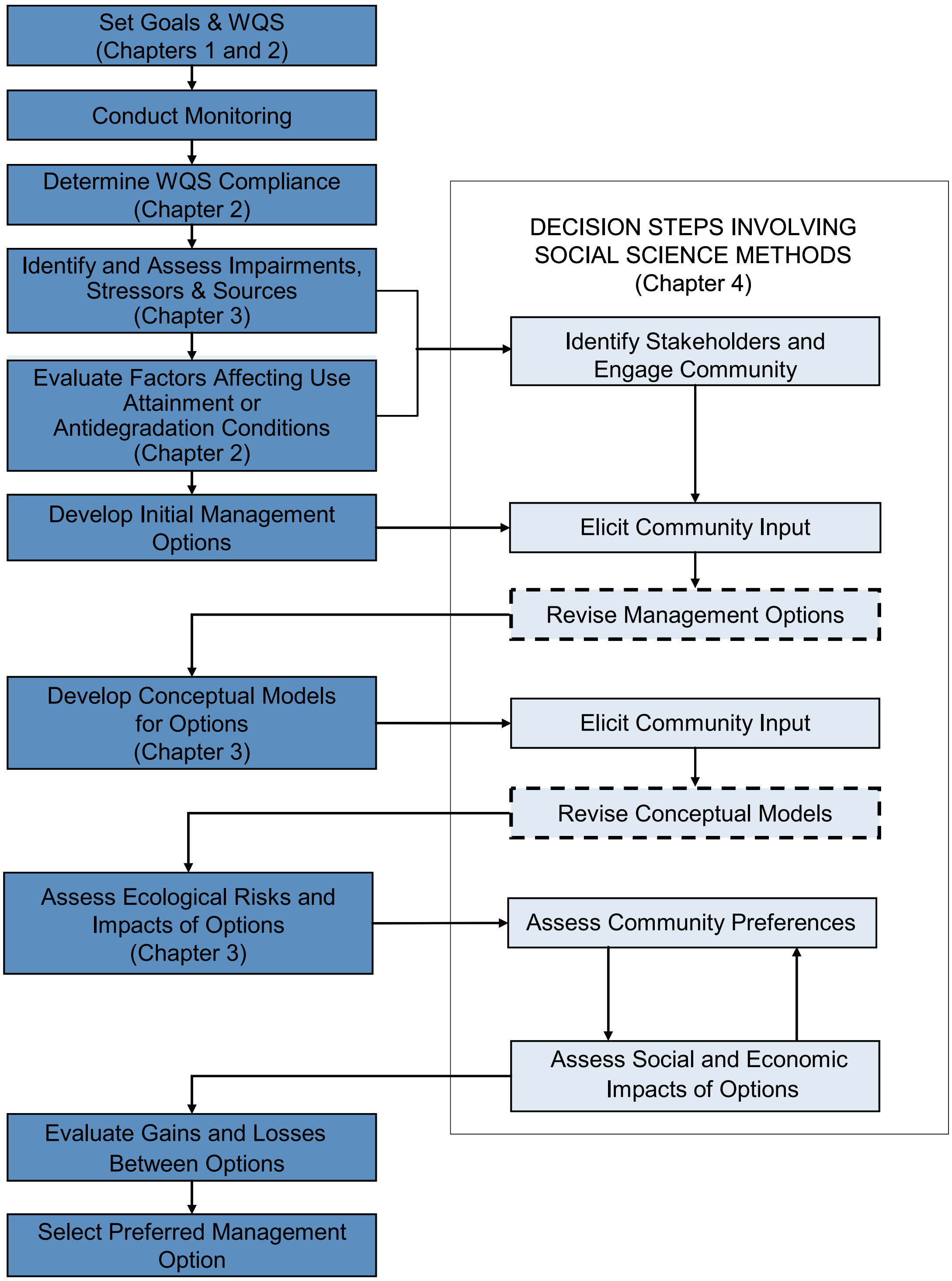

FIGURE 1-6

Framework for Incorporating Community Input and Preferences and Evaluating Ecological and Socioeconomic Gains and Losses in WQS Decisions
(chapter listed provides details of decision step)

Chapter 3 discusses methods for identifying and characterizing the relevant water quality problem(s) and the gains and losses associated with alternative management options. It characterizes impairments and their causes; it summarizes approaches for assessing ecological risks, including the identification of ecological risk assessment endpoints; and it defines ecosystem services and how they are affected by setting WQS. It then describes how flow diagrams can be used as conceptual models for representing the WQS management decisions. These diagrams depict the linkages between sources, stressors, ecological impacts, ecosystem services, and human welfare and the ecological and socioeconomic changes associated with different management options. The development of these conceptual models is illustrated through a series of hypothetical case studies involving complex management issues such as acid mine drainage affecting a river and its main tributary, combined sewer overflows, intermittent streams, commercial development and antidegradation, and effluent-dominated streams.

Chapter 4 presents a variety of social science methods that can be used to support and strengthen the WQS decision-making process. In particular, they can be used in a variety of ways to address the steps highlighted on the right hand side of Figure 1-6 (i.e., identify and engage stakeholders, elicit community input, assess community preferences, and assess socioeconomic impacts). Chapter 4 divides these methods into two main categories: sociocultural and economic methods. The main distinguishing feature of economic assessment methods is that they are based on a common conceptual paradigm for evaluating the human welfare effects and the benefit-cost trade-offs involved in policy decisions. Sociocultural methods, in contrast, provide a number of alternative perspectives and approaches for eliciting stakeholder input, assessing community preferences, and evaluating gains and losses as part of the decision-making process. In essence, Chapter 4 provides the reader with a toolkit of potentially useful social science methods. It briefly describes and compares the different techniques, highlighting some of their main advantages and disadvantages, and it provides references for more in-depth descriptions and illustrations of the methods.

Finally, Chapter 5 illustrates how the proposed decision framework can be implemented in practice, with particular emphasis on how social science methods can be applied. It divides the decision process outlined in Figure 1-6 into three main phases: (1) framing the WQS decision, (2) comparing the advantages and disadvantages of the different management options and (3) making the decision (selecting the most preferred option). For each phase, it describes the main components of the decision process and the techniques that can be used to address each component. It also uses two of the UAA case studies described in Chapter 3—one involving acid mine drainage and the other combined sewer overflows—to illustrate how the methods and tools described in the previous chapters can be applied to inform and strengthen each stage of the decision-making process.

1.2. REFERENCES

Colorado Water Quality Control Division. 2003. Discussion Paper: Addressing Water Quality Standards Issues Regarding Effluent Dependent and Effluent Dominated Waters. Final Draft. Colorado Department of Public Health and Environment.

U.S. EPA. 1992. Guidance for Modifying Water Quality Standards and Protecting Effluent-Dependent Ecosystems. Guidance Interim Final. U.S. Environmental Protection Agency, Region 9. June.

U.S. EPA. 1995. Interim Economic Guidance for Water Quality Standards Workbook. U.S. Environmental Protection Agency, Office of Water, Washington, DC. EPA/823/B-95/002. Accessed January 24, 2005 at http://www.epa.gov/waterscience/econ/complete.pdf.

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2. UNDERSTANDING THE GROUND RULES: AN INTRODUCTION TO WATER QUALITY STANDARDS, USE ATTAINABILITY ANALYSES, AND ANTIDEGRADATION REVIEWS

This chapter explains how the water quality goals and ecological integrity for a water body, termed its designated uses, are established as part of a WQS program. It discusses the circumstances under which designated uses can be changed with a focus on whether these changes are wanted by communities. Understanding these ground rules—determining what is allowable—is a prerequisite for the subject to be addressed in the following chapters—determining whether the changes are worth making (see U.S. EPA [1994] for more detail).

2.1. CLEAN WATER ACT GOALS AND THE ESTABLISHMENT OF WATER QUALITY STANDARDS

States adopt WQS in accordance with the Water Quality Standards Regulation (40 CFR 131) to protect public health and welfare, enhance the quality of water, and serve the purposes of the CWA. Section 101(a)(2) of the CWA identifies two overarching goals:

- Restore and maintain the chemical, physical, and biological integrity of the nation's waters, and
- Achieve a "fishable/swimmable" level of water quality: one that provides for the protection and propagation of fish, shellfish, and wildlife, and for recreation in and on the water, wherever attainable.

The CWA recognizes other objectives when it requires states to consider the use and value of public water supplies, and agricultural, industrial, and other purposes, including navigation, in revising or adopting new WQS (Section 303(c)). Although the CWA does not present a hierarchy of uses, U.S. EPA's Water Quality Standards Regulation highlights the uses in the "fishable/swimmable" goal (U.S. EPA, 1994).

The WQS program is a partnership between U.S. EPA and states and authorized tribes to work toward achieving the goals of the CWA. The states and tribes have primary responsibility for setting, reviewing, revising, and enforcing WQS. U.S. EPA develops regulations, policies, and guidance to help states and tribes implement the program and oversees their activities to ensure that standards are consistent with the requirements of the CWA and the WQS regulation. U.S. EPA has authority to review and approve or disapprove state standards and, where necessary, to promulgate federal WQS.

2.1.1. What are Water Quality Standards?

To comply with the provisions of the CWA, states and authorized tribes must establish WQS. According to U.S. EPA (1994) and 40 CFR 131, WQS are the foundation of the water quality-based control program mandated by the CWA. WQS define the goals for a water body by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants. A water quality standard consists of four basic elements:

(1) Designated uses of the water body (e.g., recreation, water supply, aquatic life, agriculture)

(2) Water quality criteria (numeric pollutant concentrations and narrative requirements) to protect designated uses

(3) An antidegradation policy to maintain and protect existing uses[1] and high-quality waters, and

(4) General policies addressing implementation issues (e.g., low flows, variances, mixing zones)

The following sections describe these elements in greater detail.

2.1.2. Designated Uses

States and authorized tribes are required to specify, for each water body, appropriate uses to be achieved and protected. The appropriate uses are determined by taking into consideration the use and value of the water body for a variety of purposes: public water supply; protection of fish, shellfish, and wildlife; and recreational, agricultural, industrial, and navigational purposes. In designating uses for a water body, states and tribes examine the suitability of a water body for the uses based on the physical, chemical, and biological characteristics of the water body, its geographical setting and scenic qualities, and economic considerations. Because each state considers its own set of water bodies, each state could have a unique set of designated uses (e.g.,

[1] The WQS regulation defines existing uses as those uses "actually attained in the water body on or after November 28, 1975, whether or not they are actually included in the water quality standards" (40 CFR 131.3 (e)).

see Table 2-1). Designated uses must be at a minimum the uses actually attained, termed existing uses, at any time since November 28, 1975 (U.S. EPA, 1994). Existing uses are different from designated uses because, whereas a designated use can be removed, existing uses set a historical baseline that must be maintained. The inclusion of existing uses in WQS helps ensure that a temporary impairment does not become permanent.

If a state or tribe designates a use that does not include uses of aquatic life and contact recreation (the fishable/swimmable goal of the CWA), it must conduct a UAA. Such water bodies must be reexamined every 3 years to determine if new information has become available that would warrant a revision of the standard. If new information indicates that "fishable/swimmable" uses can be attained, those uses must be designated. In addition, states and tribes may remove a designated use that is not an existing use or establish subcategories of a use if the state can demonstrate through a UAA that attaining the designated use is not feasible. For example, to meet the deadline of submitting WQS (if states had not adopted WQS for intrastate waters) to the Administrator prior to 180 days after October 18, 1972, some states designated all waters as fishable/swimmable because they did not have time to evaluate the attainability before designating the use. Because no evaluation was done, some designations may not be attainable or some could actually be upgraded. The WQS regulation (40 CFR 131.10(g)) lists reasons why a designated use might not be feasible; they include physical, chemical, biological, and socioeconomic reasons (Section 2.2 describes these six factors in more detail).[2]

2.1.3. Water Quality Criteria

Under 40 CFR 131.11, states are to adopt numeric (e.g., pH measured from 6.0 to 9.0 to protect the cold-water fishery use) and/or narrative criteria (e.g., "aquatic life should be as it naturally occurs") with sufficient coverage and stringency to protect designated uses. States can choose to

- adopt the criteria that U.S. EPA publishes under 304(a) of the CWA,[3]
- modify the Section 304(a) criteria to reflect site-specific conditions, or
- develop other criteria based on scientifically defensible methods.

[2] These analyses could also establish that a higher use is attainable.
[3] Water quality criteria documents can be found at http://www.epa.gov/waterscience/criteria.

<table>
<tr><td colspan="4">TABLE 2-1

Examples of States' Designated Uses</td></tr>
<tr><td colspan="2">OREGON[a]</td><td colspan="2">OHIO[b]</td></tr>
<tr><td>Domestic water supply
Industrial water supply
Irrigation
Livestock watering
Fish and aquatic life
Wildlife and hunting</td><td>Fishing
Boating
Water contact recreation
Aesthetic quality
Hydropower
Commercial navigation and transportation</td><td>Warm-water habitat
Limited warm-water habitat
Exceptional warm-water habitat
Modified warm-water habitat
Seasonal salmonid habitat
Cold-water habitat
Limited resource waters</td><td>Bathing waters
Primary contact recreation[c]
Secondary contact recreation[d]

Public water supply
Agricultural water supply
Industrial water supply</td></tr>
<tr><td colspan="4">MAINE[e]</td></tr>
<tr><td colspan="2">Class AA: Must be of such quality that they are suitable for the designated uses of drinking water after disinfection, fishing, agriculture, recreation in and on the water, navigation and as habitat for fish and other aquatic life. The habitat must be characterized as free-flowing and natural.

Class A: Must be of such quality that they are suitable for the designated uses of drinking water after disinfection; fishing; agriculture; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; navigation; and as habitat for fish and other aquatic life. The habitat must be characterized as natural.</td><td colspan="2">Class B: Must be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; agriculture; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; navigation; and as habitat for fish and other aquatic life. The habitat must be characterized as unimpaired.

Class C: Must be of such quality that they are suitable for the designated uses of drinking water supply after treatment; fishing; agriculture; recreation in and on the water; industrial process and cooling water supply; hydroelectric power generation, except as prohibited under Title 12, section 403; navigation; and as habitat for fish and other aquatic life.</td></tr>
</table>

[a]Accessed on March 26, 2007, at www.deq.state.or.us/wq/standards/uses.htm.
[b]Accessed on March 26, 2007, at www.epa.state.oh.us/dsw/wqs/designation_summary.pdf.
[c]Water depth allows full body immersion (e.g., swimming).
[d]Water depth precludes full body immersion (e.g., wading).
[e]All copyrights and other rights to statutory text are reserved by the State of Maine. The text included in this publication reflects changes made through the Second Regular Session of the 122nd Legislature, and is current through December 31, 2006, but is subject to change without notice. It is a version that has not been officially certified by the Secretary of State. Refer to the Maine Revised Statutes Annotated and supplements for certified text. Accessed on March 26, 2007, at http://janus.state.me.us/legis/statutes/38/title38sec465.html.

Criteria are developed to protect human health and aquatic life (both freshwater and saltwater) and to specify desirable biological characteristics (biocriteria) and nutrient levels (nutrient criteria). Criteria are science-based; as new information becomes available, criteria are revised to reflect it.

2.1.4. Antidegradation Policy

Antidegradation policy specifies a three-tier program. Tier 1 protects existing uses and the water quality conditions needed to protect those uses. Tier 2 maintains and protects "high-quality" waters—water bodies where water quality exceeds "fishable/swimmable." Tier 3 maintains and protects water quality in outstanding natural resource waters. Under Tier 2, water quality may be lowered as long as existing and "fishable/swimmable" uses are not impaired; however, U.S. EPA (1994) states, "This provision is intended to provide relief only in a few extraordinary circumstances…" (p. 4-7). For example, a proposed wastewater treatment plant discharge is expected to change pH, but because pH should remain in the range of 6.0 to 9.0, the cold-water fishery use should not be impaired. To justify lowering water quality in Tier 2 cases, an AR analysis must be performed (Section 2.2 provides more detail on ARs).

2.1.5. General Provisions

States and tribes may adopt policies and provisions regarding WQS implementation. For example, variances allow states and tribes to temporarily relax a water quality standard to progress toward attainment. Mixing zone policies allow numeric criteria to be exceeded for small areas near outfalls if the integrity of the water body as a whole is protected. Finally, a water quality standard may include procedures for critical low-flow conditions that differ from higher flows. Such policies are first subject to U.S. EPA review and approval.

2.1.6. Review and Revision

After state or tribal WQS are officially adopted, a governor or designee submits the standards to the appropriate U.S. EPA Regional Administrator for review to determine whether any analyses performed are adequate. The Agency also evaluates whether the designated uses and criteria are compatible throughout all water bodies covered and whether downstream water quality is protected. The CWA requires states to hold public hearings to review their WQS at least once every three years and to revise them if appropriate.

States may identify necessary additions or revisions to existing standards based on their 305(b) reports (i.e., biennial reports describing the quality of states' waters including the extent to which designated uses are supported and the impairments), other water quality monitoring data, etc. WQS reviews and revisions may include additions to and modifications of uses, criteria, the antidegradation policy or procedures, or the general policies.

2.2. CONDUCT OF USE ATTAINABILITY ANALYSES AND ANTIDEGRADATION REVIEWS

As described above, states or tribes that wish to designate a use for a water body that is not consistent with CWA Section 101(a)(2) (i.e., "fishable/swimmable"); remove a designated use for a water body that is specified in Section 101(a)(2); or adopt a subcategory of a use must conduct a UAA. A UAA is a structured scientific assessment of the factors affecting the attainment of a use. UAA is best understood as a means of determining which uses are feasible and appropriate for a water body, rather than as a process for downgrading uses. For example, in certain cases, initial use designations made by states and tribes were not actually attainable (see Section 2.1.2). UAA constitutes a process for recognizing and correcting these historical mistakes. The WQS regulation lists factors states can use to demonstrate that attaining a use is not feasible (40 CFR 131.10(g)):

(1) naturally occurring pollutant concentrations prevent the attainment of the use;

(2) natural, ephemeral, intermittent or low-flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating state water conservation requirements to enable uses to be met;

(3) human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;

(4) dams, diversions, or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use;

(5) physical conditions related to the natural features of the water body, such as a lack of proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or

(6) controls more stringent than minimum technology requirements (as specified in Sections 301(b) and 306 of the CWA[4]) would result in substantial and widespread economic and social impact.

As the above list makes clear, economic and social impacts are only one of several reasons states may cite in a UAA for adopting a lower designated use or subcategorizing a use. Thus, the majority of UAAs rely on noneconomic arguments, but economics may play a determining role in some cases. In contrast, economics is more central in ARs. The WQS regulation (131.12 (a)(2)) provide that water quality in "high-quality" or Tier 2 waters may be lowered without changing the current uses of the water body if it is necessary to permit "important economic and social development." In addition to these provisions, the WQS regulation (131.13) allow states to grant a variance from WQS to specific dischargers, allowing them to exceed water quality-based permit limits for a certain pollutant for a limited period of time.

U.S. EPA provides guidance on the need for and conduct of UAAs and other economic analyses in the *Water Quality Standards Handbook* (U.S. EPA, 1994) and the *Interim Economic Guidance for Water Quality Standards: Workbook* (U.S. EPA, 1995). A short summary of existing economic guidance in the WQS program follows.

2.2.1. Economics in Use Attainability Analysis

When applying for a change in a designated use or a subcategory of use, or for a variance, specifically based on economic criteria (i.e., factor six in WQS regulation), the state must demonstrate that meeting WQS will cause substantial and widespread economic and social impacts. The *Interim Economic Guidance for Water Quality Standards: Workbook* (hereafter referred to as *Interim Economic Guidance*) defines a set of measures to determine whether impacts are substantial, including separate measures for private-sector and public-sector pollution sources (U.S. EPA, 1995). U.S. EPA notes that, to justify modifying a use or granting a variance, the state must demonstrate both substantial impacts on the discharger and widespread

[4] Sections 301(b) and 306 do not list any specific requirements.

impacts on the geographic area. The *Interim Economic Guidance* defines financial ratios (e.g., profitability, liquidity, solvency, and leverage) to determine whether impacts are substantial, and it identifies a group of socioeconomic indicators (see Section 2.2.4) that should be considered when assessing whether impacts are widespread. The financial ratios to determine substantial impacts are further explained in Appendix A.

2.2.2. Economics in Antidegradation Reviews

As with removing a use or granting a waiver, economic impacts are also considered as part of an AR. Where water quality exceeds "fishable/swimmable," states can allow reduction in water quality (as long as existing uses are protected) if the reduction is necessary to accommodate important economic or social development in the area of the water body. U.S. EPA's *Interim Economic Guidance* notes that ARs are in a sense the "flip side" of UAAs. Variances and use downgrades refer to situations where additional treatment to meet standards may result in substantial and widespread economic impacts, while antidegradation refers to situations where lowering water quality may result in improved social and economic development. Although the terminology associated with economic analyses for UAAs and ARs is different, the *Interim Economic Guidance* recommends using the same analytical tools for both.

In conducting an AR, the state must show both that the costs of treatment needed to maintain water quality would interfere with development and that the development is important to the region. These requirements are analogous to the UAA requirement that impacts show both substantial and widespread effects.

2.2.3. Evaluating Substantial Impacts or Costs Sufficient to Interfere with Development

Although U.S. EPA (1995) demonstrates that the same measures can be used for UAAs and ARs, it defines separate measures for public-sector and private-sector entities. For simplicity, the rest of this discussion will refer to these measures as demonstrating substantial impacts; however, the same measures are applicable for ARs as well.

2.2.3.1. *Measures for Private-Sector Entities*

Analyzing impacts on private-sector entities relies on the use of financial ratios that compare the costs of complying with the WQS with baseline company sales, profits, and other financial variables. U.S. EPA (1995) recommends the following process to assess whether impacts are substantial, which can be conducted for a single affected facility or a group of facilities that discharge pollutants to a water body:

(1) Verify project costs and calculate the annual cost of the pollution control project.

(2) Conduct financial impact analysis:

- Primary measure = Profit─How much will profits decline because of the pollution control expenditure?
- Secondary measures
  - Liquidity—How easily can an entity pay its short-term bills?
  - Solvency—How easily can an entity pay its fixed and long-term bills?
  - Leverage—How much money can the entity borrow?

U.S. EPA advises computing various ratios that measure profit, liquidity, solvency, and leverage both with and without the control costs. The *Interim Economic Guidance* states that the analysis should be conducted at the facility level and that the application should be accompanied by data to demonstrate it. U.S. EPA also notes that facility-level data may be unavailable or considered proprietary; in this case, U.S. EPA suggests estimating facility-level data based on data for the company that owns the facility. Appendix A describes in detail the ratios used for each measure and the values of each ratio that indicate when an impact is substantial.

2.2.3.2. *Measures for Public-Sector Entities*

If a facility is owned by a public-sector entity (such as a publicly owned treatment works [POTW] or public construction project), the indicators of impact are different. In this case, the process involves several steps:

(1) Verify project costs and calculate the annual cost of the pollution control project.

(2) Calculate the total annualized pollution control cost per household.

(3) Calculate and evaluate the municipal preliminary screener score, which compares the cost per household with the municipal median household income.

(4) Apply the secondary test, which characterizes community baseline financial and socioeconomic well-being based on measures such as debt indicators, unemployment rate, median household income, and measures of financial management.

(5) Determine where a municipality falls in the "substantial impacts matrix."

Appendix A provides the substantial impacts matrix for a public-sector entity. Overall, U.S. EPA states that socioeconomic conditions should be weighted more heavily than financial management indicators.

2.2.4. Determining if Impacts are Widespread

Determining that impacts are substantial is a necessary but not sufficient condition to remove a use or allow a waiver or to permit a reduction in water quality. The analyst must also demonstrate that the impacts are widespread. U.S. EPA's *Interim Economic Guidance* states that there are no definitive ratio measures to evaluate widespread impacts. Instead, the analyst must examine relative magnitudes of a variety of socioeconomic indicators.

The first step in examining whether economic impacts are widespread is to define the affected geographic area. For example, in the case of municipal pollution control projects, the affected community is most often the immediate municipality. In other circumstances, the geographic area may include adjacent or downstream communities too.

To evaluate whether costs incurred by a private-sector entity result in widespread impacts, U.S. EPA suggests that the criterion is whether the economy of the region is able to absorb reductions in employment and business activity resulting from them, which depends largely on the baseline strength or weakness of the local economy and on how important the affected facility is to the local economy. U.S. EPA again advises considering possible economic impacts on development opportunities if the need to install water pollution controls to comply with the standards discourages or delays investment.

To assess whether costs incurred by a public-sector entity result in widespread impacts, U.S. EPA recommends examining potential changes in such indicators as median household income, community unemployment, percentage of households below the poverty line, impacts on property values, and impaired development opportunities. Whether an impact is considered widespread according to the *Interim Economic Guidance* depends on its magnitude and on the current condition of the community.

Decreased employment, decreased personal income, and reductions in local expenditures by the entity or entities will generate additional indirect and induced effects throughout the rest of the economy as directly affected businesses and households reduce their spending on locally produced goods and services. U.S. EPA notes that these impacts can be evaluated using multipliers (such as the U.S. Department of Commerce's RIMS II Regional Multipliers, currently based on the 1997 Economic Census) (DoC, 1997). These multipliers capture the spending linkages between the directly affected entities and the rest of the economy and permit the analyst to trace the changes in spending throughout the economy (additional information can be found in Chapter 4, see Section 4.25).

2.2.5. Differences in Application for Antidegradation Reviews

If the quality of water (i.e., water quality criteria) exceeds "fishable/swimmable" (in other words, it is a "high-quality water"), some reduction of water quality may be permitted if an AR determines that the lowering is necessary to accommodate important economic or social development in the area where the waters are located. For the AR, the analyst first assesses whether the costs of control required to maintain the water quality would interfere with economic development (usually, a specific proposed project). If so, the next step is to determine whether the development would be important economically or socially to the area.[5] The *Interim Economic Guidance* identifies the following steps in an AR:

[5] U.S. EPA (1995) states that "the term important is intended to convey a general concept regarding the level of social and economic development," which is measured by geographical area and changes to socioeconomic indicators like unemployment, income, and tax revenue, for example.

(1) Verify project costs and calculate the annual cost of the pollution control project.

(2) Determine if requirements would interfere with development.

(3) Determine if the economic and social development that is at risk would be important.

2.3. OTHER PERSPECTIVES ON ECONOMIC ANALYSES AND USE ATTAINMENT DECISIONS

As described above, the U.S. EPA *Interim Economic Guidance* recommendation for UAAs based on the socioeconomic factor is to use **economic impact analysis** methods to assess both substantial and widespread impacts. Nevertheless, there are other perspectives on the appropriate methods to apply. In particular, the Water Environment Research Foundation (WERF, 1997), National Research Council (NRC, 2001), and Shabman (2005) are all examples of documents that use approaches other than economic impact analysis for evaluating the socioeconomic effects of changing designated uses. However, it is not clear if these other approaches are consistent with current WQS regulation. In this section, we present these other perspectives. The purpose is not to advocate for or against these other approaches, but rather to inform the reader about other viewpoints on applicable research related to economic UAAs.[6]

Benefit-cost analysis (BCA) is one of the main alternatives to economic impact analysis. BCA is a widely used economic analysis method for evaluating the overall effect of a policy on society's well-being; however, it is generally not part of the UAA process. As the name implies, BCA involves identifying, quantifying, and valuing the positive effects (benefits) and negative effects (costs) on society's well-being that result from a water quality change and then comparing these benefits and costs to assess whether the change improves society's well-being overall. This is different from economic impact analysis, which tends to focus on changes in financial and fiscal outcomes—profits, revenues, incomes—and employment measures. Although benefits analysis is described in U.S. EPA *Interim Economic Guidance*, the process

[6] This report, as described in Chapter 1, supports and presents the idea that community preferences can play a role in UAAs and ARs but still remain within the current regulatory framework. By following the recommendations within the *Interim Economic Guidance*, we suggest additional analyses to examine whether the community prefers the outcomes suggested by the *Interim Economic Guidance* (i.e., if substantial and widespread impacts are found, does the community still want to downgrade the use and lose the potential ecological benefits?).

described in the guidance focuses on measuring the costs and economic impacts of meeting water quality goals.

The WQS regulation (40 CFR 131) allows for the consideration of economic impacts on regulated entities and the economic health and development of the surrounding communities, in cases where either the state wishes to remove a use, obtain a pollutant-specific waiver, subcategorize a use, and require it when the state wishes to allow a reduction of water quality while still maintaining water quality that is "fishable/swimmable." The language in the regulation calls for economic impact analysis, including an assessment of impacts on regulated entities, communities, and economic development. It does not call specifically for a comparison of benefits and costs (for details, see Bruins and Heberling, 2005). This is consistent with other regulations under the CWA, which incorporate a criterion of "economic achievability" into consideration of point-source water pollution controls and best management practices for nonpoint sources.

WERF's *A Comprehensive UAA Technical Reference,* which describes socioeconomic analysis in the context of a UAA (WERF, 1997, Chapter 10), argues that socioeconomic analysis can be accomplished through either financial impact analysis (FIA, a type of economic impact analysis) or BCA or both.[7] Although the U.S. EPA *Interim Economic Guidance* guidance clearly states that "benefit-cost analysis is not required to demonstrate substantial and widespread effects under the Federal Water Quality Standards regulation" (U.S. EPA, 1995, p. 4-6), WERF suggests that FIA is not a sufficient approach for a UAA proposal that involves large changes in WQS or water quality, changes that have widespread impact, changes that affect many people, and changes that require other financing mechanisms in addition to the investments provided by regulated dischargers. The WERF document then discusses the use of BCA for socioeconomic analysis. The document includes a discussion of benefits estimation and a discussion of social and financial costs of water quality improvements. WERF prefers BCA because it incorporates consideration of the values of water quality changes (improvements or reductions). WERF then describes, through the use of interrelated flow diagrams, the process of BCA for UAAs.

The financial analysis described in U.S. EPA's *Interim Economic Guidance* provides a detailed assessment of impacts on regulated entities and communities. Although the financial

[7] Whereas U.S. EPA distinguishes between UAAs, which are for removing, waiving, or subcategorizing uses, and ARs, in WERF's terminology there are two types of UAAs: one assessing nonattainment situations and one assessing antidegradation situations.

tests suggested are straightforward, WERF believes there are limitations: the data for these tests may need to be estimated, they do not incorporate likely behavioral responses by either the regulated entity or others indirectly affected, and their interpretation is somewhat arbitrary.

BCA, as noted by WERF, provides a more complete assessment of the effects of the change in water quality, including both costs and impacts to the regulated entity and the surrounding community, and changes in the value of the water body as a resource. It is, however, a more costly and complex process than economic impact analysis (involving first estimating changes in water quality, then quantifying the effects of those changes on the ecosystem and the services provided by the ecosystem, and then estimating the value of those changes). According to WERF, BCA may be warranted when changes in water quality are expected to be economically consequential, because of the magnitude of the change or the economic importance of the water body.

The NRC (2001) argues that a lack of clear guidance on what is an acceptable UAA and how to conduct economic analysis within the UAA decision leads to few states actually determining "substantial and widespread economic and social impact" (see Section 2.4). Therefore, one of NRC's recommendations is for U.S. EPA to provide "broadened socioeconomic evaluation and decision analysis guidelines for states to use during UAA." However, the NRC does not go into detail on what constitutes a "broadened socioeconomic evaluation."

Shabman (2005), providing some details omitted in the NRC (2001) report, describes an adaptive implementation (AI) process that refines uses and criteria over time. To bring economics into AI, he describes an analysis called "proximate knee of the cost curve," which allows the public to discover the gains and losses over time. It sets the starting point for the analysis at the current conditions and asks the public whether the additional costs of moving away from the current conditions to some goal are reasonable. The current U.S. EPA approach sets the WQS as the goal and requires the polluter to prove that costs are unreasonable. Shabman (2005) assumes that having the current conditions as the starting point reduces the uncertainty bounds around the benefits and costs of moving away from the current conditions.

2.4. EXAMPLES OF EXISTING USE ATTAINABILITY ANALYSES AND ANTIDEGRADATION REVIEWS USING ECONOMIC CONSIDERATIONS

To provide the reader with a resource for understanding the current practices, this section of the report identifies and describes several examples of existing UAAs and ARs. The WERF (1997) and the U.S. General Accounting Office (GAO, 2003) both surveyed the 50 states in order to gain an understanding of the UAA activity level and the number of designated uses that have been changed. No other sources of information could be found related to current practices. WERF found that approximately 3200 UAAs were undertaken between 1983 and the end of 1992. The GAO asked states how many designated use changes were adopted between 1997 and 2001. They found that approximately 3900 changes were identified.

In our search of the literature, we identified 13 UAAs and 4 ARs that incorporate economic arguments. The examples found in the search were initiated between 1983-2003. Documentation for the examples was obtained from materials that could be downloaded from state agency Web sites and reports submitted by the states to U.S. EPA Regional program offices. Tables 2-2 and 2-3 summarize select elements from each example, and Figure 2-1 shows their locations within states and watersheds (8-digit U.S. Geological Survey [USGS] cataloging units).

This collection of examples is not meant to be exhaustive, and the methods used in these cases are not necessarily recommended. The main goal in compiling them is to provide examples from different parts of the country that used economic analyses of varying sophistication or different methods in presenting socioeconomic arguments.

It should be noted that the vast majority of UAAs do not involve economic arguments. For ARs, many states are still defining their methodologies. This means that ARs involving socioeconomic arguments are not plentiful, and finding examples was difficult. The "record of decision" process does not usually involve publishing materials in the *Federal Register* or other readily available national dockets. Also, states tend to submit materials to their U.S. EPA Regional offices to initiate a potentially lengthy series of negotiations. In many cases, technical alternatives to an actual UAA (e.g., site-specific adjustments to criteria for existing uses) are employed to avoid actual changes in the designated uses. The status of the review process as of the end of 2003 is noted in Table 2-2, but a large number are best viewed as still in process or even as draft submissions.

TABLE 2-2 Use Attainability Analysis Examples					
Example ID	State	Name	Reason for Analysis	Type of Economic Analysis	Status
1	CA	Ballona Creek	TMDL process	Narrative discussion of costs and benefits	Under review by U.S. EPA Region
2	ID	Blackbird Creek	Impacts from inactive mine lands and mine tailings	Narrative discussion of costs and benefits	Under review by U.S. EPA Region
3	VA	Blacks Run Creek	TMDL process	Narrative discussion of costs and benefits	Unclear
4	MA	Boston Harbor Area	Combined sewer overflow (CSO) issues	Narrative discussion of costs	Approved by U.S. EPA Region
5	OR	Burnt River	TMDL process	Narrative discussion of costs	Under review by U.S. EPA Region
6	NY	Cayadutta Creek	National Pollutant Discharge Elimination System (NPDES) discharge permit issue	Cost data for alternatives	Approved by U.S. EPA Region
7	DE/ PA/ NJ	Delaware Estuary	National Estuary Program recommendation	Narrative discussion of benefits	National Estuary Program recommendation approved by U.S. EPA Regions
8	ME	Gulf Island Pond	NPDES discharge permit issue involving pollution effects in a reservoir	Cost data for alternatives, narrative discussion of benefits	Under review by U.S. EPA Region
9	CO	Lower French Gulch/Blue River	Acid mine drainage from abandoned mine lands	Narrative discussion of costs and benefits, some valuation	Under review by U.S. EPA Region
10	NY	Lower Hudson/East River	Long Island Sound Study recommendations	Narrative discussion of costs and benefits	Analysis shared with U.S. EPA Region
11	ME	Lower Salmon Falls River	NPDES discharge permit issue	Cost data for alternatives, quantified assessment of water quality impacts, socioeconomic analysis	Under review by U.S. EPA Region
12	CA	Santa Ana River	NPDES discharge permit issues on an effluent-dominated system	Cost data for alternatives, quantified assessment of water quality impacts, socioeconomic analysis	Approved by U.S. EPA Region
13	IN	White River	CSO issues	Cost data for alternatives, quantified assessment of water quality impacts, socioeconomic analysis	Approved by U.S. EPA Region

TABLE 2-3

Antidegradation Examples

Example ID	State	Name	Reason for Analysis	Type of Economic Analysis	Status
14	ND	Devils Lake	Impacts of lake/wetland drainage on water quality	Cost data for alternatives, qualitative discussion of water quality and ecological impacts	Under review by U.S. EPA Region
15	WY	Northwest Basins	Coal bed methane operations general discharge permits	Cost data for alternatives, qualitative assessment of environmental impacts	Approved by U.S. EPA Region
16	OK	Snake Creek	Concentrated animal feeding operations (CAFO) issues (poultry wastes)	Narrative discussion of costs and benefits	Approved by U.S. EPA Region
17	OH	Sycamore Creek	NPDES discharge permit issue	Cost data for alternatives, qualitative comparison of benefits	Under review by U.S. EPA Region

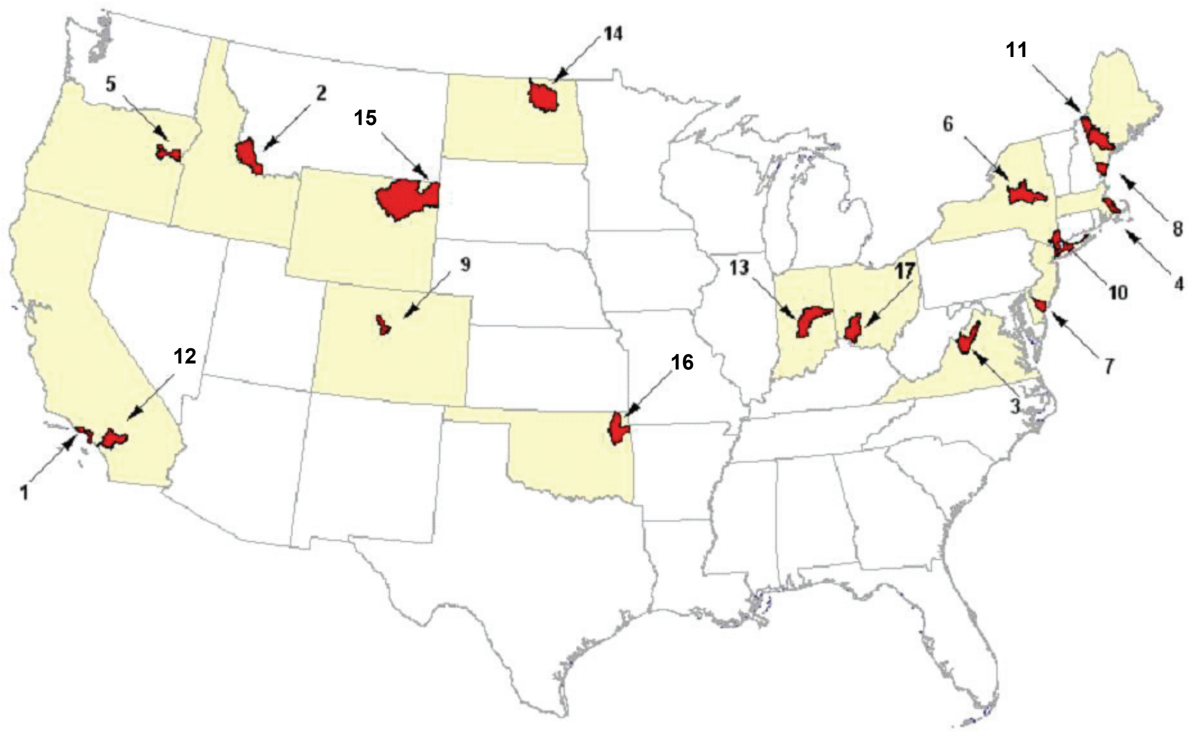

FIGURE 2-1

States and Watersheds Containing UAAs or Antidegradation Reviews that Incorporate Economic Arguments. Numbers correspond with the “Example ID” column in Tables 2-2, 2-3, and with the “Example” column in Table B-1.

Although somewhat limited in number, these examples offer a good illustration of the types of socioeconomic methods and techniques that states have applied. Appendix B provides more detailed summaries that include information on the location of the water bodies, the designated uses and pollution stressors of concern, the primary reasons for undertaking the studies, the types of analyses considered, and alternatives proposed to address the WQS issues. The different stakeholders involved are noted along with the year when the UAAs or ARs were initiated and the current status of the process.

2.5. LESSON

An important lesson that emerges from even a cursory review of the examples listed above is, to the extent that an economic analysis is conducted, most attention is given to the cost data of attaining designated uses or of maintaining high water quality. Very little attention is given to the kinds or amounts of economic benefits that would be obtained in the process. Therefore, the current approach used in the economic analysis, although useful for regulatory determinations, may not fully inform affected communities about the effects these decisions will have on their well-being. No UAA or AR was based on collecting community preferences suggesting that those UAAs and ARs did not provide the local community all the information it could have considered. A broader analysis, one that makes the preparation of UAAs and ARs more informed, may help a community decide that a use change or degradation is not warranted. On the other hand, it may reveal that a higher use is preferred. The subsequent sections of this report introduce a set of approaches that can be used to obtain a broader perspective on ecological and economic changes, including both qualitative and quantitative methods that result from decisions about WQS.

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3. UNDERSTANDING THE CHOICES: RELATING WATER QUALITY MANAGEMENT DECISIONS TO CHANGES IN ECOSYSTEMS, ECOSYSTEM SERVICES AND ECOLOGICAL BENEFITS

Existing WQS guidance for evaluating socioeconomic impacts in UAAs and ARs includes analyses of financial impacts on affected entities and regional economic impacts on communities. Nevertheless, states, tribes, and communities could take a broader approach in analyzing the effects of water quality management options (see Chapter 1). A variety of socioeconomic analysis methods can be used (see Chapter 4) to provide decision-makers with a broader understanding of who the relevant stakeholders are and how alternative management options are likely to affect them. Decision-makers must often weigh gains and losses to different groups, and these analytical methods provide them with tools for evaluating the relevant trade-offs.

Chapter 3 provides decision-makers with a general framework for understanding how the choices affect ecosystems and human well-being. It can be used to organize analyses and to characterize conditions for a wide variety of water quality management situations and scenarios. In this chapter, the framework is first described and then illustrated with several hypothetical case study examples.

This chapter combines concepts from ecological risk assessment (ERA), stressor identification, and socioeconomic analyses, such as BCA. Section 3.1 defines water body impairment and describes approaches for identifying impairments and their causes through stressor identification. ERA and stressor identification are two tools that can contribute to UAA, and this section summarizes the main components of ERA and explains how stressor identification can be used to inform ERA in an iterative fashion to compare risks to aquatic ecosystems associated with various mitigation strategies. Section 3.2 extends this framework to show how aquatic ecosystems are linked to and support humans through the provision of "ecosystem services." It defines and categorizes these services and provides examples of how they can be characterized. It also discusses how ecosystem services are related to designated uses.

To further illustrate these connections and show how they can be used to inform use-attainment decisions, Section 3.3 describes relevant socioeconomic endpoints and Section 3.4 develops flow diagrams representing expanded conceptual models. These expanded models include the interconnections between sources, stressors, ecosystem components and processes, and ecological assessment endpoints. They also extend these links to include effects on ecosystem services and related socioeconomic impacts. In addition, they include linkages to management alternatives, showing how these alternatives alter stressor impacts, services, human welfare, and designated use attainment. The models are applied and illustrated through five hypothetical case studies. The main objective in defining these expanded conceptual models is to provide decision-makers with an initial framework to consider for identifying and evaluating a broader range of ecological and socioeconomic endpoints associated with WQS. Most of these endpoints will not otherwise be captured using existing WQS guidance.

3.1. IDENTIFYING IMPAIRMENTS AND THEIR CAUSES

Understanding impairments and their causes is central to establishing appropriate designated uses for water bodies through UAAs and ARs. Thus, the purpose of this section is to

- provide the reader with an understanding of impairments in terms of designated uses and indicators;
- identify the causes of the biological impairment (referred to as stressor identification); and
- use information gleaned from the stressor identification to improve the conceptual models that characterize the relationships among source, stressor, and impairment.

Figure 3-1 adapts the decision framework outlined in Figure 1-6 to specifically convey where in the process stressor identification occurs and how that information is used in improving the conceptual models that compare alternative approaches to address nonattainment. Whereas ERA is a forward-looking process that evaluates the likelihood that adverse ecological effects (such as disease or injury) may occur as a result of exposure to a stressor—a chemical, physical, or biological agent—stressor identification is a retrospective process used to identify which of several possible stressors is most likely causing a water body's observed impairment. Stressor identification can identify the causes of impairment, supporting both the development of proposed management alternatives as well as the improvement of ERA conceptual models

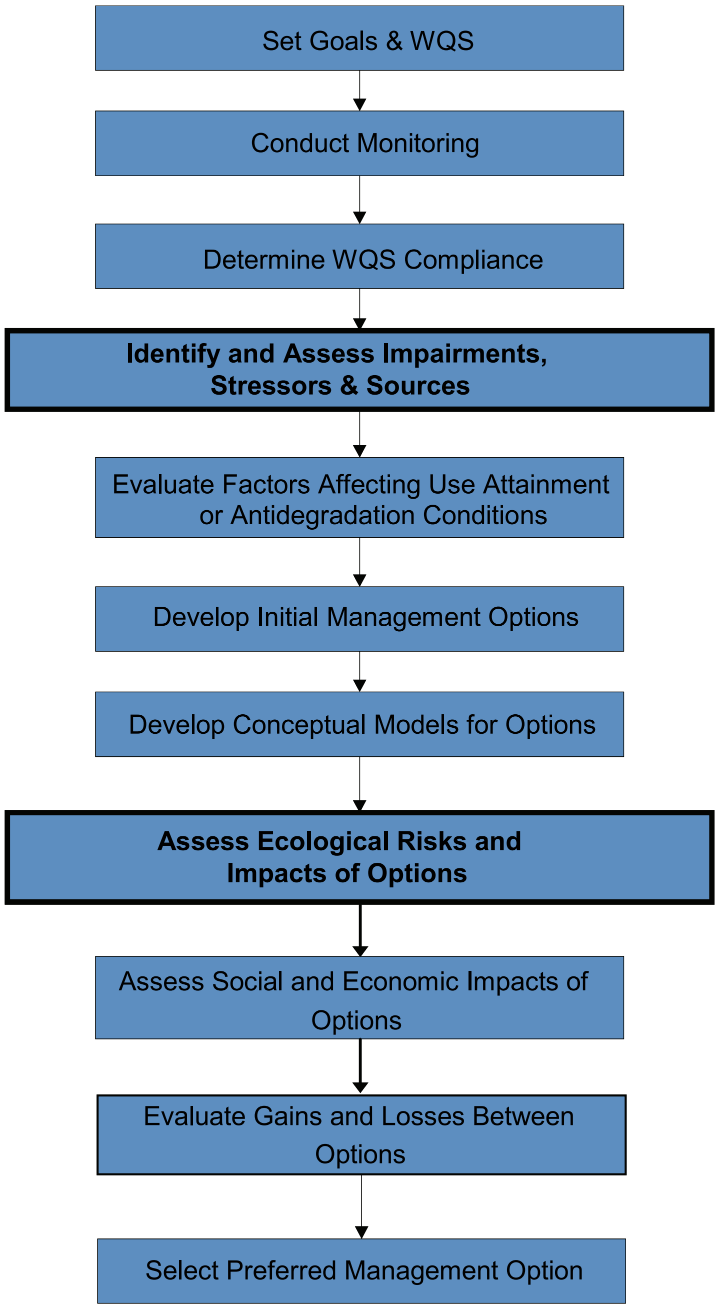

FIGURE 3-1

Relationship of Stressor Identification and Ecological Risk Assessment to the Other Components of Use-Attainment Decisions expanded to describe the relationships among sources, stressors, exposures, responses, and ecosystem services.

Management alternatives can include various voluntary or regulatory actions to reduce the causes or limit the effects of impairment. As described above, the expanded conceptual models can then illustrate the anticipated effects of each of the management alternatives on the ecosystem services. ERA, stressor identification, and socioeconomic analyses then provide the means to characterize and compare the management alternatives to support use-attainment decisions (Bruins et al., 2005).

3.1.1. Impairments

Impairment under the CWA may be broadly defined as any detrimental effect on the integrity of a water body caused by a stressor (or stressors) that prevents attainment of the designated use. The breadth of this definition underscores the importance of characterizing the nature of a detected impairment, including its spatial and temporal scale, and identifying all of its potential causes. Although the focus of this report is not on the detection of impairments, it is important to understand what kinds of impairments are possible, what indicators are used in detecting an impairment, and what sorts of stressors may lead to an impairment.

3.1.1.1. *Types of Impairments*

Because impairments are defined in terms of designated uses, it is useful to think about impairments in a relative sense; that is, the reduction in the quality/quantity of the designated use relative to either the initial conditions (before introduction of a stressor) or a reference water body (i.e., a similar water body where human disturbance is at a minimum). Designated uses cover a wide variety of categories that reflect the biological, chemical, and physical attributes of the water body. Therefore, impairments include a broad range of water body characteristics, including, for example, elevated concentrations of toxics in fish, objectionable odors or low visibility in the water, decreased depth of navigable waters, or reduced flow in agricultural water supplies. Note that all of these impairments are directly linked to designated uses (e.g., elevated fish tissue concentrations of pollutants affect fish consumption), and all are defined in terms of measurable changes in how the water body is used.

3.1.1.2. ***Indicators of Impairments***

WQS may use various criteria to indicate impairment. These fall into two major groups: narrative criteria and numeric criteria. Narrative criteria are qualitative descriptions of the conditions within a water body that are necessary to support designated uses such as recreation (e.g., swimming) or aquatic life. Narrative criteria can be in the form of simple statements such as "free from pollutants that produce objectionable color, odor, or taste" or they may be more explicit with respect to biological integrity, toxicity, nuisance algal growths, or settleable solids. Impairment may be determined based on the ability of the water body to support a designated type of fishery (e.g., a river that does not meet narrative WQS because it fails to support adequate salmonid spawning). Narrative criteria are an integral component of states' WQS, and they are used often to establish water body-specific numerical criteria.

Numeric water quality criteria provide quantitative measures of the "health" of the water body and provide standards that are easily interpretable with respect to impairment. For example, numeric criteria include the Ambient Water Quality Criteria (AWQC) for the protection of health and aquatic life, respectively, from exposure to toxic pollutants. Other numeric criteria include measures of water quality characteristics such as dissolved oxygen (DO) content, pH, and suspended solids; concentrations of nutrients or chlorophyll *a* to indicate overenrichment; and microbial water quality criteria for waterborne bacteria and other pathogens. In addition, biological numeric criteria have been developed to describe the expected attainable community attributes and establish values based on measures such as species richness, presence or absence of indicator taxa, and distribution of classes of organisms. The Index of Biological Integrity (IBI) is an example of a biological numeric criterion for fish community health that combines several specific, quantitative measures of biological components (e.g., number of pollution-intolerant fish species present, percentage of individual fish with deformities) and is used to determine when a water body is impaired. U.S. EPA's (1994) *Water Quality Standards Handbook* provides a thorough discussion of water quality criteria, and descriptions of ongoing research into developing quantitative water quality criteria are available at http://www.epa.gov/waterscience/standards.

3.1.1.3. *Stressors that Lead to Impairments*

The broad scope of the narrative and numeric indicators of impairment implies that aquatic ecosystems are susceptible to a wide variety of stressors. For example, impairment of fish consumption as a designated use could be determined by an exceedance of the AWQC for toxic pollutants (i.e., violation of numeric water quality criteria) or through the comparison with one or more reference sites (i.e., failure to meet narrative biological criteria). This type of impairment also could be determined by a decrease in the DO concentration in the water body below target levels. Each of these indicators leads to the same finding that the water body is impaired; however, each indicator may be related to a different type of stressor and source. Therefore, a key to understanding impairments and, ultimately, to effective management of watersheds is to understand the stressors that cause impairments and the likely sources of those stressors. Specifically, distinguishing between the different stressors and sources that cause impairments will help identify those that are most amenable to control.

As shown in Table 3-1, stressors related to water body impairment may be organized into three major categories—physical, chemical, and biological. As discussed in Section 3.1.2, identifying/characterizing stressors is essential in developing a comprehensive understanding of the impairment of designated uses.

TABLE 3-1

Examples of Stressors and Sources that Can Cause Impairments

Stressor Category	Stressor Examples	Source Examples
Physical	Change in sediment substrate DO, temperature Physical or thermal injury to fish Flow/gradient changes	Destruction of riparian habitat Dam construction Cooling towers Water withdrawal
Chemical	Pesticides (atrazine) Metals, pH Nutrients, ammonia Polycyclic aromatic hydrocarbon (PAHs), phthalates Disinfection by-products Dioxins, mercury	Agricultural applications Stormwater runoff Animal feedlot operations Industrial discharges Wastewater treatment Stack emissions
Biological	Predation, competition Pathogens Overharvesting	Nonnative species introduction Combined sewer operations Commercial fishing pressure

3.1.2. Understanding Stressor Identification

In 2000, U.S. EPA published the *Stressor Identification Guidance Document* (hereafter *Guidance*) (U.S. EPA, 2000) to provide assistance to U.S. EPA regions, states, and tribes in their efforts to protect the biological integrity of the nation's waters. The document recognizes that, although bioassessments are useful for identifying biological impairments, they do not identify the causes of impairments. This shortcoming is due in large part to the complexity in linking biological effects with causes when multiple stressors (e.g., toxics, nutrient loads, habitat destruction) affect a water body. Thus, the *Guidance* bridges an important gap between identifying impairments and characterizing the causes (i.e., stressors) of those impairments (U.S. EPA, 2000). To provide the reader with a sense of how stressor identification supports the ERA process discussed in Section 3.1.3, this section presents a brief summary of how evidence is analyzed and how impairment causes are characterized (Chapters 3 and 4 of the *Guidance*).

3.1.2.1. *Analyzing the Evidence*

Once candidate causes of impairment are identified, the next step in the stressor identification process is to determine whether existing data are sufficient to determine a causal relationship between stressor and impairment. Data from studies of a particular water body, as well as from studies on other water bodies or from laboratories (e.g., effluent toxicity tests, biological surveys, habitat analyses), are all potentially useful, but site and laboratory data do not constitute evidence of causation. Investigators have to analyze these data to delineate associations between stressors and responses relevant to the site of interest. Chapter 3 of the *Guidance* includes detailed instructions for these analyses, including discussions on the following elements:

- associations between measurements of candidate causes and effects,
- use of effects data from elsewhere,
- measurements associated with causal mechanism, and
- associations of effects with mitigation or manipulation of causes.

This step in stressor identification feeds the development of stressor-response profiles in the ERA to establish, and possibly quantify, the relationship between stressors and adverse ecological effects.

3.1.2.2. *Characterizing Causes*

After the available evidence has been compiled and analyzed, the next step in the process is to characterize causes *and* state the level of confidence in that conclusion. Chapter 4 of the *Guidance* presents a systematic method for reaching a conclusion, consisting of two steps: (1) inferring causation and (2) summarizing probable cause and evaluating confidence. To characterize causation, U.S. EPA recommends an iterative process. This process begins with eliminating alternatives based on negative evidence, such as when the effects of concern occur upstream, as well as downstream, of the discharge of the stressor. The elimination step is followed by diagnoses that rely on positive evidence, such as the observation in affected organisms of symptoms known to be characteristic of a particular stressor. The process culminates in a strength of evidence analysis. Evaluating the strength of evidence involves a series of considerations, such as plausibility, specificity, analogy, and predictive performance, among other attributes pertinent to evidential discussions. Assuming that the iterative process identifies one or more sufficient causes of the impairment, the results of the characterization must be summarized and described with respect to uncertainties.

3.1.3. Understanding Ecological Risks

There is a substantial body of information available from U.S. EPA and other sources on ERA. In particular, U.S. EPA's *Guidelines for Ecological Risk Assessment* (U.S. EPA, 1998) provides a widely accepted framework for designing, implementing, and interpreting ERAs; and Bruins et al. (2005) discuss the application of ERA specifically to watershed management problems and presents a series of case studies. Consequently, the following discussion on ERA is intentionally brief and focuses on three elements: (1) defining assessment endpoints for aquatic ecosystems, (2) understanding key ERA concepts in building the conceptual model and the influence of stressor identification on that process, and (3) characterizing risks to aquatic ecosystems.

3.1.3.1. *Defining Assessment Endpoints for Aquatic Ecosystems*

Assessment endpoints are developed to characterize and represent the valued ecological characteristics identified in the management objectives. The process of defining these endpoints identifies the characteristics that are both ecologically relevant and susceptible to stressors, and it selects specific ecological entities and measurable attributes to embody those valued characteristics in the analysis. However, selecting assessment endpoints remains a challenging step. A recent U.S. EPA report (U.S. EPA, 2003) has developed a set of generic ecological assessment endpoints (GEAEs) that can be used as examples for ERA. In that document, the process of developing assessment endpoints is described in terms of five basic questions:

(1) What is susceptible to the stressor (stressor characteristics)?
(2) What is present and ecologically relevant (ecosystem/receptor characteristics)?
(3) What is relevant to the management goals (management goals)?
(4) What is of concern to stakeholders (input by interested parties)?
(5) What is supported by policy or precedent (GEAEs and policies/precedents)?

The document also identifies several specific examples of assessment endpoints that are grouped into four categories according to whether they characterize conditions at the level of organisms, populations, or ecosystems and communities, or whether they correspond to officially designated endpoints, such as critical habitats under the Endangered Species Act.

3.1.3.2. *Understanding Key Concepts in ERA Conceptual Model Development*

The framework for ERA consists of three phases: (1) problem formulation, (2) analysis, and (3) risk characterization. In the first phase, information is gathered to develop and evaluate preliminary theories about why ecological effects (or impairments) have occurred, or may occur, as a result of human actions. The conceptual model that emerges from that process depicts how the stressor is presumed to interact with the ecosystem. It provides both a written description and visual representation (diagram) of predicted relationships between ecological entities and the stressors to which they may be exposed (U.S. EPA, 1998). In developing the conceptual model, the diagram depicts exposure scenarios in which land-use or human activities are linked to specific stressors, and it shows the relationship between those stressors and the ecosystem processes and components that influence receptor responses (and, therefore, relate directly to impairment). Thus, as information from the stressor identification process is brought into the ERA, the conceptual models will evolve to reflect new data and analyses of the causes of water quality impairment. These improvements in the quality of the expanded conceptual models will reduce the overall uncertainty in the ERA and provide a more rigorous basis for decision-making.

One of the most important features of the conceptual model is its representation of a set of theories that describe predicted relationships among the source, stressor, exposure, and assessment endpoint response. Although these theories are sometimes referred to as "risk hypotheses" this term does *not* refer to a test for causality based on statistical inference. As discussed later, developing these risk theories is particularly important because they provide the basis for expanding the conceptual models (Section 3.3). These expanded models depict the impact of management options (e.g., protecting riparian buffer) on stressors; track these changes through ecosystem processes/components; and, ultimately, assess changes in both ecosystem services and regulatory compliance (e.g., attainment of designated uses). Thus, the conceptual model allows one to fully understand the risk theories that are being evaluated by selecting management option "A," and it allows one to identify the ecological responses that are expected under option "A." The risk theories illustrated in the conceptual model provide the framework to evaluate the functional relationships among management options, stressors, and responses within the context of decisions involving use attainment and antidegradation.

Any conceptual model that illustrates complex relationships among sources, stressors, exposure, and responses is, of course, subject to uncertainty. Indeed, conceptual model development may be one of the most important sources of uncertainty in risk assessment (U.S. EPA, 1998). Uncertainty arises from many sources, including a lack of knowledge about how the ecosystem is currently functioning (e.g., is it already in a vulnerable state?); inadequate data on the effects of a stressor on biological components of the ecosystem; and insufficient information on the interactions among different types of chemical, biological, and physical stressors. If important relationships between stressors and other model components are misrepresented (or missed entirely), the risk characterization may misrepresent actual risks. Because model simplification and knowledge gaps are the norm in conducting an ERA, it is particularly important that information developed during the stressor identification be used to reduce the sources of uncertainty or, at a minimum, to characterize the relative importance of key sources of uncertainty.

3.1.3.3. *Characterizing Risks to Aquatic Ecosystems*

The scientific components of the WQS used in an ERA primarily include the AWQC. The AWQC include (1) numeric limits for toxic contaminants and water quality metrics such as

DO; (2) nutrient criteria, which may establish target concentrations for nitrogen or phosphorous; and (3) biocriteria, which are numeric target values of multimetric indices such as the IBI and Invertebrate Community Index (ICI). These indices and their target values are often adjusted to fit regional conditions. They provide "what should be" benchmarks that represent unimpaired reference water bodies. Thus, the ecological risk characterization for aquatic systems typically compares modeled or measured conditions (e.g., pollutant concentrations, abundance and composition of invertebrate species) to reference benchmarks to determine whether the water body is in compliance with these standards. Because the numeric WQS tend to be point values for nationwide or regional use, the uncertainty in these limits is seldom explored; however, the uncertainty in exposure to pollutants released into aquatic systems is often examined using probabilistic modeling simulations.

With few exceptions, the practice of ERA tends to rely on consensus reference benchmarks (i.e., concentration thresholds) rather than on all of the information on the toxicity of a given pollutant. Thus, the emphasis of the risk characterization is on developing a qualitative discussion and, in some cases, a quantitative expression of the certainty that the WQS will or will not be exceeded. Unfortunately, this approach to characterizing risks to aquatic ecosystems addresses only some of the multiple stressors that affect the structure, function, and general "health" of the ecosystem. For instance, hydrological modification (e.g., water withdrawal, flow control), stream channel modification, removal of riparian vegetation, and introduction of nonnative species are not addressed in characterizing risks as part of the WQS. In addition, the potential effects associated with exposure to multiple stressors (e.g., increased macrophyte growth and toxics loadings) and the effects of chemical stressors for which no WQS have been developed are not considered. Although mechanistic models such as AQUATOX Version 2.0 (U.S. EPA, 2004) significantly expand our ability to evaluate effects from multiple stressors, the focus of risk characterization to aquatic ecosystems tends to be limited to the probability of meeting each of the WQS relevant to a particular body of water.

3.2. UNDERSTANDING ECOSYSTEM SERVICES AND DESIGNATED USES

For decision-makers to understand the broader ramifications of alternative approaches for attaining WQS, it often is necessary to look beyond the financial and economic impacts and changes in designated use attainment discussed in Chapter 2 and the ecological endpoints discussed above in Section 3.1. It requires a framework that helps decision-makers better understand how humans interact with and derive services from the affected ecological systems and how these services are related to WQS management options and designated uses. To establish this type of framework, the following sections define and describe aquatic ecosystem services and their relationship to designated uses.

3.2.1. Aquatic Ecosystem Services

The concept of ecosystem services is fundamental for evaluating how humans are supported by ecological systems and how their well-being is affected by changes in these systems (see, for example, Daily [1997] or Millennium Ecosystem Assessment [2005]).[1] This report adopts the following definition provided by U.S. EPA (2006):

> **Ecosystem services** are outputs of ecological functions or processes that directly or indirectly contribute to social welfare or have the potential to do so in the future. Some may be bought and sold, but most are not marketed.

For the purpose of setting and evaluating WQS, the concept of *aquatic ecosystem services* is particularly important. These are the services specifically derived from surface water resources and their connected ecosystems. They are also the ecosystem services primarily affected by alternative water quality management options.

Figure 3-2 illustrates the link between aquatic ecosystems and the services derived from these systems. It describes in simplified terms the primary components and processes of a functioning aquatic ecosystem.[2] They include the physical habitat (e.g., stream bed characteristics and the flow of water through the system) and the biological components of the habitat (e.g., fish populations and species diversity), and the chemical, biological, and hydrological processes that occur within the ecosystem. These components and processes directly influence and are also influenced by the level of water quality (e.g., DO content and pH levels) in the system.

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[1] The Millennium Ecosystem Assessment supports decision-making related to the effects of ecosystem change on humans. It focuses on ecosystem services and human well-being. It also examines local, national, and global options for conserving these services. Although this U.S. EPA report was not written to correspond with the Millennium Ecosystem Assessment, both are fairly consistent in definitions and framework.

[2] Although Figure 3-2 represents stream processes, it could depict other aquatic ecosystems.

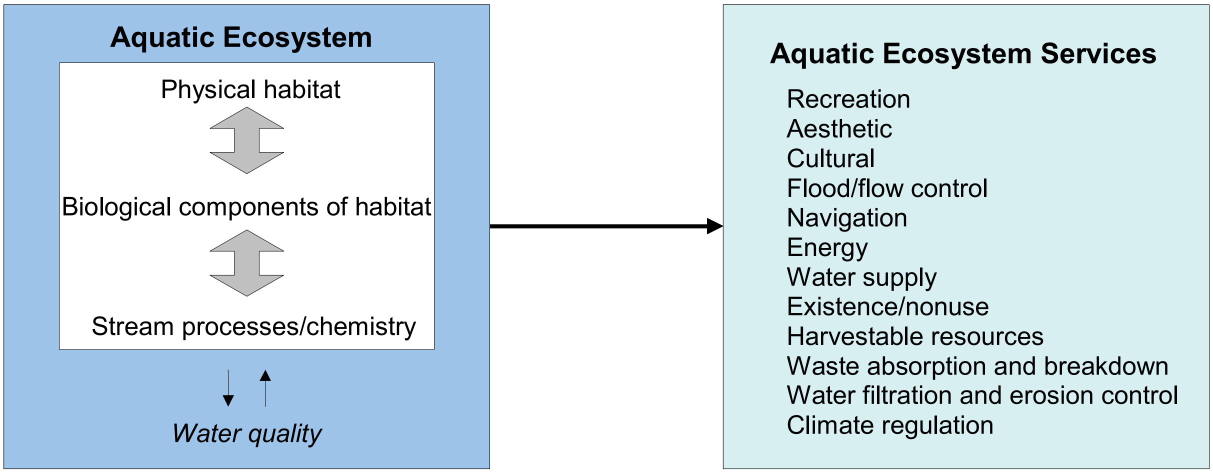

FIGURE 3-2

Services Derived from Aquatic Ecosystems

Figure 3-2 shows that the interrelated features of an aquatic ecosystem are together capable of providing a wide range of ecosystem services to humans. These services are in many cases derived from specific human uses of surface water resources and their associated aquatic ecosystems. The uses include activities that are primarily commercial, such as commercial fishing, navigation, energy production, and agriculture (e.g., through crop irrigation). They also include "nonmarket" activities that are unrelated or only indirectly related to commercial activities, such as water-based recreation, subsistence fishing, and household water use. Other services provided by aquatic ecosystems relate to or support a wide variety of human uses. For example, flood control services protect commercial and residential properties as well as water-based recreational facilities. The Millennium Ecosystem Assessment (2005) describes some of these as supporting services which are used to support or produce other ecosystem services. Nutrient cycling is another example that supports and affects the condition of other ecosystem services. Aesthetic services from aquatic ecosystems (e.g., through appreciation of their natural beauty) enhance recreational, residential, and many other uses of water resources.

Only one of the ecosystem service categories—existence/nonuse—is, by definition, unrelated to any specific human uses of water resources. The argument for including existence/nonuse as a distinct category of ecosystem service is that individuals can gain satisfaction and fulfillment simply from the knowledge that an ecosystem (particularly a well-functioning and healthy one) exists. These services can arise for several reasons, including

- individuals value the ecosystem intrinsically,
- they value the satisfaction others get from using the resource (altruistic value),[3]
- they value preserving the resource for future generations (bequest/preservation value), and/or
- they gain satisfaction from a sense of environmental stewardship.

Table 3-2 provides decision-makers with a richer characterization of the range, type, and measures of aquatic ecosystem services that may be affected by alternative water quality management options. It is intended to assist decision-makers in identifying, comparing, and

[3] In certain cases, altruism may not be a valid motive for existence value (see McConnell, 1997).

TABLE 3-2

Aquatic Ecosystem Services: Classification and Description of Services Supported by Healthy Aquatic Ecosystems

Service Category	Service Subcategory	Characteristics Related to the Service	Example Measures of Characteristics	Examples of Language Used to Describe the Service[a]	Location and Citation for Language Used
Recreational Services		Water quality • Clarity • Smell • Taste • Toxic pollutants • Visual impairments • Indicators of healthy ecosystem	• Visual (e.g., "Secchi") depth • Reported odors • Reported unpleasant tastes • Measurable pollutant concentrations • Presence of foam, oil scum, algal blooms • pH level, DO content	• No foam, clarity, purity, color, no odor, no bacteria, not so much algae • Odor • Floating objects, foam, algae, discoloration, cloudiness, oil scum, domestic sewage, weeds, odor, taste • Would not harm someone who happened to fall into it for a short time while boating or sailing	• Clear Lake, IA (Downing et al., 2001) • Connecticut River, New England (Mullens and Bristow, 2003) • Lakes in Canada (Parkes, 1973) • Water bodies in the U.S. (Carson and Mitchell, 1993)
		Site characteristics • Recreational facilities • Congestion • Landscape aesthetics • Location • Uniqueness	• Number of boat launches, piers, beach/shore access points, lifeguards, hiking paths, camping sites, picnic facilities, wildlife viewing blinds, and/or hunting blinds • Number of people or boats in view • Number of visible manmade structures • Presence of unique vistas • Proximity to population centers • Proximity to comparable sites	• People or boats one expects to see • Number of other groups (canoeing) encountered per day • Take guests for ride, picnic, celebrate events • Number of people seen at the hunting site, travel method, distance of hunting site from home	• Susquehanna River Basin, PA, and James River Basin, VA (Heberling, 2000) • Three Ontario parks, Canada (Boxall et al., 2003) • Mangrove wetlands of Yucatan, Mexico (Kaplowitz, 2000) • Northwest Saskatchewan, Canada (Haener et al., 2001)

TABLE 3-2 cont.

Service Category	Service Subcategory	Characteristics Related to the Service	Example Measures of Characteristics	Examples of Language Used to Describe the Service[a]	Location and Citation for Language Used
Recreational Services (continued)	Recreational fishing	Presence/abundance of target species	• Catch rate per unit effort • Size/number/health of adult fish	• Fish population	• John Day River, OR (Johnson and Adams, 1989)
				• Population of salmon in river	• Elwha River, WA (Loomis, 1996)
				• Number and size of fish caught • Catch rate (actual, potential, expected)	• Idaho (Donnelly et al., 1985) • San Francisco Bay, CA (Huppert, 1989); Cache la Poudre River, CO (Daubert and Young, 1981); Tar-Pamlico River, NC (Whitehead and Groothius, 1992)
		Healthy aquatic community	• Age structure of population • Diversity of species	• Presence of game fish and rough fish	• Water bodies in the U.S. (Carson and Mitchell, 1993); Iowa and Illinois river basins (Lant and Roberts, 1990)
		Safety of fish for human consumption	• Fish consumption advisories (presence and type) • Pollutant concentrations in fish tissue	• Sensory cues (e.g., smell, observations of dead or dying fish, bad taste)	• Michigan and Kansas (Cable and Udd, 1990)
				• Aware of fish consumption advisories or health advisories for sport-fish caught in certain waters	• New York State (Connelly et al., 1992); Great Lakes waters (Connelly and Knuth, 1993)

TABLE 3-2 cont.

Service Category	Service Subcategory	Characteristics Related to the Service	Example Measures of Characteristics	Examples of Language Used to Describe the Service[a]	Location and Citation for Language Used
Recreational Services (continued)	Recreational fishing (continued)	Habitat quality • Flow/hydrology • Water quantity • Stream bed quality • Spawning habitat	 • Volume per unit time after rain events • Baseline volume of water • Sediment substrate type and size • Presence of pools/rooted vegetation • Mature vegetation in buffer area	• Development threatens wildlife • Variety of vegetation, vegetation shade to keep water cool for fish and reduce algae growth, stream corridors important for animal migration	• Grand River Watershed, Canada (Brox et al., 1996) • South Platte River, CO (Loomis et al., 2000)
	Boating	Habitat quality • Flow/hydrology • Water quantity	 • Volume per unit time after rain events • Baseline volume of water	• Development threatens fish, waterfowl, songbirds, and other creatures in marshes and woodlands	• Grand River Watershed, Canada (Brox et al., 1996)
	Swimming	Safety	• Presence/type of water quality advisories • Frequency of water quality advisories • Frequency of water quality-related beach closures • Incidence of skin/eye/ear irritation	• Irritation (skin, eyes, ears)	• Lakes in Canada (Parkes, 1973)
	Hiking	Habitat quality	• Health and maturity of riparian vegetation	• Development threatens fish, waterfowl, songbirds, and other creatures in marshes and woodlands	• Grand River Watershed, Canada (Brox et al., 1996)
				• Variety of vegetation, shelter and areas for nesting and roosting, vegetation shade to keep water cool for fish and reduce algae growth, stream corridors important for animal migration	• South Platte River, CO (Loomis et al., 2000)

TABLE 3-2 cont.

Service Category	Service Subcategory	Characteristics Related to the Service	Example Measures of Characteristics	Examples of Language Used to Describe the Service[a]	Location and Citation for Language Used
Recreational Services (continued)	Wildlife viewing	Presence/abundance of target species	• Population of target species, in particular wild, rare, symbolic, and charismatic species	• Populations and sightings of endangered species	• California coast (Loomis and Larson, 1994)
		Habitat quality	• Population and health of riparian and aquatic vegetation • Presence/quality/extent of habitat for species of interest	• Development threatens fish, waterfowl, songbirds, and other creatures in marshes and woodlands • Variety of vegetation, shelter and areas for nesting and roosting, vegetation shade to keep water cool for fish and reduce algae growth, stream corridors important for animal migration	• Grand River Watershed, Canada (Brox et al., 1996) • South Platte River, CO (Loomis et al., 2000)
	Hunting	Presence/abundance of target species	• Population of target species • Bag rate per unit effort	• Signs of moose seen daily	• Northwest Saskatchewan, Canada (Haener et al., 2001)
		Habitat quality	• Presence/quality/extent of habitat for target species	• Development threatens fish, waterfowl, songbirds, and other creatures in marshes and woodlands • How long it has been since the site was harvested • Shelter and areas for nesting and roosting, stream corridors important for animal migration	• Grand River Watershed, Canada (Brox et al., 1996) • Northwest Saskatchewan, Canada (Haener et al., 2001) • South Platte River, CO (Loomis et al., 2000)

TABLE 3-2 cont.					
Service Category	Service Subcategory	Characteristics Related to the Service	Example Measures of Characteristics	Examples of Language Used to Describe the Service[a]	Location and Citation for Language Used
Aesthetic Services		Water quality • Clarity • Smell • Visual impairments	• Visual (e.g., “Secchi”) depth • Reported odors • Visible foam, oil scum, algal blooms	• No foam, clarity, purity, color, no odor, no bacteria, not so much algae • Odor • Floating objects, foam, algae, discoloration, cloudiness, oil scum, domestic sewage, weeds, odor	• Clear Lake, IA (Downing et al., 2001) • Connecticut River, New England (Mullens and Bristow, 2003) • Lakes in Canada (Parkes, 1973)
		Habitat quality	• Presence/quality/extent of habitat	• Variety of vegetation, shelter and areas for nesting and roosting, vegetation shade to keep water cool for fish and reduce algae growth, stream corridors important for animal migration	• South Platte River, CO (Loomis et al., 2000)
		Site characteristics • Landscape aesthetics • Location • Uniqueness	• Number of visible manmade structures • Presence of unique vistas • Proximity to population centers • Proximity to comparable sites	• Appearance • Beauty (beautiful, pretty, views), take guests for ride, picnic, celebrate events • Percentage difference in rental value/sale price for: unit facing water one facing away from water in the same building, different types of water bodies (river vs. canal), proximity to water body, and proximity to dock on canal	• Grand River Watershed, Canada (Brox et al., 1996) • Mangrove wetlands of Yucatan, Mexico (Kaplowitz, 2000) • Mercy Basin, England (Wood and Handley, 1999)

TABLE 3-2 cont.

Service Category	Service Subcategory	Characteristics Related to the Service	Example Measures of Characteristics	Examples of Language Used to Describe the Service[a]	Location and Citation for Language Used
Cultural Services		Presence and significance of cultural sites	• Number of cultural sites • Number of archeological sites • Number of religious sites	• Protection of historic shipwrecks from treasure hunters	• Eastern North Carolina (Whitehead and Finney, 2003)
		Access to cultural sites	• Absence of barriers to culturally significant uses of resources • Absence of barriers to visit or view sites	• Distance of hunting site from home, number of people seen at the hunting site, signs of moose seen daily, travel method, how long it has been since the site was harvested	• Northwest Saskatchewan, Canada (Haener et al., 2001)
Flood/Flow Control Services		Property protection	• Reduced frequency/extent of flood damage • Avoided costs of flood damage	• Flood protection	• Wetlands in New England (Stevens et al., 1995)
		Safety	• Reduced risk of death or injury due to floodwaters	• Percentage chance of flood waters entering the first floor or basement	• Roanoke, VA (Shabman and Stephenson, 1996)
Navigation Services		Capacity for navigation (depends on depth and flow)	• Maximum volume/weight of shipped goods per unit time • Maximum number of persons per unit time • Cost of shipping or transportation • Quantity/volume of goods shipped • Quantity of trips • Price of shipped goods • Producer surplus[b] – Returns/profits from commercial transport – Returns/profits to uses of shipped goods • Consumer surplus[c] – Availability of cheaper or better quality transport		

TABLE 3-2 cont.

Service Category	Service Subcategory	Characteristics Related to the Service	Example Measures of Characteristics	Examples of Language Used to Describe the Service[a]	Location and Citation for Language Used
Energy Services		Water flow for hydroelectricity generation	• Cost of electricity production and delivery • kWh of electricity produced and consumed • Producer surplus[b] – Returns/profits for commercial energy suppliers – Returns/profits for commercial users of electricity • Consumer surplus[c] – Availability of cheaper electricity and other goods	• Presence (or absence) of a hydroelectric power station in a national park	• Riverside wetlands in "Donau-Auen" national park, Austria (Kosz, 1996)
Water Supply Services	Industrial water supply • Cooling water • Other industrial uses	Water flow/quality for industrial uses	• Costs of water for industrial uses • Costs of treating water for industrial uses • Quantity of water used for industrial uses • Producer surplus[b] – Returns/profits for industrial producers • Consumer surplus[c] • Availability of cheaper goods		

TABLE 3-2 cont.					
Service Category	Service Subcategory	Characteristics Related to the Service	Example Measures of Characteristics	Examples of Language Used to Describe the Service[a]	Location and Citation for Language Used
Water Supply Services (continued)	Agricultural water supply • Irrigation • Other agricultural uses	Water flow/quality for agricultural uses	• Costs of water for agricultural uses • Costs of treating water for agricultural uses • Quantity of water used for agricultural uses • Producer surplus[b] – Returns/profits for agricultural producers – Returns/profits for users of agricultural goods • Consumer surplus[c] • Availability of cheaper agricultural and other goods		
	Household water supply • Drinking water • Other house-hold uses	Water supply for household users	• Costs of water for household uses • Costs of treating water for household uses • Quantity of water used for household uses • Producer surplus[b] – Returns/profits to commercial water utilities • Consumer surplus[c] • Availability of cheaper household water	• Million gallons of water daily (mgd) extracted, reduction in the level of water in river	• Río Mameyes and Río Fajardo, Puerto Rico (González-Cabán and Loomis, 1997)

TABLE 3-2 cont.

Service Category	Service Subcategory	Characteristics Related to the Service	Example Measures of Characteristics	Examples of Language Used to Describe the Service[a]	Location and Citation for Language Used
Water Supply Services (continued)		Water quality • Clarity • Odor • Taste • Health/safety	• Cloudiness • Reported odors • Reported tastes • Concentrations of harmful pollutants • Presence of drinking water advisories	• No foam, clarity, purity, color, no odor, no bacteria, not so much algae • Odor • Discoloration, cloudiness, odor, irritation (skin, eyes, ears), taste • Bad water quality (color and bad smell) • Appearance, odor • Taste, odor, color, skin/eye irritation	• Clear Lake, IA (Downing et al., 2001) • Connecticut River, New England (Mullens and Bristow, 2003) • Lakes in Canada (Parkes, 1973) • Mexico City, Mexico (Soto Montes de Oca et al., 2003) • Grand River Watershed, Canada (Brox et al., 1996) • Orlando, FL (DeLorme et al., 2003)
		Characteristics of water distribution • Reliability • Capacity	• Number of water outages per unit time • Number of hours of service per unit time	• Shortages, low water pressure • Avoidance of water restrictions, reliability improvement in water supply system • Quality of city water service and reliability of water system, shortages, restrictions on water use, cost	• Mexico City, Mexico (Soto Montes de Oca et al., 2003) • Seven Texas cities (Griffin and Mjelde, 2000) • Boulder, Longmont, and Aurora, CO (Howe et al., 1994)
	Groundwater recharge	Water flow	• Base flow • Groundwater levels	• Improve aquifer recharge rate and ensure a stable supply of groundwater	• Cagayan de Oro, Phillipines (Palanca-Tan and Bautista, 2003)

TABLE 3-2 cont.					
Service Category	Service Subcategory	Characteristics Related to the Service	Example Measures of Characteristics	Examples of Language Used to Describe the Service[a]	Location and Citation for Language Used
Existence/ Nonuse Services[d]		Biodiversity • Complexity of community and redundancy of species • Sustainability of rare, threatened, or endangered species	• Number of different species present in ecosystem • Number/size/health of rare, threatened, or endangered species • Probability of long-term survival of key species • Preservation of genetic resources	• Containing rare species of plants that provide ecosystem stability and genetic diversity • Populations and sightings of endangered species • Population of salmon in river	• Wetlands in New England (Stevens et al., 1995) • California coast (Loomis and Larson, 1994) • Elwha River, WA (Loomis, 1996)
		Water quality • Clarity • Smell • Toxic pollutants • Visual impairments • Indicators of healthy ecosystem	• Visual (e.g., "Secchi") depth • Reported odors • Measurable pollutant concentrations • Visible foam, oil scum, algal blooms • pH level, DO content		
		Habitat quality • Water quantity • Spawning habitat • Nutrient management	• Baseline volume of water • Presence of pools/rooted vegetation • Presence/quality/extent of habitat for charismatic species • Mature vegetation in buffer area • Total nitrogen and phosphorous concentrations	• Instream flows (presence of water in rivers and streams as well as support of wildlife, vegetation, and habitat) • Variety of vegetation, shelter and areas for nesting and roosting, vegetation shade to keep water cool for fish and reduce algae growth, stream corridors important for animal migration	• New Mexico (Berrens et al., 2000) • South Platte River, CO (Loomis et al., 2000)

TABLE 3-2 cont.

Service Category	Service Subcategory	Characteristics Related to the Service	Example Measures of Characteristics	Examples of Language Used to Describe the Service[a]	Location and Citation for Language Used
Harvestable Resources	Commercial harvesting • Fishing • Harvest-ing of raw materials	Presence/abundance of target species	• Capital and operating costs for fishermen • Cost of fishing trips • Wholesale and retail price of fish • Quantity of fish caught • Quantity of fish consumed in wholesale or retail market • Producer surplus[b] – Costs of production (catch rate per unit effort) – Returns/profits to commercial fishers • Consumer surplus[c] – Availability of cheaper commercial fish		
		Safety of harvest for human consumption	• Fish consumption advisories (presence and type) • Fish tissue pollutant concentrations		
		Presence/abundance of materials	• Cost of harvest • Wholesale and retail price of materials • Quantity of material harvested • Quantity of materials consumed in wholesale or retail market • Producer surplus[b] – Returns/profits to commercial harvesters of raw materials – Returns/profits to users of harvested materials • Consumer surplus[c] – Availability of cheaper material	• Mining development (impact of resulting pollution would eliminate potential for recreational use in waterways)	• South Platte River Basin, CO (Greenley et al., 1981)

TABLE 3-2 cont.

Service Category	Service Subcategory	Characteristics Related to the Service	Example Measures of Characteristics	Examples of Language Used to Describe the Service[a]	Location and Citation for Language Used
Harvestable Resources (continued)	Subsistence harvesting • Fishing • Hunting	Presence/abundance of target species	• Population of target species • Catch rate per unit effort • Size/health of fish	• Sport fishing as a source of food (anglers may not consider themselves to be subsistence fishing)	• Buffalo, NY (Beehler et al., 2003)
		Safety of harvest for human consumption	• Fish consumption advisories (presence and type) • Fish tissue pollutant concentrations		
Waste Absorption and Breakdown		Assimilative capacity	• Avoided alternative waste disposal costs	• Adequate river flows to dilute fertilizer and pesticides from runoff, wastewater discharges, and pollutants in stormwater, insures the river is not toxic to fish and safe for water-based recreation	• South Platte River, CO (Loomis et al., 2000)
Water Filtration and Erosion Control		Riparian and wetland vegetation	• Presence and extent of riparian buffer • Presence and extent of wetland vegetation		
Climate Regulation		Capacity for carbon storage	• Presence and extent of vegetation		
		Microhabitat features	• Humidity levels		

[a]Sources of these terms include actual questionnaires, survey descriptions, and summaries of focus group discussions.
[b]Measure of seller's well-being.
[c]Measure of buyer's well-being.
[d]Although not shown here, service subcategories for existence/nonuse services could include the existence of all the other service categories. For example, someone may value cultural services they would never use.

evaluating the relevant gains and losses between affected services.[4] The table also presents terminology that may be more adequate for communicating changes to communities. Table 3-2 highlights how ecosystem services are connected to water quality or water quantity characteristics. It begins to link changes in ecosystems to measurements in ecosystem services in order to understand the gains and losses perceived by communities.

The first column of Table 3-2 includes the main categories of aquatic ecosystem services, which correspond with those shown in Figure 3-2. The second column divides 3 of the 12 main categories into a total of 12 subcategories. For example, recreational services are divided into six subcategories of recreational activities—fishing, boating, swimming, hiking, wildlife viewing, and hunting. The third column identifies key characteristics of the water resource or service category that affect the level and quality of the services provided. For example, water quality, habitat quality, health/safety, water flow, and landscape aesthetics are included in multiple subcategories. Importantly, water quality does not play a significant role in all of the service categories. Although recreational, aesthetic, and existence/nonuse services are undoubtedly enhanced by improvements in water quality, others such as energy and navigation services are more strongly influenced by water flow and other physical characteristics of the water resource. However, even ecosystem services that are not directly affected by water quality may need to be considered in evaluating WQS management options. For example, one option for attaining boatable/fishable water quality conditions on a river segment might be to remove a dam, but this removal could have a negative impact on energy and flood control services. In this case, the WQS management decision requires consideration of the gains and losses between different types of aquatic ecosystem services, some of which involve water quality and others that do not.

The fourth column in Table 3-2 lists examples of measures that correspond to the characteristics in the previous column. By measuring characteristics of water resources that relate to specific services, they also can be thought of and used as indicators of the level or quality of services provided by aquatic ecosystems. The measures listed in this column do not provide an exhaustive list of the relevant and possible measures for each service. Rather they provide key examples of measures to serve as a reference and starting points for analysts and

[4] As discussed in Chapter 1, the examination of the relevant gains and losses is in addition to the analyses described in the existing guidance to determine if the communities would prefer the new situation.

decision-makers. These measures can be adapted or supplemented as necessary to evaluate and compare changes to specific ecosystem services.

The fifth column presents examples of how aquatic ecosystem services have been described to (e.g., in surveys) or by the general public. These descriptors are generally less technical than those listed in the previous column, and they are meant to serve a different purpose. Whereas the measures listed in column four are intended to provide analysts with tools for quantifying and evaluating changes in ecosystem services, the descriptors listed in column five provide terms that may be more appropriate for communicating these changes to the general public. These terms were drawn from the research literature exploring values, attitudes, and perceptions regarding water quality and aquatic ecosystem services. Locations and references for each of the relevant studies are provided in the last column of Table 3-2.

3.2.2. Relating Aquatic Ecosystem Services to Designated Uses

Given the well-defined and critical role of designated use attainment in WQS decision-making and the potential role of aquatic ecosystem services in evaluating communities' preferences, it is important to consider how they relate to one another. In essence, they represent two distinct but related ways of characterizing how well conditions in a water resource support human well-being. One important difference is that use attainment is a dichotomous indicator of conditions in the water body (i.e., for each designated use category, either the designated use is attained or it is not), whereas services are best represented by more continuous measures. Consequently, when water quality management decisions result in changes to designated uses, they also are likely to affect the types and levels of ecosystem services that are provided by the water resource.

However, changes in designated use attainment are not a necessary condition for changes in aquatic ecosystem services. As Figure 3-2 implies, *any* alteration to the structure or functioning of the aquatic ecosystem will have potential implications for the types and levels of services that are derived from the system. Therefore, decisions about changing designated uses could effect multiple ecosystem services, but they will not likely be identified by the analyses described in the existing guidance.

To illustrate the relationship between designated use attainment and aquatic ecosystem services, Table 3-3 provides a matrix linking the main designated use categories with the main

TABLE 3-3

Aquatic Ecosystem Services

Aquatic Ecosystem Services		Example of Designated Use Category										
Main Category	Subcategory	Primary Contact Recreation (Safe to Swim)	Secondary Contact Recreation (Safe to Fish, Boat)	Ag Water Supply (Irrigation and Livestock)	Industrial Water Supply	Hydro-power Generation	Public Water Supply	Aesthetics (Visibility, Odor)	Fish Consump-tion (Safe to Eat Fish)	Aquatic Life (Cold and Warm Water)	Shellfish Harvest-ing Waters	Naviga-tion
Recreation												
	Fishing		●					○	●	●	●	
	Boating		●					○		○		
	Swimming	●						○				
	Hiking							○		○		
	Wildlife viewing							○		○		
	Hunting							○		○		
Aesthetic								●		○		
Cultural								○		○		
Flood/Flow Control												
Navigation												●
Energy						●						
Water Supply												
	Industrial				●							
	Agricultural			●								
	Household						●					
	Groundwater recharge											

●—Attainment of this designated use category directly supports/enhances this aquatic ecosystem service.
○—Attainment of this designated use category indirectly or partially supports/enhances this aquatic ecosystem service.

TABLE 3-3 cont.

Aquatic Ecosystem Services		Example of Designated Use Category										
Main Category	Subcategory	Primary Contact Recreation (Safe to Swim)	Secondary Contact Recreation (Safe to Fish, Boat)	Ag Water Supply (Irrigation and Livestock)	Industrial Water Supply	Hydro-power Generation	Public Water Supply	Aesthetics (Visibility, Odor)	Fish Consump-tion (Safe to Eat Fish)	Aquatic Life (Cold and Warm Water)	Shellfish Harvest-ing Waters	Naviga-tion
Existence/ Nonuse										●	●	
Harvestable Resources												
	Commercial harvesting		●						●	●	●	
	Subsistence harvesting		●						●	●	●	
Waste Absorption and Breakdown												
Water Filtration and Erosion Control												
Climate Regulation												

●—Attainment of this designated use category directly supports/enhances this aquatic ecosystem service.
○—Attainment of this designated use category indirectly or partially supports/enhances this aquatic ecosystem service.

aquatic ecosystem service categories. Although there are several closely corresponding categories, particularly for aquatic ecosystem services derived from specific uses of water (e.g., recreation, navigation, energy, water supply and harvestable resources), the categories do not all correspond one to one. In the matrix, the dark circles represent categories for which there is a direct correspondence between designated uses and services. For example, if a water body goes from nonattainment to attainment of the primary contact recreation use designation, this implies that the potential swimming services from the water body are directly enhanced.[5] The open circles represent categories for which a less direct correspondence is expected. For example, attainment of aquatic life and aesthetic standards in a water body will most likely but not necessarily enhance most recreational services from the water body.[6] It is important to note that, even for matched categories, nonattainment of a designated use does not necessarily mean that the corresponding services are zero. For example, nonattainment of the fish consumption designated use does not necessarily imply that the water body fails to provide any fishing services, but it does imply that those services are restricted. Similarly, attainment of a designated use category does not necessarily imply that the corresponding services are positive (see Footnote 5). The links between ecosystem services and designated uses are further described in the following section through expanded flow diagrams and case study examples of WQS decisions.

3.3. ASSESSMENT OF SOCIOECONOMIC ENDPOINTS AFFECTED BY USE ATTAINMENT DECISIONS

As discussed in Chapter 2, U.S. EPA's (1995) *Interim Economic Guidance* provides decision-makers and analysts with specific recommendations for estimating the financial impacts on private- and public-sector entities and the economic impacts on the community. Although these impacts are undoubtedly important endpoints for decision-makers to consider, the overall socioeconomic impacts associated with setting or modifying WQS are potentially much broader.

[5] Services are only "potentially" enhanced in these cases because attainment of a designated use does not necessarily imply that the use will take place at the water body; rather, it implies that the water body becomes more suitable for the use. For example, a water body may not be used in practice for swimming (e.g., due to difficulties with access to the water body) even if its water quality is suitable for swimming.

[6] We do not attempt to present all of the ecosystem services protected by the designated uses. For example, attaining the criteria established for public water supply may, in many but not all instances, enhance aesthetics and recreational services. The opposite could be true as well. A human activity that prevents the attainment may reduce more ecosystem services than identified in Table 3-3. These ancillary benefits or costs are important and should be examined on a case-by-case basis.

As described above, a more comprehensive view of the relevant impacts and trade-offs can be achieved by considering how ecosystem services are affected by alternative management options.

Any changes in human well-being (i.e., "human welfare gains or losses") resulting from WQS changes should be interpreted as relevant socioeconomic endpoints. Even in situations where it is not feasible to conduct a detailed, quantitative BCA, important insights can be gained by identifying and considering the full range of socioeconomic endpoints affected by changes in ecosystem services.

Changes to aquatic ecosystem services can affect human well-being in a variety of ways. Some of these effects will have direct monetary or market implications for individuals. For example, several services provided by water resources, such as commercial fishing, energy supply, and agricultural water supply, directly support market activities. As a result, changes in these services can affect both producers and consumers by changing the costs of production, prices, incomes, and employment related to these activities. These types of services and human welfare effects are illustrated, for example, in the case studies described in Section 3.4. For example, in Case Study 3, an intermittent stream ecosystem initially supports livestock and agricultural production, but with the management options in place, these services are curtailed. As a result, the farmer loses some of the profit he would have earned by selling his products on the market. Consumers of his products may be affected negatively. These market-related effects (referred to in the case study as changes in "market surplus") represent potentially important socioeconomic endpoints. In other cases, the costs of management options are not borne through market interactions, but rather through charges for public services (e.g., taxes, fees). In these cases (e.g., Case Study 1 below), the human welfare effects can be described as reductions in disposable income, disposable income, or the amount of money available for spending or saving net income taxes.

Both market surplus and disposable income changes can be addressed at least partially using methods outlined in the *Interim Economic Guidance* developed by U.S. EPA (1995). However, some aquatic ecosystem services have less direct but equally relevant monetary or market implications. For example, flood control services help prevent financial losses associated with property damage, and aesthetic services for near-shore residents are reflected in housing prices and property values. Therefore, changes to these services also can have impacts on prices, incomes, and employment (in these cases, mostly related to property markets and ownership). These socioeconomic endpoints also deserve consideration. In Case Study 4 below, these endpoints are included when considering the effects of allowing a mall development to occur. Possible damages to the wetland could result in more flooding and sedimentation downstream, which could, among other things, result in property value losses for downstream residents.

Other aquatic ecosystem services have little or no connection to markets or incomes; nevertheless, they still are valued by individuals and contribute to their well-being. Recreational services are a prime example. If, for instance, services from recreational fishing, boating, swimming, or other activities are affected by changes in water quality, these changes will not necessarily affect prices, incomes, or employment in any market. However, the absence of a direct monetary effect on individuals does not imply that there is no socioeconomic effect. In these cases, the relevant endpoint is the change in enjoyment individuals derive from their recreational activities. In all of the case studies, reducing the effects of stressors on aquatic ecosystems is shown to enhance recreational services and provide more value to recreational users of the resources.

Several other categories of ecosystem services have similar "nonmarket" characteristics. For example, in many cases, changes to aesthetic services or changes to services derived from cultural and subsistence activities will not have observable effects on prices or incomes. Again, despite the lack of a direct monetary impact, the change in individuals' enjoyment of these activities represents a potentially important socioeconomic endpoint to be considered.

One category of ecosystem services is unique because it is not derived from any specific use or market related to the aquatic resource—nonuse/existence services. The effects of these services on human well-being are less tangible than other services and certainly more difficult to measure, but they may nonetheless be significant. As discussed in Section 3.2, the argument for considering these services is that individuals may well value protecting the existence and quality of natural resources that they never expect to use in any way. The motivations for these values may be altruistic (protecting the resource for other users and future generations), or they may be derived from a sense of stewardship or inherent responsibility for protecting the resource. These values are likely to be particularly strong for aquatic resources that are unique, threatened, or endangered. Regardless of the motivation for nonuse values, they represent another potentially important socioeconomic endpoint to consider as part of setting or modifying WQS, and for this reason they are included as potential human welfare gains in all five of the case study examples discussed in the next section.

3.4. MAPPING THE WATER QUALITY MANAGEMENT PROBLEM: DEVELOPING CONCEPTUAL MODELS

Conceptual models expressed as flow diagrams are particularly useful tools for representing relationships within and between ecological and human systems. As discussed in Sections 3.1 and 3.2 above, these diagrams play an integral role in stressor identification and in the problem formulation stage of ERA by illustrating relationships between sources, stressors, ecological entities, and their responses to the stressors. They can be used to illustrate the links between aquatic ecosystems and the services derived from them. This section presents conceptual models that expand Figure 3-2 to evaluate the broader societal implications and gains and losses associated with setting or modifying WQS. Their purpose is to illustrate how to lay out the problem and identify important trade-offs that need to be quantified or measured. The evaluation methods will be discussed in Chapter 4.

The section begins by presenting these expanded conceptual models in general terms. Second, several main steps are described for applying the general framework and developing conceptual diagrams that depict specific WQS conditions. Third, the diagrams are applied and illustrated through five case study WQS examples. The expanded models include the interconnections between sources, stressors, ecosystem components and processes, and ecological assessment endpoints, and they extend these links to include effects on ecosystem services and related socioeconomic impacts. In addition, they include linkages to management alternatives by showing how these alternatives alter inputs, relationships, ecosystem services, human welfare effects, and designated use attainment.

3.4.1. General Framework for the Expanded Conceptual Models

Figure 3-2, which illustrates the idea that ecosystem services are derived from the ecosystem components and processes, is the foundation for the expanded conceptual models. Building directly on Figure 3-2, Figure 3-3 shows that land uses and other sources of stress are capable of introducing stressors to aquatic ecosystems. These stressors disrupt the normal functioning of the ecosystem, which can cause reductions in water quality and can impair the ecosystem's ability to provide key services. However, as shown in Figure 3-3, these same

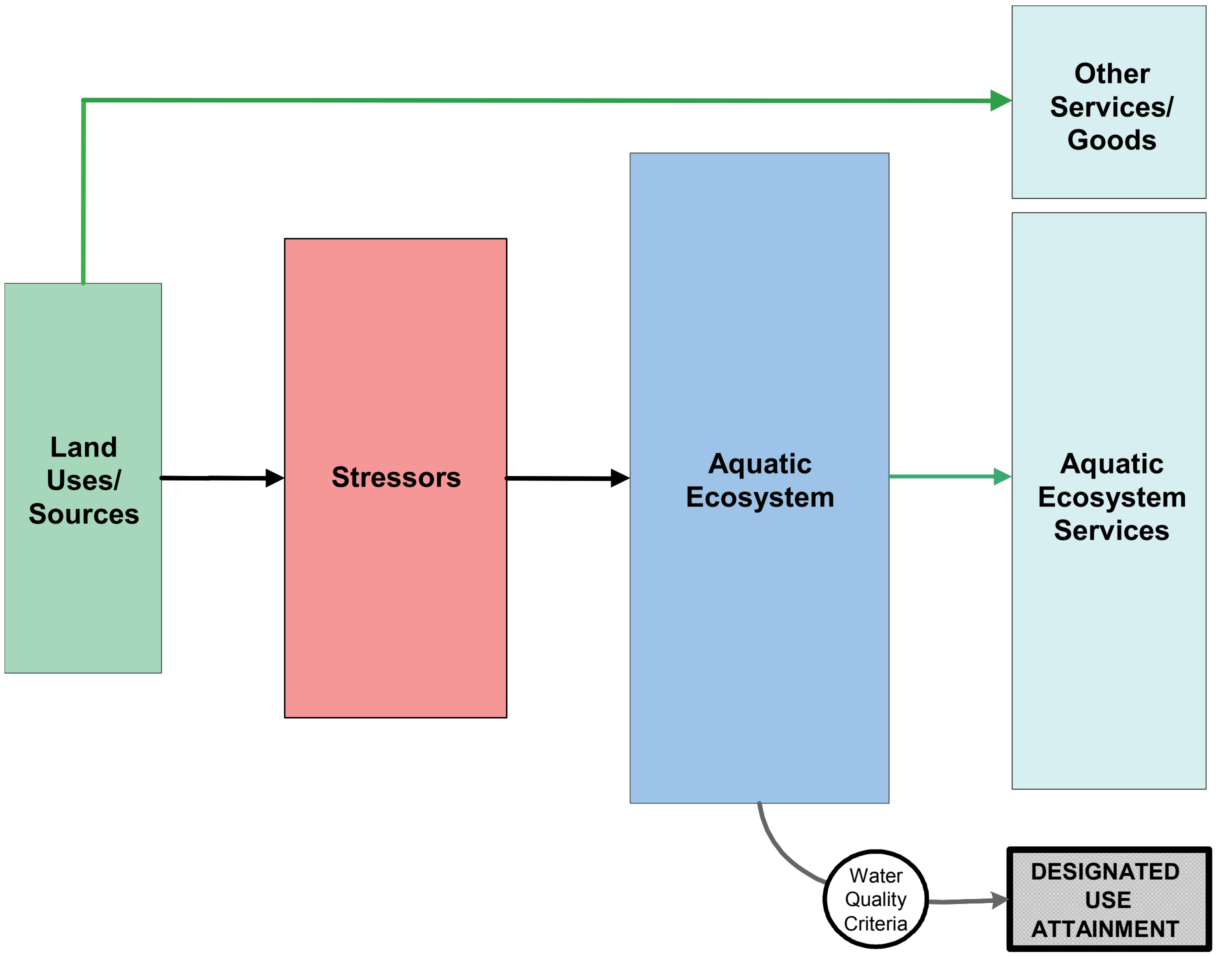

FIGURE 3-3

Effects of Sources/Stressors on Aquatic Ecosystem Services, Use Attainment and Provision of Other Goods and Services sources and land uses are also capable of providing other important goods and services to humans. For example, agricultural land uses may degrade water quality in local streams while at the same time providing valued food crops for consumers.

Figure 3-4 further extends the framework shown in Figure 3-3. It illustrates how management options considered in a standard-setting process, such as restoring a riparian area or building a stormwater retention pond, typically will alter the effects of land uses and other sources of impairment on human well-being. Because humans may experience both gains and losses as a result of these options, the figure also demonstrates the trade-offs that are inherent in the standard-setting process (shown by purple lines). By controlling stressors to the aquatic ecosystem (represented by the blue lines), a management option should improve certain ecosystem services, resulting in gains to individuals who value these services. At the same time, however, controlling stressors may impose losses on certain individuals. Some of these losses will result from the *direct* costs associated with controls (e.g., capital and operating costs for effluent treatment systems). Other losses will result from *indirect* costs, which are the value of foregone opportunities (i.e., “opportunity” costs). For example, restrictions on agricultural land uses will generally result in fewer goods being available from agricultural production.

In addition to illustrating the relevance of ecosystem services for evaluating WQS and the inherent gains and losses involved in the standard-setting process, Figures 3-3 and 3-4 show how these considerations are related to the attainment of designated uses. Use attainment is ultimately determined by comparing observed water quality (or related conditions) in the aquatic ecosystem with the relevant water quality criteria. Without a management option in place (Figure 3-3), water quality may well be degraded to the point at which specific criteria are not met and the corresponding designated uses are not attained. Once an option is implemented (Figure 3-4), water quality may improve to the point where the criteria are met and the designated use is attained.

3.4.2. Stages for Developing Expanded Conceptual Diagrams

Applying the general framework outlined above to evaluate specific WQS conditions requires gathering and organizing several types of information, first to characterize baseline conditions (based on Figure 3-3) and then to characterize the effects of alternative management

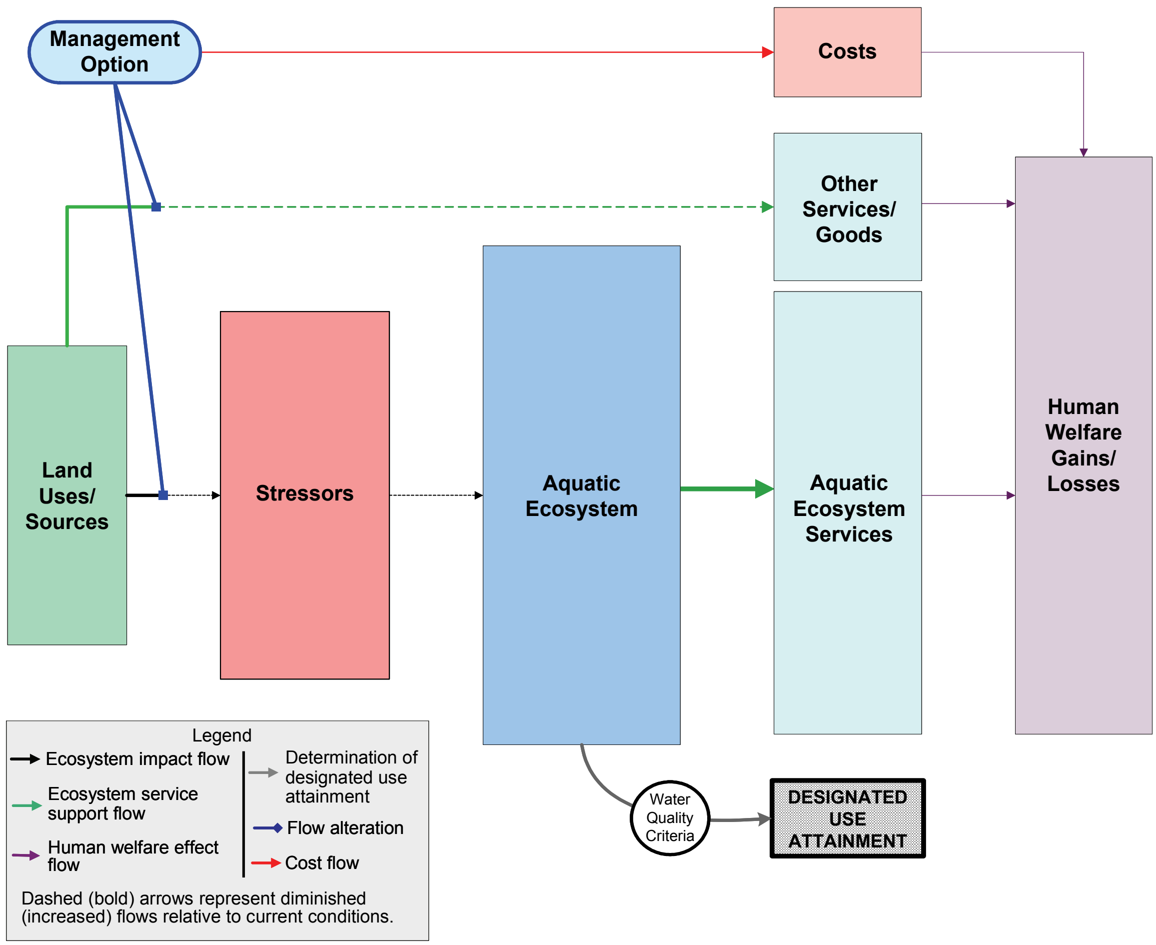

FIGURE 3-4

Effects of Management Options on Aquatic Ecosystem Services and Human Well-Being options (based on Figure 3-4). The following steps are recommended for these two development stages.

To characterize baseline conditions

(1) List the main ecosystem components and functions that are or could be affected.

(2) List and describe the activities (land uses and/or sources) in and around the water body that affect or could affect water body integrity.

(3) List the main stressors associated with each activity or source.

(4) Identify and show how these stressors are expected or known to enter and impair the ecosystem components and functions.

(5) List the services and goods that are or could be derived from the affected aquatic ecosystems as well as from the land uses and sources.

(6) List the designated uses for the affected water body and, in particular, identify the uses not being attained.

(7) Identify the ecosystem services (and other goods and services) that are or would be primarily affected by the identified land uses, sources, and stressors.

To characterize the relevant management decision

(1) List the management alternatives that will help attain designated uses.

(2) Determine the types of costs (including opportunity costs) incurred by implementing the management alternatives.

(3) Identify and show how the management alternatives will affect the sources and/or land uses and how they will alter the impacts of stressors on the ecosystem.

(4) Identify and show how the management alternatives will strengthen and/or weaken different ecosystem services (and other goods and service flows).

(5) Identify and show how the management alternatives will positively and/or negatively affect different aspects of human welfare.

Note that all of the steps outlined above are applicable for evaluating the results from both UAAs and ARs (see Chapter 2). With ARs, however, current conditions typically will involve fewer stressors than under alternative conditions, and the management decision typically will revolve around whether to allow additional stressors to enter the system. Therefore, the baseline characterization for ARs must be constructed in anticipation of the stressors (and related impacts) that would result if specific activities or sources were allowed to occur. For example, if the AR involves consideration of a mall development (as in Case Study 4 discussed below) that may increase sediment loads to a water body, baseline conditions will not include the mall as a source or the increased loads as stressors. Nevertheless, it is useful to represent the *absence* of these sources and stressors in the baseline conceptual diagram.

3.4.3. Case Study Examples of the Expanded Conceptual Models

This section presents several specific examples of expanded conceptual models that were developed based on the general framework and the development steps described above. These examples, which together comprise five "case studies," address the following hypothetical WQS scenarios:

- Case Study 1 presents a hypothetical UAA addressing acid mine drainage (AMD) impacts on a tributary stream and a river.
- Case Study 2 presents a hypothetical UAA addressing combined sewer overflows (CSO) and stormwater impacts on a river system.
- Case Study 3 presents a hypothetical UAA addressing agricultural impacts on an intermittent stream.
- Case Study 4 presents a hypothetical AR of a proposed retail development complex.
- Case Study 5 presents a hypothetical UAA addressing discharges to an effluent-dominated stream.

The purpose of these examples is to demonstrate how expanded conceptual models can illustrate key connections within and between aquatic ecosystems and humans and to evaluate the relevant impacts and gains and losses associated with alternative management options.[7]

Each WQS case study is introduced below with a written description of the key issues, conditions, and assumptions. Diagrams representing current conditions and one or more alternative management scenarios follow. To provide additional context for each case study, most of the conceptual flow diagrams are also accompanied by spatial diagrams that depict conditions in the affected water bodies (with and without the management options).

To represent current conditions, each case study includes a conceptual diagram based on Figure 3-3. These figures typically illustrate a sequence of effects, beginning with how specific sources (including land uses) contribute different stressors to the aquatic ecosystem. They then show how these stressors affect different components of one or more aquatic ecosystems and how these systems support a range of ecosystem services. Within the conceptual framework, they also depict designated use-attainment status under current conditions.

To represent the ecological and socioeconomic effects of different management options, each case study also includes diagrams based on Figure 3-4. First, they show how each management option affects the stress-related flows from sources to ecosystems, in most cases by reducing the negative impacts caused by specific stressors. Across the different management options, differences in the strength of these flows are represented by the format of the arrows, with dashed lines representing diminished flows relative to current conditions. The bold lines represent increased flows relative to current conditions. Second, they show the various ways (both positive and negative) in which the options ultimately affect human well-being. These gains and losses to humans are shown to result from changes to aquatic ecosystem services, as well as from the costs associated with implementing management options. They represent, in most cases, socioeconomic endpoints that are not addressed by the U.S. EPA's *Interim Economic Guidance*. The gains and losses in each of the human welfare categories (e.g., recreation values) are represented by a + or –. For these gains and losses in human welfare to exist, individuals must be aware or perceive that the changes have occurred. The number of + or – symbols shown

[7] Because all of the case studies are based on the general framework presented in Figure 3-3 and 3-4, a reader could understand the expanded conceptual model approach by examining only one case study. However, each presents unique aspects that cannot be found in just one case study and Chapter 5 uses Case Study 1 and Case Study 2 to illustrate the process presented in the report.

represents an ordinal ranking of the management options regarding their effect on the welfare category. For example, in Case Study 2 (depicted in Figures 3-8 through 3-10), compared with current conditions, Option 2 would increase the recreational value derived from the ecosystem. This increase is indicated by + for recreational value in Figure 3-10; however, Option 1 would cause an even larger increase in recreational value compared with Option 2. This larger increase is indicated by ++ in Figure 3-9.[8] Third, the diagrams depict the expected designated use-attainment status when a given management option is in place.[9]

3.4.3.1. *Case Study 1: Acid Mine Drainage (Figures 3-5 through 3-7)*

In the early 1900s, parts of Pennsylvania and West Virginia prospered because of the extraction of coal. Since then, coal mining has declined and adverse environmental impacts have increased (especially from abandoned mine lands).

A tributary to a popular recreational river is a major source of AMD. The drainage from the surface mining and tailings has low pH from contact with pyrite (an iron sulfide) and has elevated levels of metals; AMD can contaminate drinking water sources, eliminate habitat and aquatic life, and corrode infrastructure like bridges. The tributary has designated uses of aquatic life, secondary water contact recreation, and agricultural water supply; the river has aquatic life (warm water), primary contact recreation, and agricultural water supply. These designated uses are not being met in particular stretches of both the tributary and the river.

The tributary is about 7 miles long and receives AMD from surface runoff linked to abandoned mine lands and mine tailings (this occurs 3 miles from the headwaters). Two seeps are visible from the tailings. Aquatic life, like fish and salamanders, are not found in the tributary after the drainage enters it.

The river, which has many activities affected by the AMD, is considered dead for 8 miles after the tributary enters it. However, the tributary is not the only cause of degradation in the river. Several smaller nonpoint sources of AMD also directly discharge into the river along this 8-mile stretch and contribute to poor water quality in this part of the river. Aluminum

[8] The number of + or – should **not** be interpreted or used to compare changes across human welfare categories (for example, more pluses for recreation values compared with consumption values does **not** necessarily mean that the gains through recreation are greater than those through consumption). Also note that two +'s does not necessarily indicate twice the increase; such quantitative evaluations are generally not possible at this stage.

[9] Stating that the diagrams depict the expected designated use-attainment status means that management options might fail. In Case Study 1, a probability that the option will fail is given in the text. In the other case studies, the diagrams show the expected results if the management options do not fail.

concentrations prevent any fish population from existing in this part of the river; however, the riparian habitat is of good quality and other wildlife is abundant.

A number of activities and land uses occur in the vicinity of the river and tributary. The river is known for its whitewater rafting and kayaking. Hiking, mountain biking, and picnicking are popular around both the river and tributary, especially along a recently completed rail-trail that follows the river and crosses the tributary. Most recreationists are not from the local area. The tributary and river are not a source for drinking water, but the tributary (above the AMD) supports some stock watering. Forests and pastures are the primary land uses in the watershed. The tributary has 10 houses near it, and 300 houses are within 5 miles of the impaired river.

In addition to considering TMDLs for aluminum, iron, and pH, the state also has conducted a UAA for the tributary and part of the river. In the UAA, the state estimated the costs of restoring both the entire segment of the tributary and the affected portion of the river. Based on an analysis of "substantial and widespread economic and social impact" (Factor 6), they have determined that they cannot afford to conduct all the restoration. In addition, the state has determined that the tributary produces more AMD than the combined discharges from the other nonpoint sources that directly affect the river. The results indicate that the costs of restoring the tributary would be considerably less than controlling the nonpoint sources along the river.

Based on the UAA, the state has decided to focus on restoring the tributary. Several methods are available to raise the pH of AMD-contaminated water from the tributary; however, the two most promising methods available to mitigate the effects of AMD in the above-mentioned reach are a limestone channel and constructed wetlands.

The first option is to install an open limestone channel and settling pond. A small dam is created before the seeps enter the channel to trap sediment and other debris. The channel includes a limestone sand liner and limestone rocks. With a pH of 4.0, the water flows through the channel to a settling basin. The treatment is expected to last 20 years, and noticeable differences in the tributary are likely to begin in year 1. However, there is a 10% chance the system will fail to meet the tributary's water quality goals. This option is expected to cost $100,000 including excavation costs and land costs. Maintenance costs will be about $2,000 per year after year 1. After 10 years, new limestone rock may be necessary at additional cost.

The second option is to construct a series of wetlands on a large area of land, just before the seeps enter the tributary, which could be built to reduce metals and AMD. First, after flowing into a settling pond, a smaller wetland reduces flow and causes metals to precipitate out. The larger wetland further reduces flow velocity and metals; a final settling pond is used for any remaining precipitation. To adequately increase pH, it will be necessary to augment this system with additional alkalinity. The chance of complete failure of this type of system is about 30%. These wetlands are expected to last 20 years, but the noticeable differences in the tributary will only begin to occur starting in year 3. The cost of the wetlands is expected to be $200,000, which includes land purchases and maintenance costs of $500 per year after year 1.

Both management options will eventually allow the tributary to support aquatic life, but few anglers will fish it because of private property restrictions. Restoration of the tributary will improve the overall aesthetic value of whitewater rafting and kayaking in the river; an additional 1000 person-days per year of kayaking (e.g., 250 individuals kayaking an additional 4 days) are expected. Both options will also allow part of the impaired portion of the river to meet its warm-water aquatic life (e.g., smallmouth bass) criterion; however, the other nonpoint sources of AMD on the river will still affect the river quality beyond those restored miles. Property values are expected to increase slightly with either alternative, although there may be an issue related to wide construction “rights of way” for either the limestone channel or wetlands. There is a small possibility that new construction of houses and cabins could occur with the restoration.

With the limestone channel, no additional wildlife habitat will be created near the tributary. However, the limestone channel will provide more buffer capacity for the river than the wetlands. The river is expected to meet its warm-water aquatic life use for 3 miles after the tributary enters it if the limestone channel is used and only 2 miles for the series of wetlands. Given the popularity of fishing in the area, the additional 3 miles that meet warm-water aquatic life could create approximately 200 person-days of recreational fishing. Fewer person-days of recreational fishing on the river are expected if wetlands are constructed and only 2 miles are restored.

In contrast to the limestone channel, the constructed wetlands will create additional wildlife habitat, which will enhance recreational and other activities near the tributary. In particular, users of the rail-trail (hikers, bikers, and picnickers) will benefit from the new ecological resource; as a result, an additional 750 person-days per year of hiking, biking, and picnicking are expected. In addition, the wetlands are expected to reduce sedimentation in the tributary and reduce flood potential through surface water storage.

Stakeholders include recreationists, a watershed group, homeowners, and the state department of environmental protection (DEP). The watershed group would like to move forward with its watershed plan that would achieve water quality goals in the entire river, but it lacks sufficient funds for reaching the water quality goals.

Data Available. The state DEP collects information on certain water bodies that are impaired and require TMDLs. Researchers at a nearby university are undertaking a number of studies related to AMD in the area. A local watershed group has developed a watershed plan that describes issues related to AMD throughout the watershed, not just the tributary and specific stretch of the river.

Additional Assumptions

- The only two significant sources of stressors on the tributary and the 8-mile portion of the river are abandoned mines and surface runoff (sedimentation).
- Healthy riparian habitat in the tributary and river helps control surface runoff and prevent flooding downstream.
- The only significant service provided by the bridge is transportation, and the main cost associated with corrosion is more frequent maintenance.
- As long as the two management options do not fail, both will allow for all designated uses on the tributary and river to be met, with the exception of warm-water aquatic life use in the river, which will still be affected by other sources of AMD.

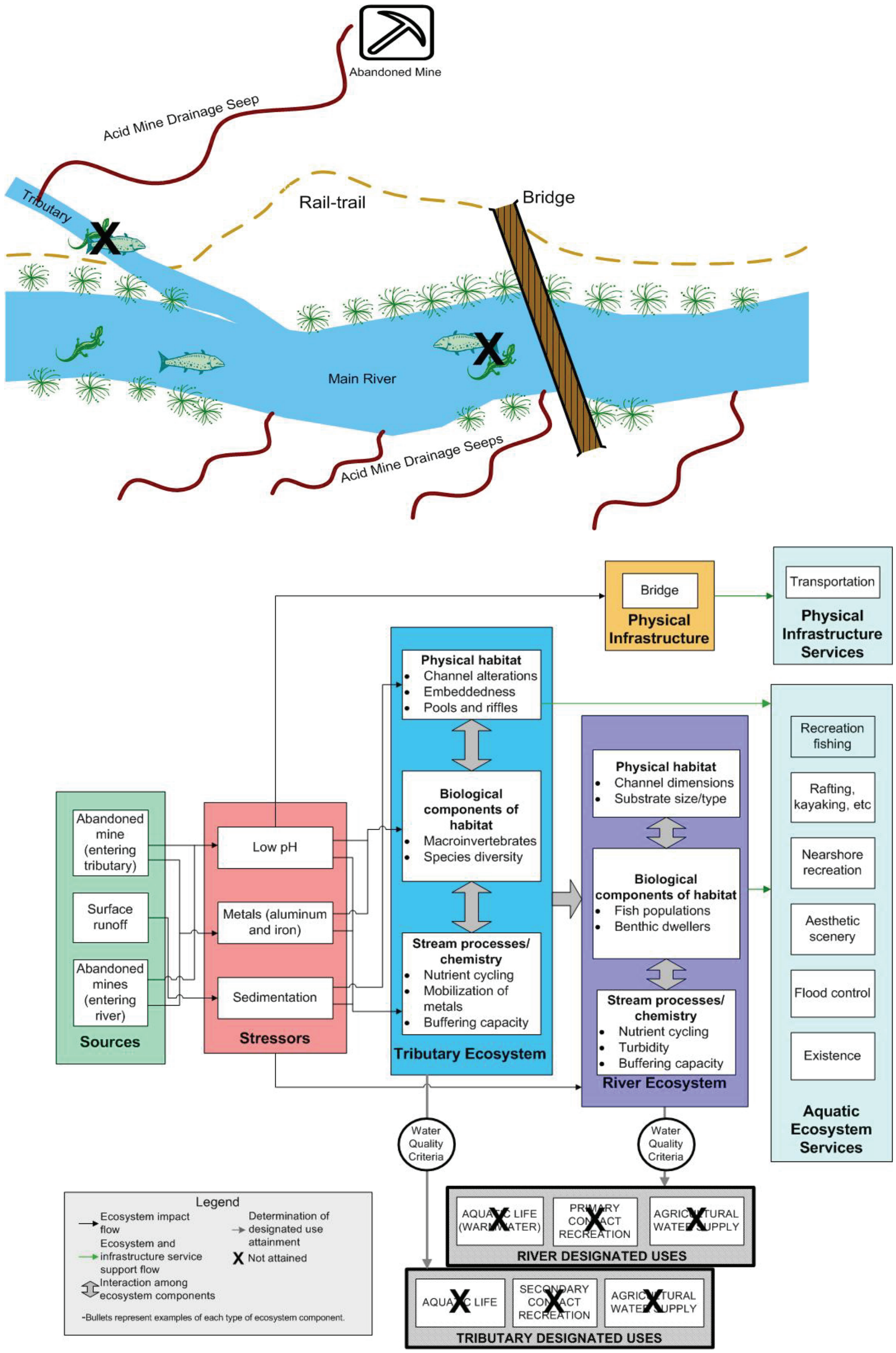

FIGURE 3-5

Mitigating Acid Mine Drainage Impacts on a Tributary and River:
Current Conditions

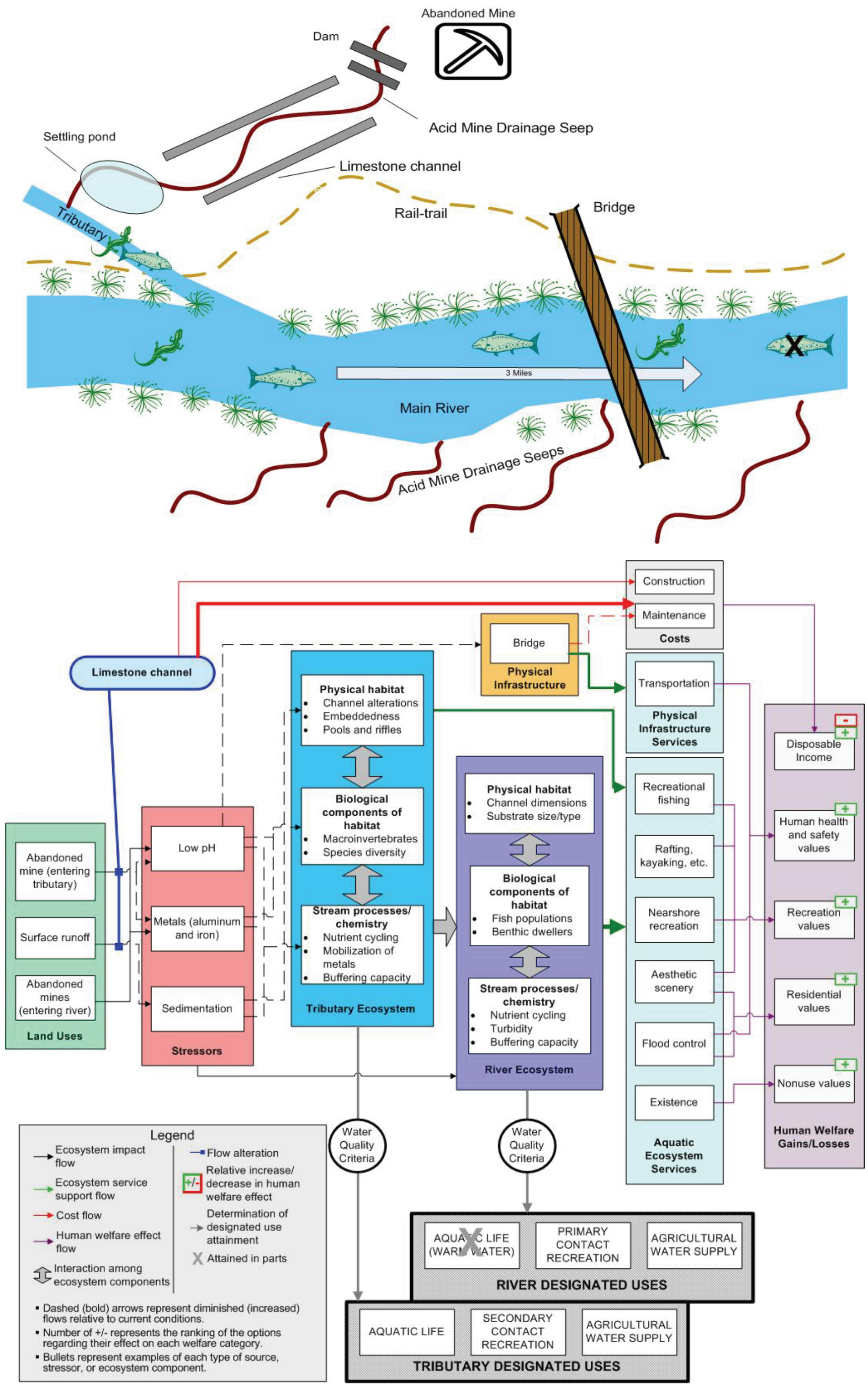

FIGURE 3-6

Mitigating Acid Mine Drainage Impacts on a Tributary and River:
Option 1: Create Limestone Channel

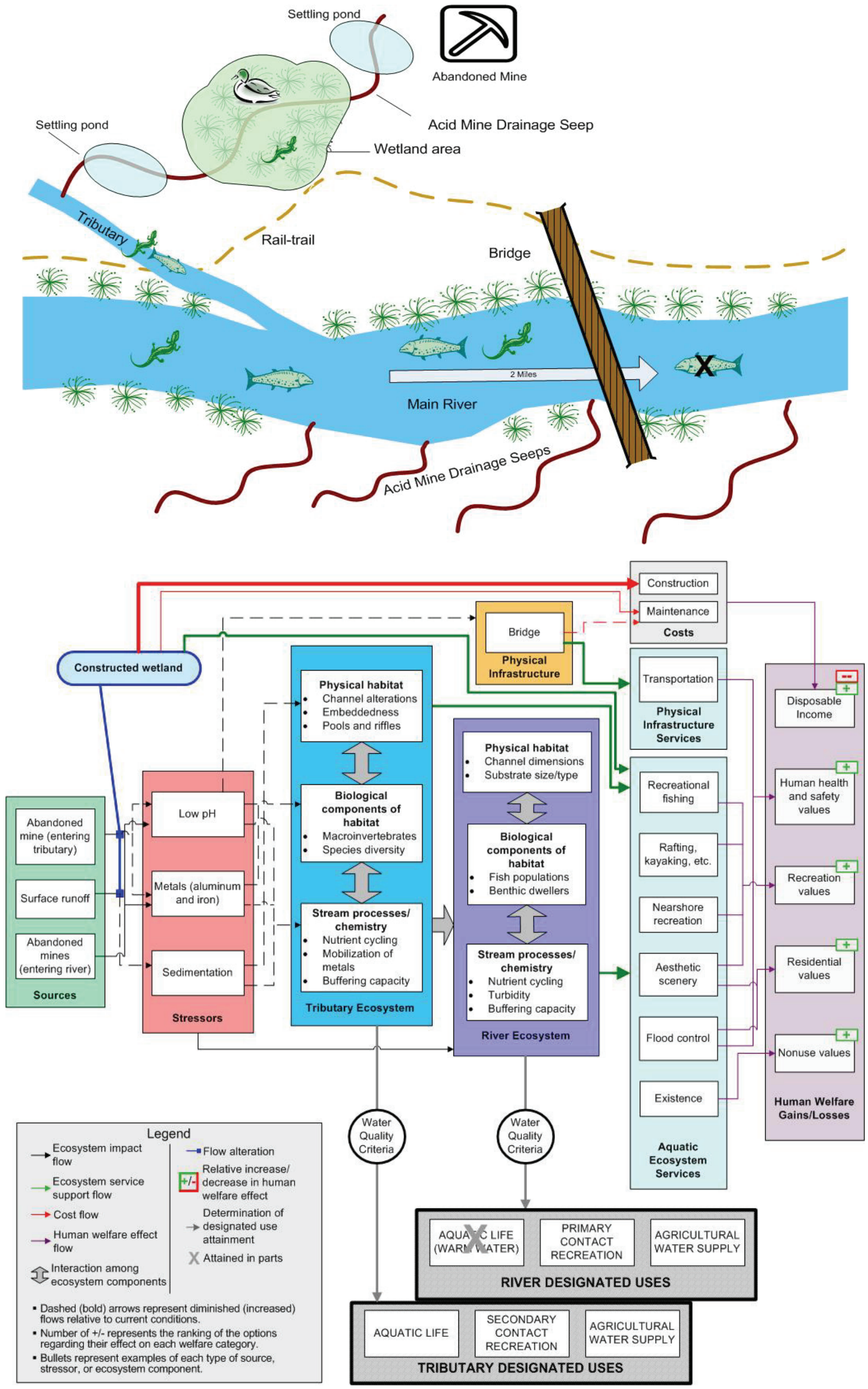

FIGURE 3-7

Mitigating Acid Mine Drainage Impacts on a Tributary and River:
Option 2: Create Wetland Area

3.4.3.2. *Case Study 2: Hypothetical Combined Sewer Overflow (Figures 3-8 through 3-10)*

A large river flows through multiple states; an interstate Basin Commission is responsible for improving the river's water quality. CSO events are a major source of pollution, especially for the urban areas located near the river (with a population of approximately 2 million people). The CSOs carry both sewage and stormwater to wastewater treatment plants (WWTPs), but, during wet weather events, can overflow directly into streams and rivers releasing millions of gallons of raw sewage. Untreated sewage and stormwater pose potential threats to human health (especially through direct contact). A total of 120 CSOs discharge directly to this stretch of the river and overflow during approximately half the number of annual rainfall events.

Designated uses for the river are public and industrial water supply after treatment, primary contact recreation (e.g., full-body contact such as swimming, canoeing, kayaking, jet skiing, and water skiing), secondary contact recreation (e.g., incidental contact such as fishing), and aquatic life use. The Basin Commission is considering whether its current standards are appropriate for the CSO problem. They are considering a UAA related to Factor 6 (see Section 2.2), widespread social and economic impact, to determine if primary contact recreation is attainable.

For this particular stretch of the river, the bacteria criterion, which protects the primary contact recreation use, was exceeded 30% of the time in the previous year. Secondary contact recreation and public water supply were always supported during this time. Besides CSOs, however, stormwater discharges, sewer leaks, and urban runoff are also sources of the problem. Although the river is suitable for primary contact recreation some of the time, it does not meet the current WQS. In addition, biological monitoring suggests that aquatic life uses are only partially supported for this stretch (i.e., one biological criterion out of three is not achieved); however, recent improvements in fish community health can be seen (with more native and pollution-intolerant species). Sediments and scour are the main stressors on aquatic life.

Recreational surveys were conducted and found that recreational motor boating is the most popular recreational activity, followed by fishing. Canoeing and kayaking were also conducted on the river. Swimming was limited to only a few areas, even though there are no designated beaches on this river.

Two potentially feasible options are being considered to address the nonattainment of primary contact recreation use: (1) attempt to meet bacteria standards through an extensive set of improvements (it is unclear if meeting the standards is feasible because of the influence of sources other than CSOs) and (2) implement fewer improvements and create a limited use subcategory of contact recreation during wet weather (other alternatives were considered, but these two were found to be the most feasible). The costs for both of these options will be passed on to local residents and businesses through increases in sewer rates.

A combination of expensive methods is necessary to attain the primary contact recreation use. Increasing sewer capacity and storage, eliminating 95% of the CSO structures, separating sewer lines, and installing disinfection capabilities in the system will need to take place over a 10-year period. Improvements that are expected include reduction of bacteria and other pollution, removal of floatables and other debris, improved aesthetics, and control of odors. This is expected to be extremely costly (some estimate a three-fold increase in sewer rates) because of construction, materials, and surface disruption (e.g., roads and railroad beds would be torn up). Disinfection capabilities may require additional evaluation because disinfection may create disinfection by-products that might create additional health problems or harmful effects to aquatic life.

The second option, which is less expensive, is to eliminate 75% of the CSO structures and change the WQS to include a wet weather limited use subcategory for primary contact recreation. These changes would improve water quality in the river surrounding wet weather events. They would reduce but not eliminate the number of exceedances of the current bacteria criterion for primary contact recreation. Therefore, the designated use for primary contact recreation would be suspended during and immediately following (maximum 4 days) specific types of severe storm events. Instead, a limited use subcategory of primary contact recreation and related bacteria criterion would be applied during severe wet weather events. This option is significantly less costly than the first (it will require roughly a 50% increase in sewer rates) and will take only 5 years to implement. A notification system would provide information on days when sewer overflows are expected. Advisories would be issued by e-mail, local radio, a Web site, and a telephone information line. The notification system would be used to announce when the designated use for primary contact recreation is suspended because of potential human health threats from CSOs and other wet weather discharges.

Stakeholders include local communities, recreationists, states, the Basin Commission, local businesses, economic development groups, and watershed groups. It is unclear how stakeholders will perceive the contact recreation alternatives. Some may think that the Commission should not lower WQS because downgrades will eliminate some of the incentives to remove CSOs. They also may believe that primary contact recreation is important on the river. Tourism may be affected because of poor aesthetics during high flows (e.g., the presence of floatables). However, the cost of the CSO controls required to achieve the water quality goals might be excessive (and passed on to local homeowners and businesses) compared with the benefit gained (e.g., even if the bacteria criterion for primary contact recreation were met, swimming would not be advisable for safety reasons because of high flow). Current businesses may choose to leave the area, and new businesses may not move into the area if sewer rates become too high, which would have negative economic effects in the region. Although limiting recreational use during wet weather may not be acceptable to local communities, recreationists, and watershed groups, it avoids the large costs.

Data Availability. The Basin Commission for the river focuses on reducing pollution. They have collected extensive water quality data for the river, and a local university has collected data on the health of aquatic species community including types of algae. A number of watershed groups have formed in the area, each of which collects water quality data in their particular watershed.

Additional Assumptions

- In addition to CSOs, sewer leaks, stormwater discharges, and urban runoff along the segment of the river being evaluated, upstream sources of pollutants also contribute to water quality impairments in the segment.
- Option 1 and Option 2 would only reduce discharges from CSOs (not from the other sources of stressors).
- Option 1 and Option 2 would lead to reductions in episodic loadings of sediments and scour from CSOs sufficient to meet all three biological criteria for the aquatic life designated uses.
- The costs of Option 1 and Option 2 ultimately would be borne by local residents and businesses (e.g., through sewer rate increases), whose incomes, and therefore consumption levels, would decrease.
- Option 1 and Option 2 would reduce pathogen-related risks in the public water supply.
- Risk of human illness for Option 1 is lower than in Option 2.

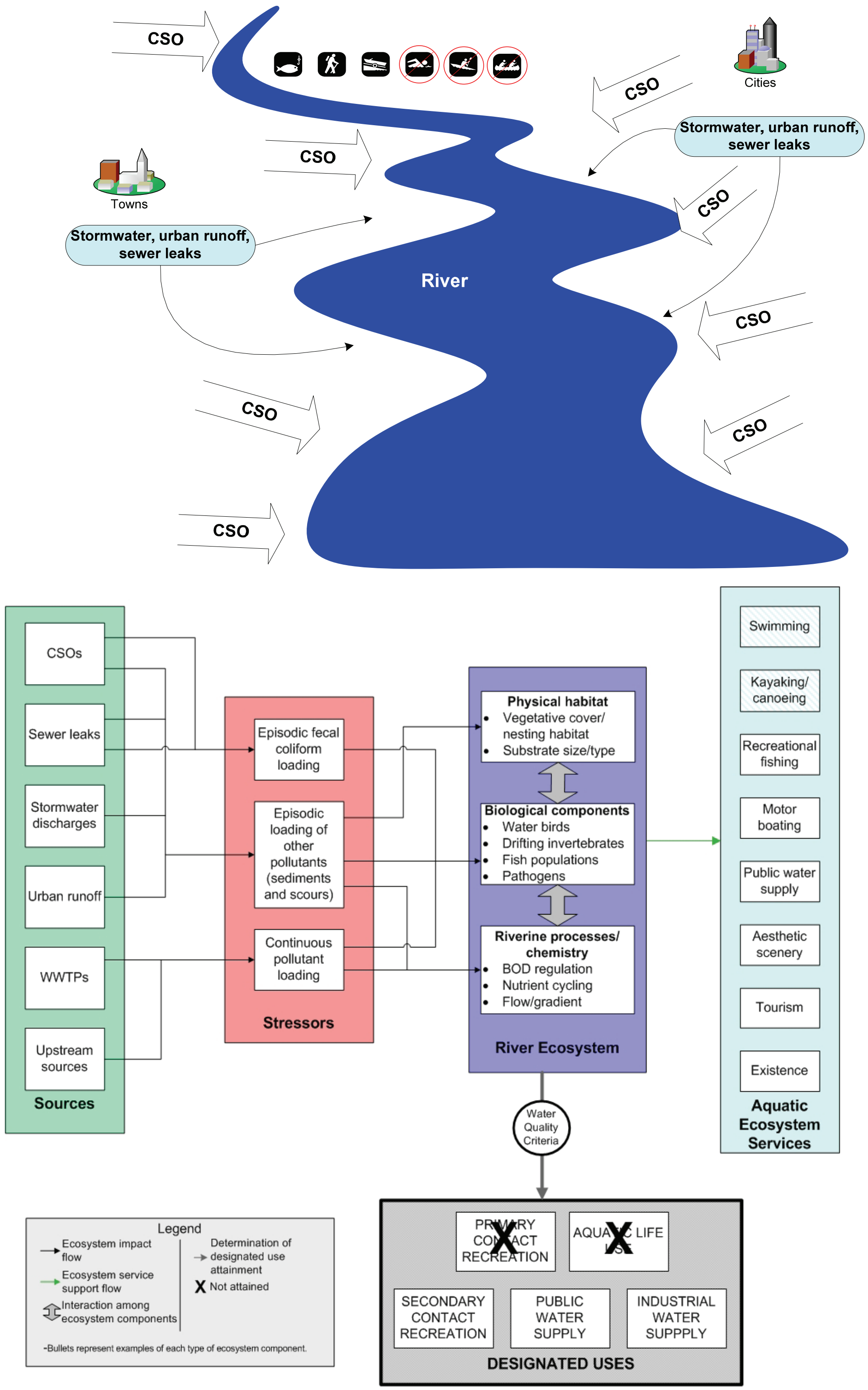

FIGURE 3-8

Mitigating CSO and Stormwater Impacts on a River System:
Current Conditions

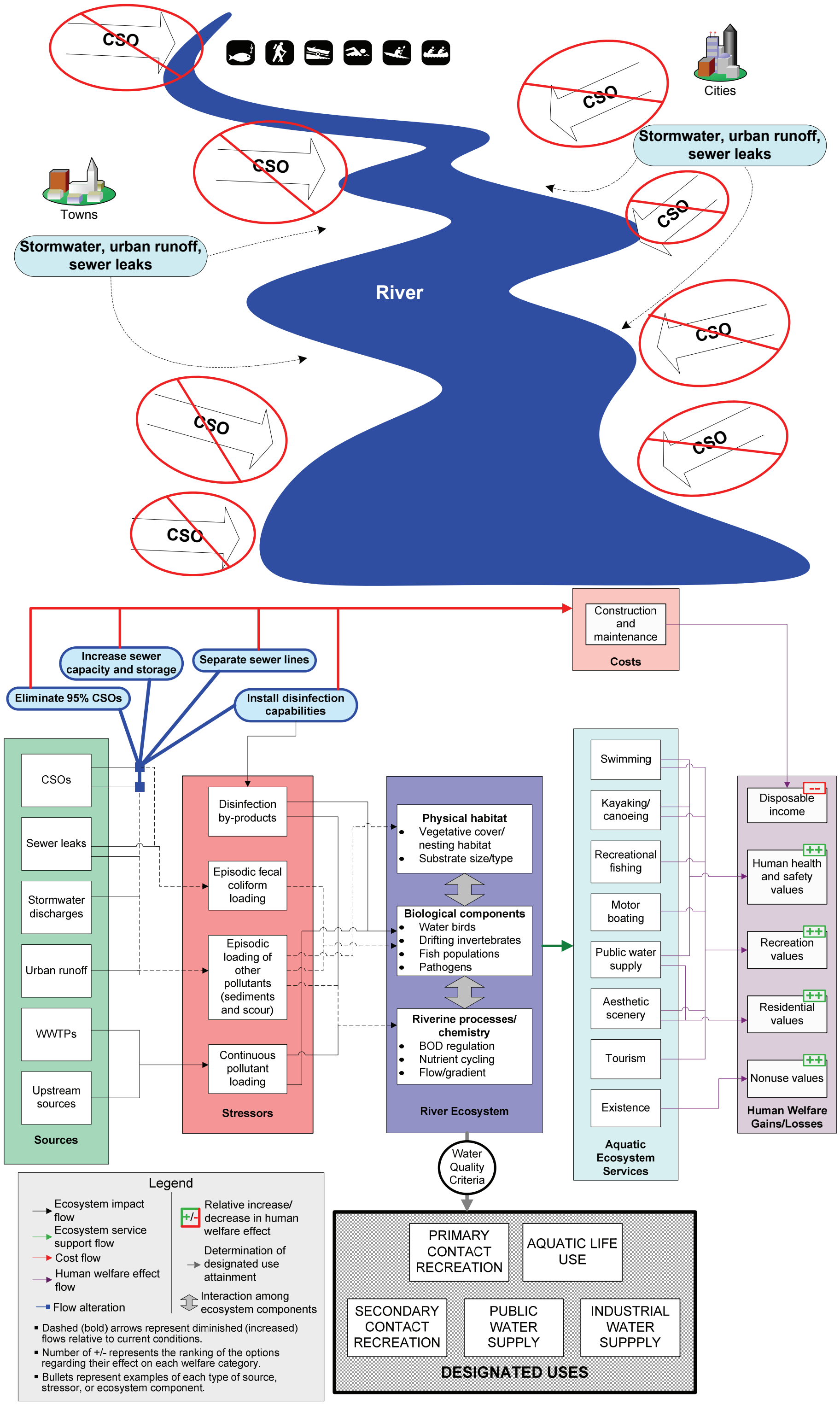

FIGURE 3-9

Mitigating CSO and Stormwater Impacts on a River System:
Option 1: Eliminate 95% of CSOs and Implement Other System Improvements

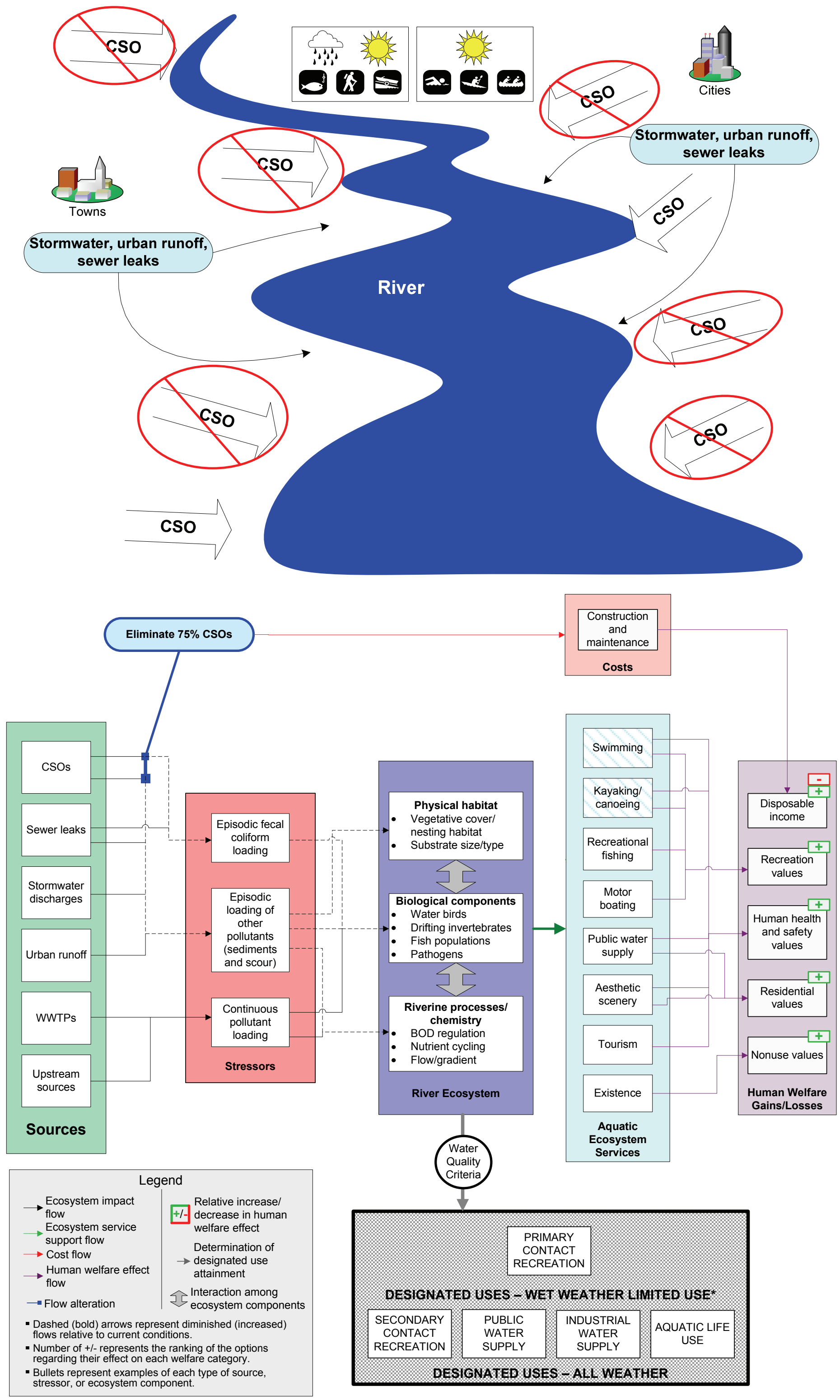

FIGURE 3-10

Mitigating CSO and Stormwater Impacts on a River System:
Option 2: Eliminate 75% of CSOs and Apply Limited Use Designation

3.4.3.3. *Case Study 3: Mitigating Agricultural Impacts on an Intermittent Stream (Figures 3-11 through 3-14)*

An intermittent stream is designated as a secondary-contact recreation water segment and aquatic life use water body. The segment is privately owned and is used to water livestock during periods of flow. The landowner has given permission to the public to hunt and trap along the segment. The primary land uses around the segment are livestock grazing and growing crops. The livestock have direct access to the stream and therefore modify the habitat by preventing regrowth of the riparian buffer and destroying the river bed. Direct access to the stream also leads to direct deposit of animal wastes into the stream. Water quality measurements taken on the segment suggest these stressors lead to increased temperature, low DO, downcutting of the channel, and increased sediments. The biological criteria are violated for aquatic life use because of the stressors and possibly because the criteria are based on perennial streams (not intermittent streams). Landowners downstream are complaining that the poor condition of the intermittent stream segment is affecting recreational fishing on their segments. Algae, sediment, and nutrients are their biggest complaints.

Options to restore this intermittent stream include fencing off livestock access to the stream and constructing either a stone crossing (Option 1) or culverts and bridges (Option 2) so the livestock can have access to the fields across the stream. Benefits include improvements to fish and wildlife habitat as stream side plants are reestablished, as well as fewer animal injuries and healthier animals for the landowner. The landowner, however, will lose access to some grazing lands because of fencing off the riparian area around the stream. Another activity and stressor on this same stream segment is growing crops around the stream. Aquatic life use standards might not be met by preventing direct access to the stream alone; the agriculture runoff associated with the cropping activities also may need to be reduced. The crops prevent any type of riparian buffer to grow, and runoff enters the segment directly. Some of the activities to prevent livestock access may help, but further restoration of riparian areas may be necessary (Option 3).

Key Assumptions and Additional Considerations

- Improving the quality of the riparian area for the intermittent stream will reduce the runoff into the stream and promote greater infiltration during rain events. This will result in less “flashy,” event-driven streams and regulate downstream flow, perhaps providing some degree of flood control.

- Improving the quality of the riparian area will result in greater channel stability through healthier vegetative cover along the stream banks. This will result in more diversity in habitats (e.g., through woody debris) and higher DO as a function of temperature regulated by overhanging vegetation.

- Residential properties are located downstream along the perennial stream, so residents would benefit from improved aesthetics and flow/erosion control.

- The perennial stream is used for various types of recreation and potentially for drinking water as well.

- Hunting and trapping along the intermittent stream would be improved only in Option 3 when livestock are fenced off and the riparian area is fully restored.

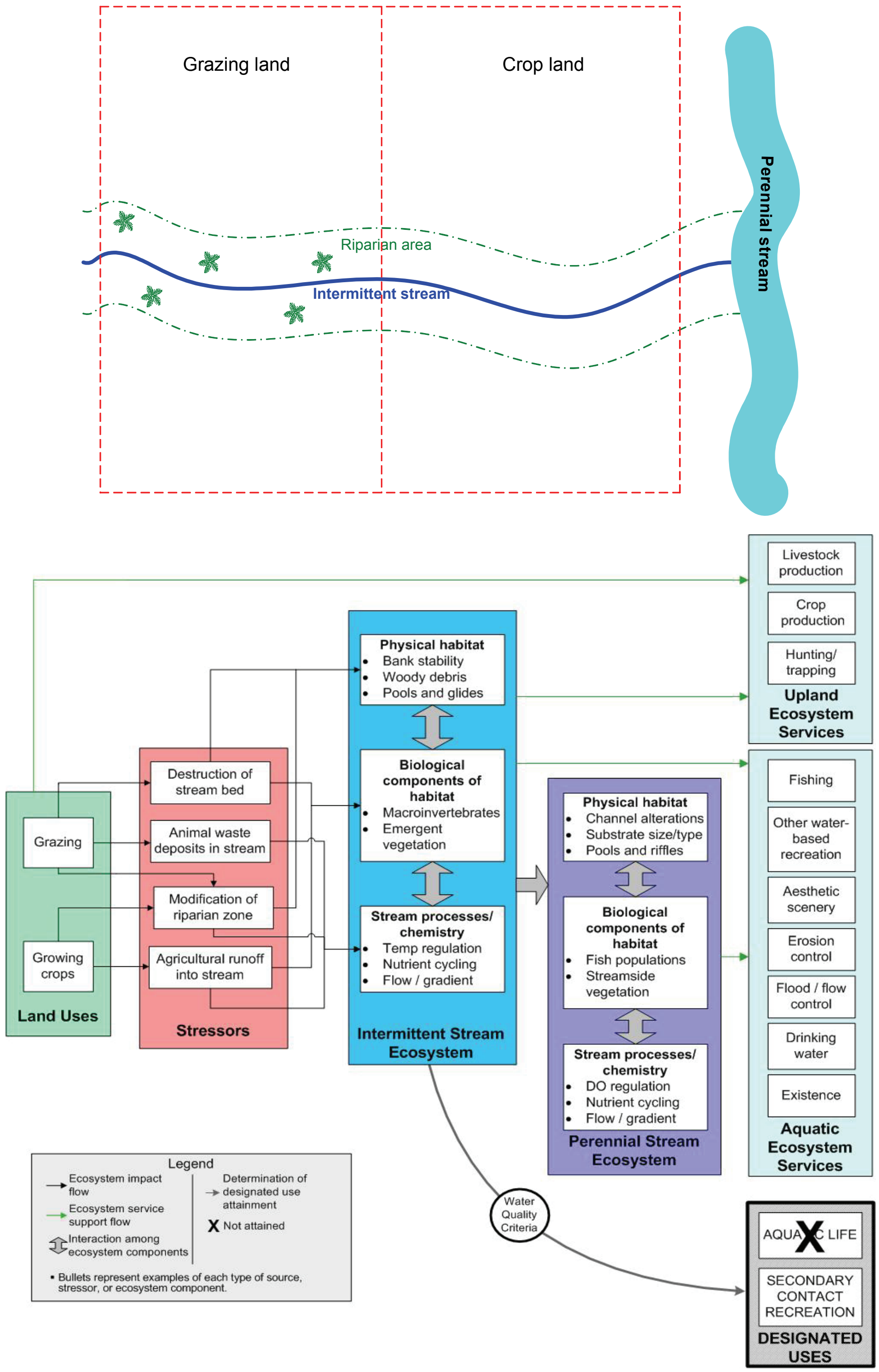

FIGURE 3-11

Mitigating Agricultural Impacts on an Intermittent Stream: Current Conditions

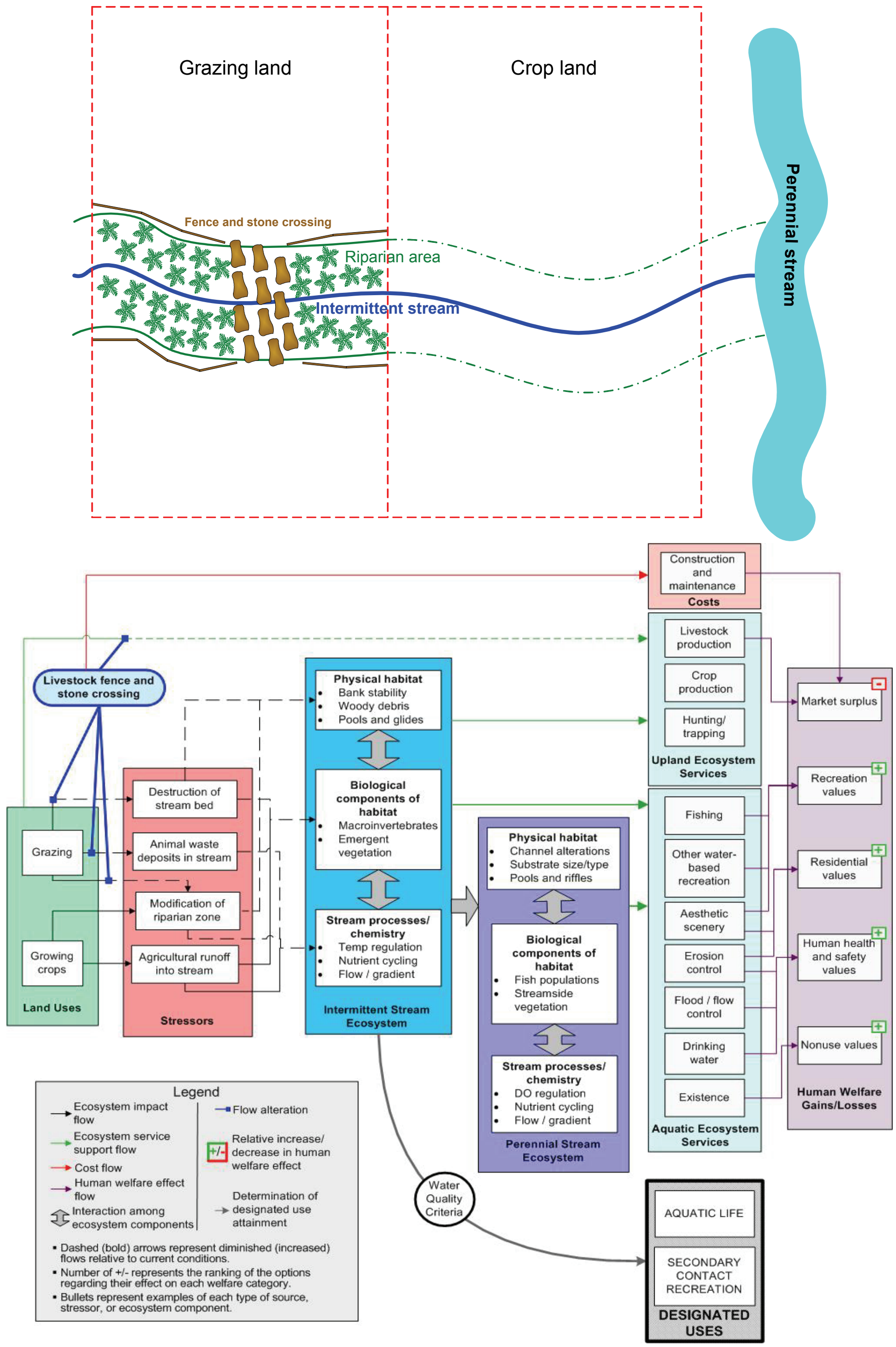

FIGURE 3-12

Mitigating Agricultural Impacts on an Intermittent Stream:
Option 1: Limiting Livestock Impact with Fence and Stone Crossing

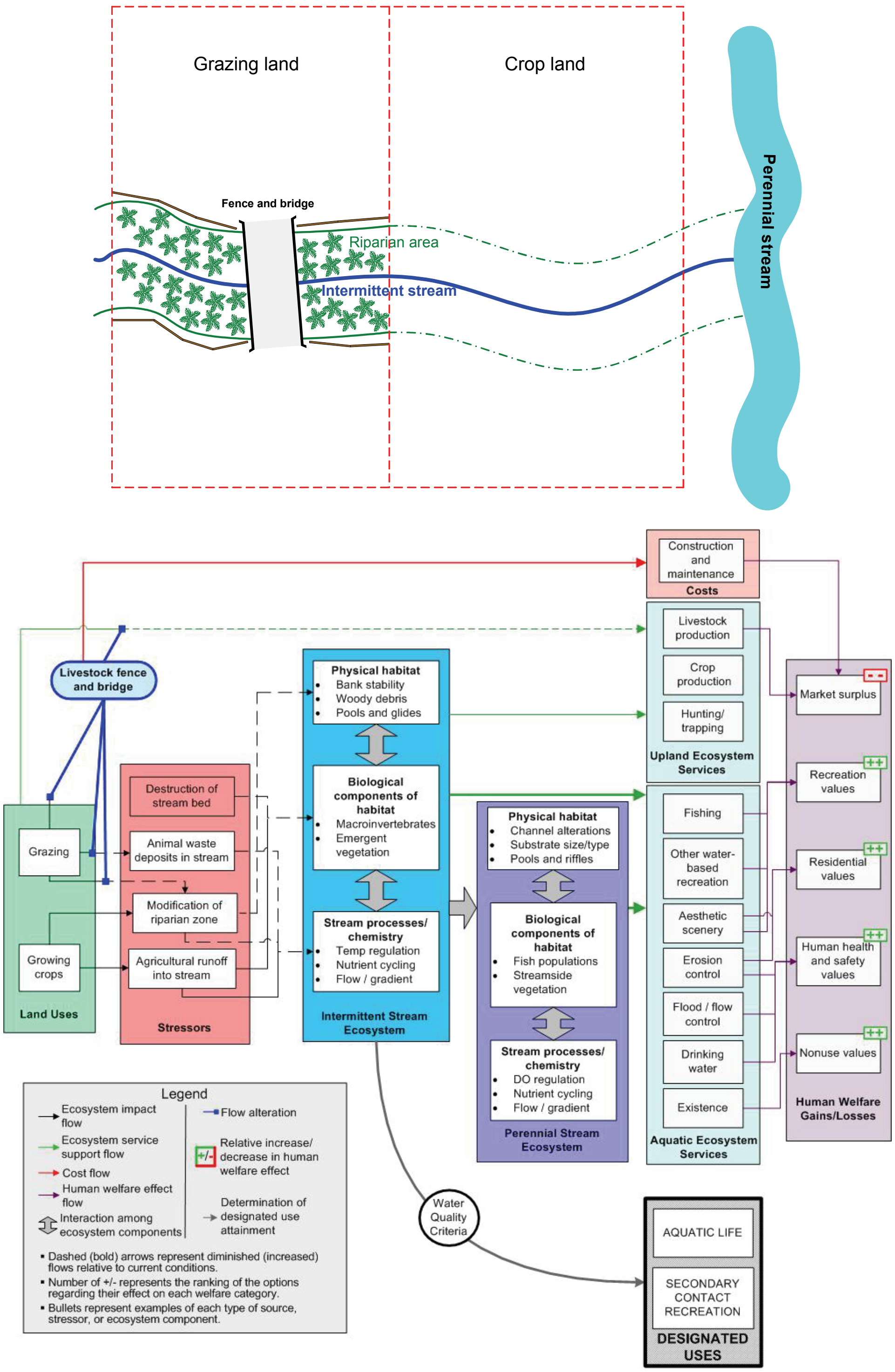

FIGURE 3-13

Mitigating Agricultural Impacts on an Intermittent Stream:
Option 2: Limiting Livestock Impact with Fence and Bridge

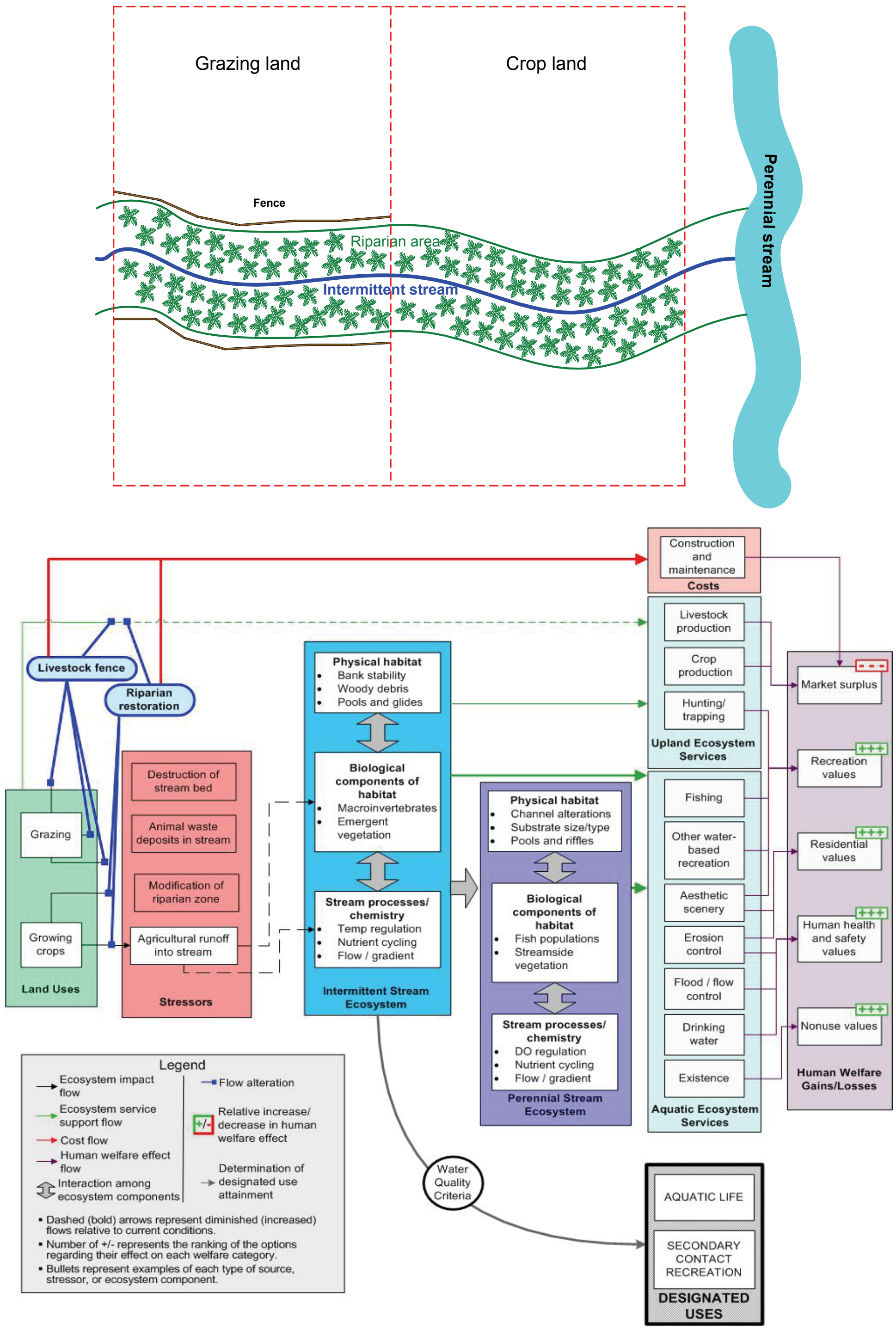

FIGURE 3-14

Mitigating Agricultural Impacts on an Intermittent Stream:
Option 3: Limiting Livestock and Crop Impact with Fence and Riparian Restoration

3.4.3.4. *Case Study 4: Antidegradation Review of Proposed Retail Development Complex (Figures 3-15 and 3-16)*

A new retail development complex is being located in a small watershed, and an antidegradation tier 2 review is necessary. For the complex to be located on an upland area of the property, a road must cross a wetland. For the roadway to be built, 0.5 acre out of 20 wetland acres must be filled. This wetland, which provides habitat for birds, is connected to a stream where current water quality is above standards for a cold-water fishery. The AR will determine whether maintaining water quality will preclude important economic and social development. No other potential location for the road exists, and the developers believe this is the best location for the complex. Given the proposed location of the new road, the main stem of the watershed may be affected by increased sediment load. The construction of the retail complex will initially increase sedimentation to the wetlands. Along with the installation of stormwater detention ponds, revegetation of the area will enable sedimentation to decrease and preconstruction conditions to return. However, the road will lead to a permanent lowering of water quality to the fishable stream (but still meet the WQS). The complex and road construction are predicted to lead to new jobs and improved living conditions within the watershed.

Key Assumptions and Additional Considerations

- Under conditions without the retail development, the upland area would primarily provide open space, which would provide some recreational opportunities and aesthetic amenities to local residents.
- Even with the construction of stormwater retention ponds, the retail area would be a long--term source of sediment loads (although less than would occur without the ponds).
- Residential properties are located downstream along the perennial stream, so residents would benefit from improved aesthetic conditions and flow/erosion control.

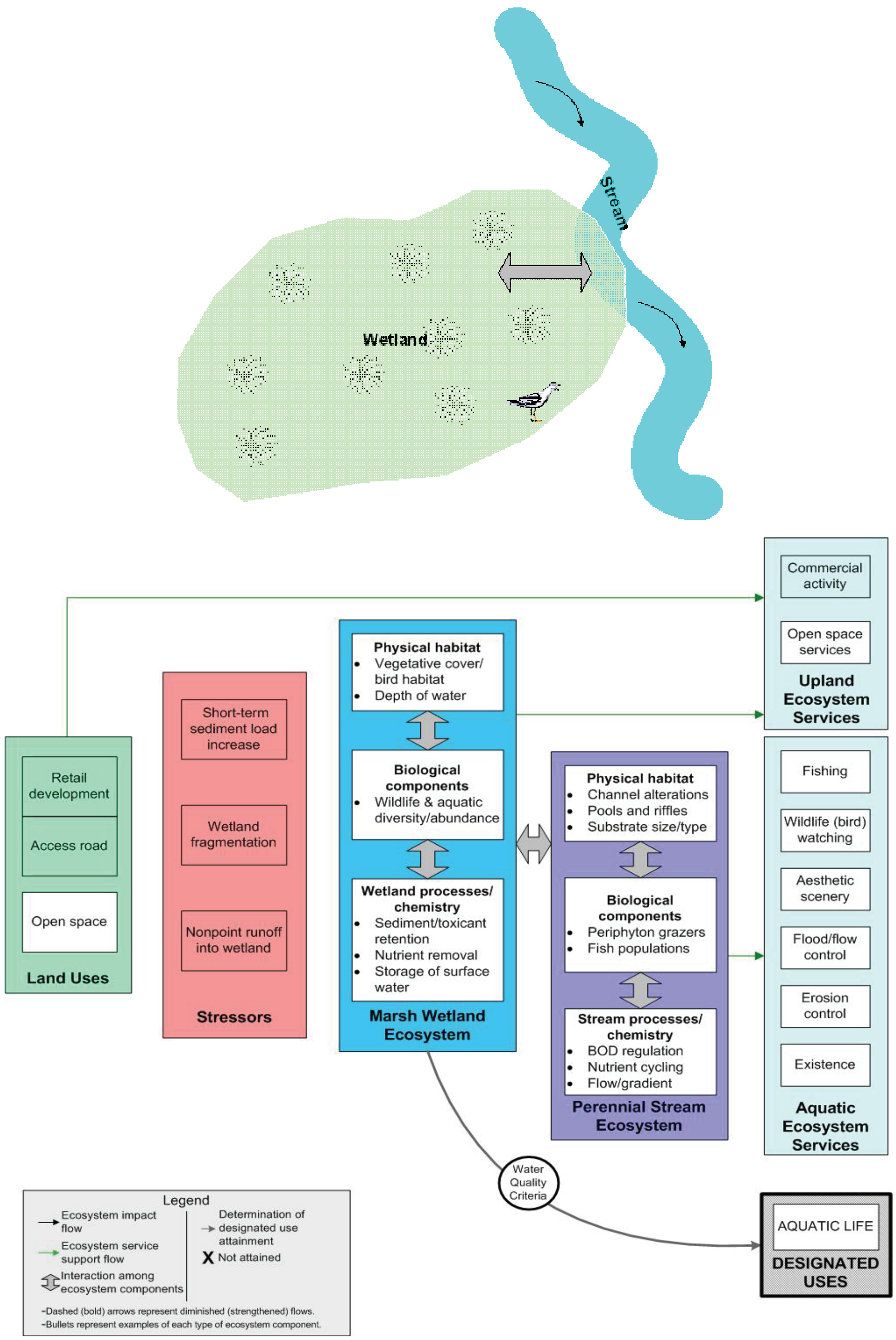

FIGURE 3-15

Antidegradation Review of Proposed Retail Development Complex Conditions Without Retail Development

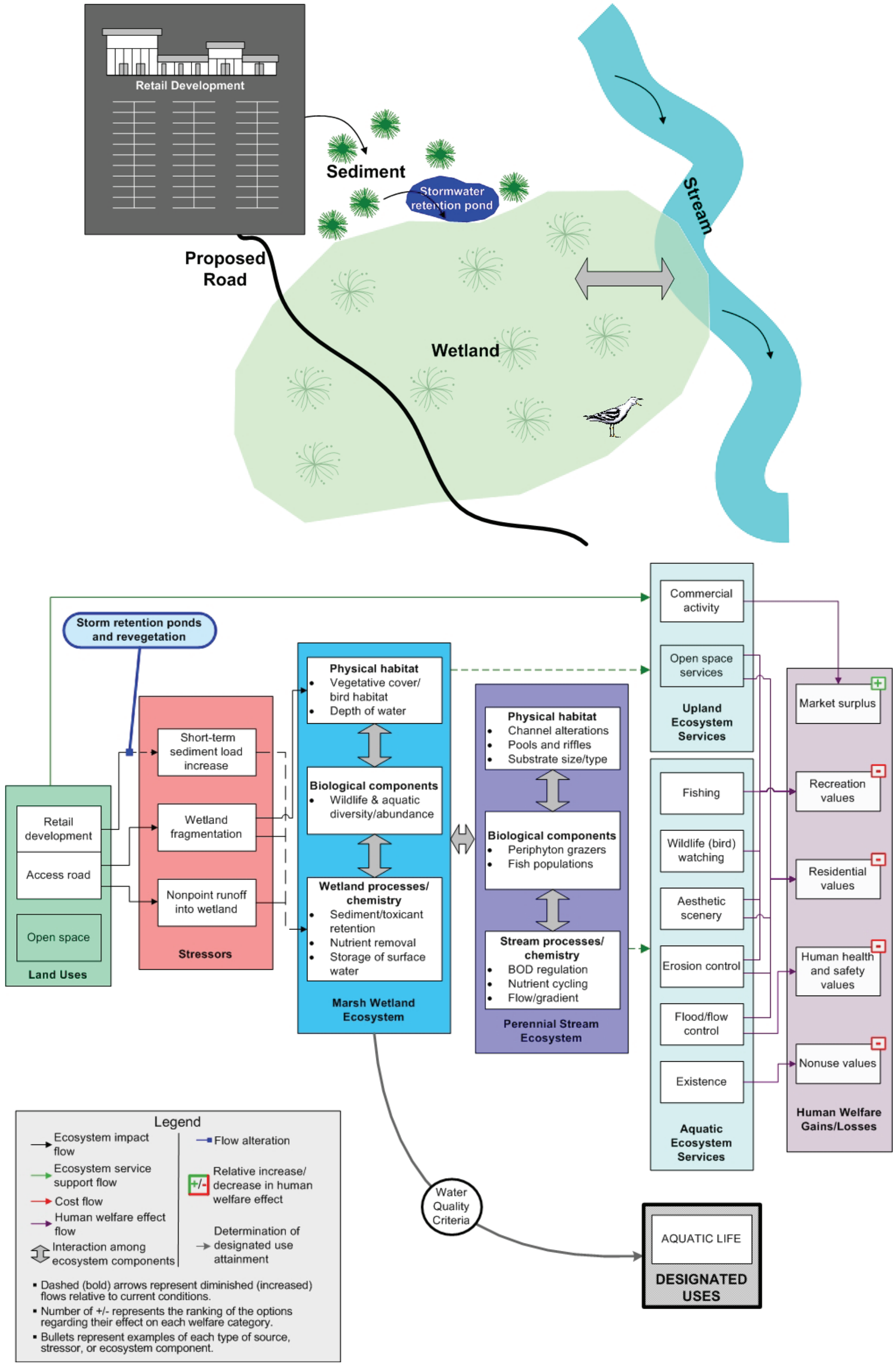

FIGURE 3-16

Antidegradation Review of Proposed Retail Development Complex
Effects of Retail Development

3.4.3.5. *Case Study 5: Management of an Effluent-Dominated Stream (Figures 3-17 through 3-19)*

A state has recently changed its designated uses for intermittent and ephemeral streams to include aquatic life. Because the state did not originally designate aquatic life uses on intermittent and ephemeral streams, many industries and wastewater facilities located on these streams to dispose of their discharges. These intermittent streams are now effluent dominated. One wastewater treatment plant's discharge has converted an ephemeral stream into one with perennial flow. It has developed a riparian area that has created new habitat for birds, wildlife, and amphibians and is a source of groundwater recharge. One rare salamander has been found in and around this stream. This particular stream is a tributary to a major river and supports the river's beneficial uses of warm-water aquatic life and primary recreation. The continuous flow of the effluent-dominated stream has also created a bird-watching area around the stream. With the new designated uses, these facilities have a limited number of options to deal with the new classifications. Pollutants that may violate aquatic life standards include metals, disinfection by-products, pH, temperature, and DO. The facilities could increase treatment to meet the new standard (Option 1) or they could cease the discharge (and effectively relocate) (Option 2). Each of these possibilities would lead to different benefits and costs to the facilities and to society.

Key Assumptions and Additional Considerations

- The cost of advanced treatment or relocation of the wastewater treatment plant would ultimately be borne by local residents (e.g., through taxes), whose incomes, and therefore consumption levels, would decrease.
- The costs of advanced treatment installation or the closure of industrial dischargers would result in lost incomes and/or higher prices for market goods. In either case, consumption levels would decrease.
- Elimination of point sources (Option 2) would reduce water flow and pollutant discharges to the stream segment; however, these point sources (in particular, the wastewater treatment plant) would need to relocate to other water bodies, where similar ecosystem impacts might be experienced (these similar impacts are not included in the conceptual model).
- Elimination of point sources (Option 2) would return the stream to intermittent flow conditions, which would provide a different and perhaps more limited set of ecosystem services.

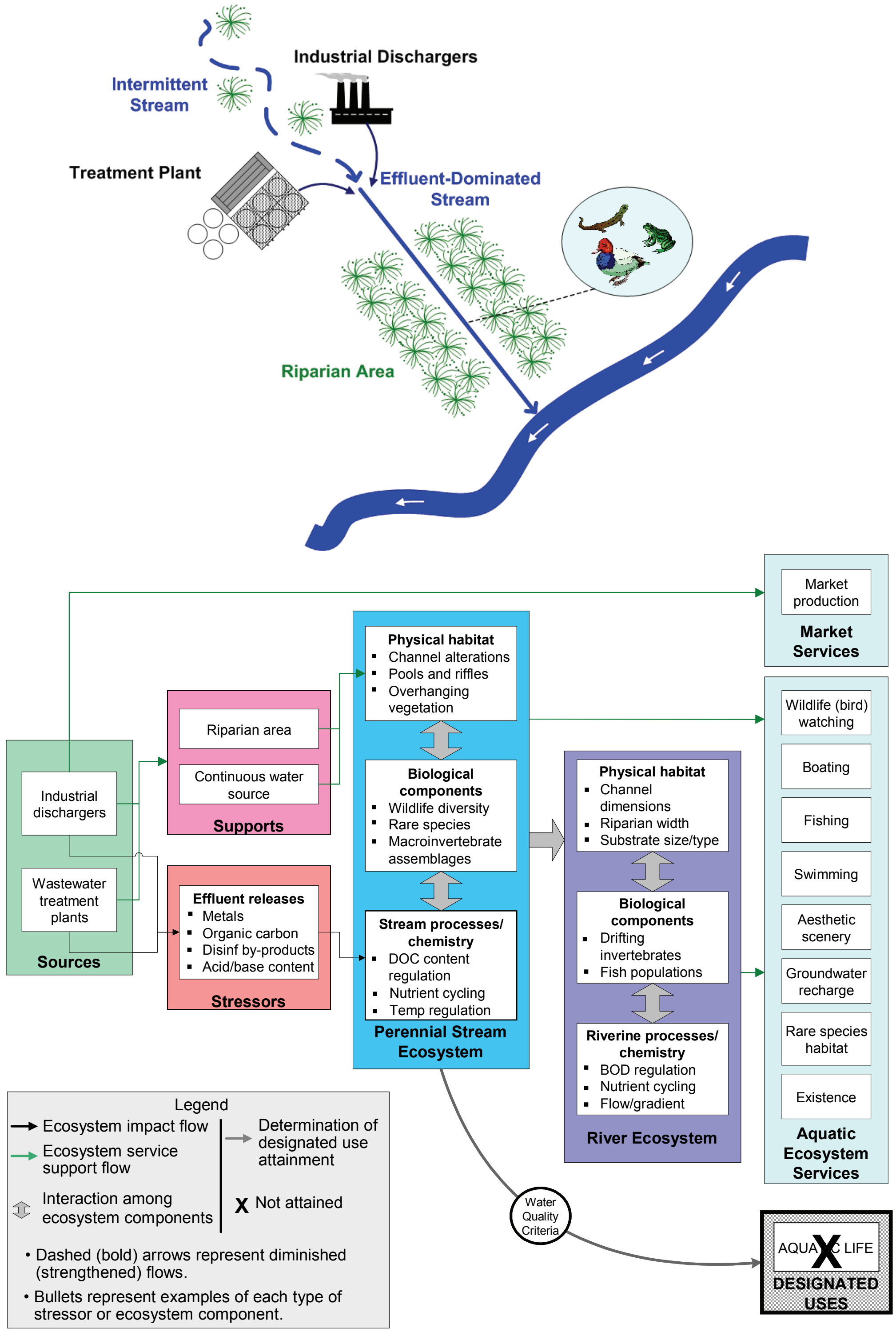

FIGURE 3-17

Management of an Effluent-Dominated Stream:
Current Conditions

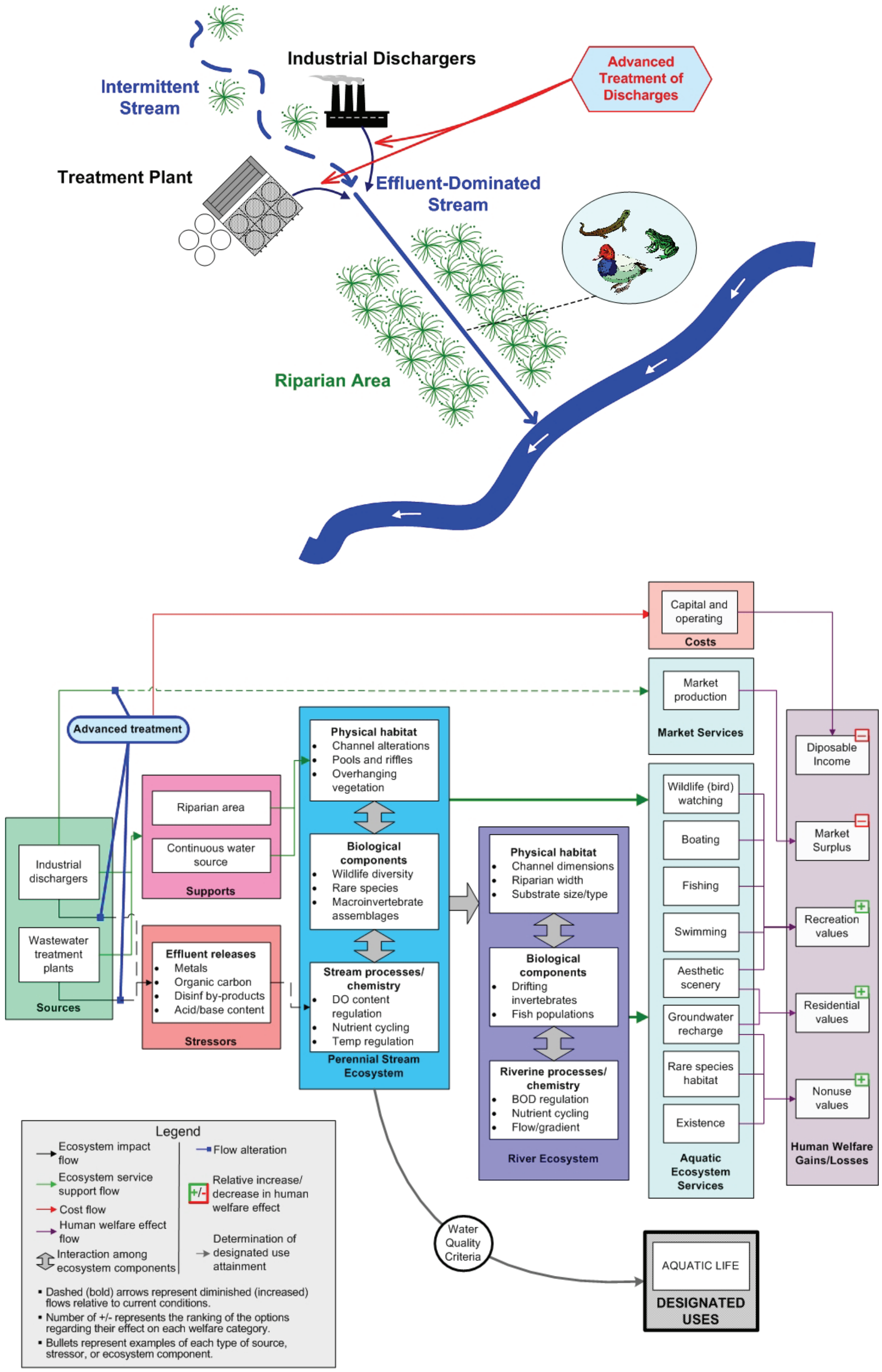

FIGURE 3-18

Management of an Effluent-Dominated Stream:
Option 1: Increased Treatment of Effluent

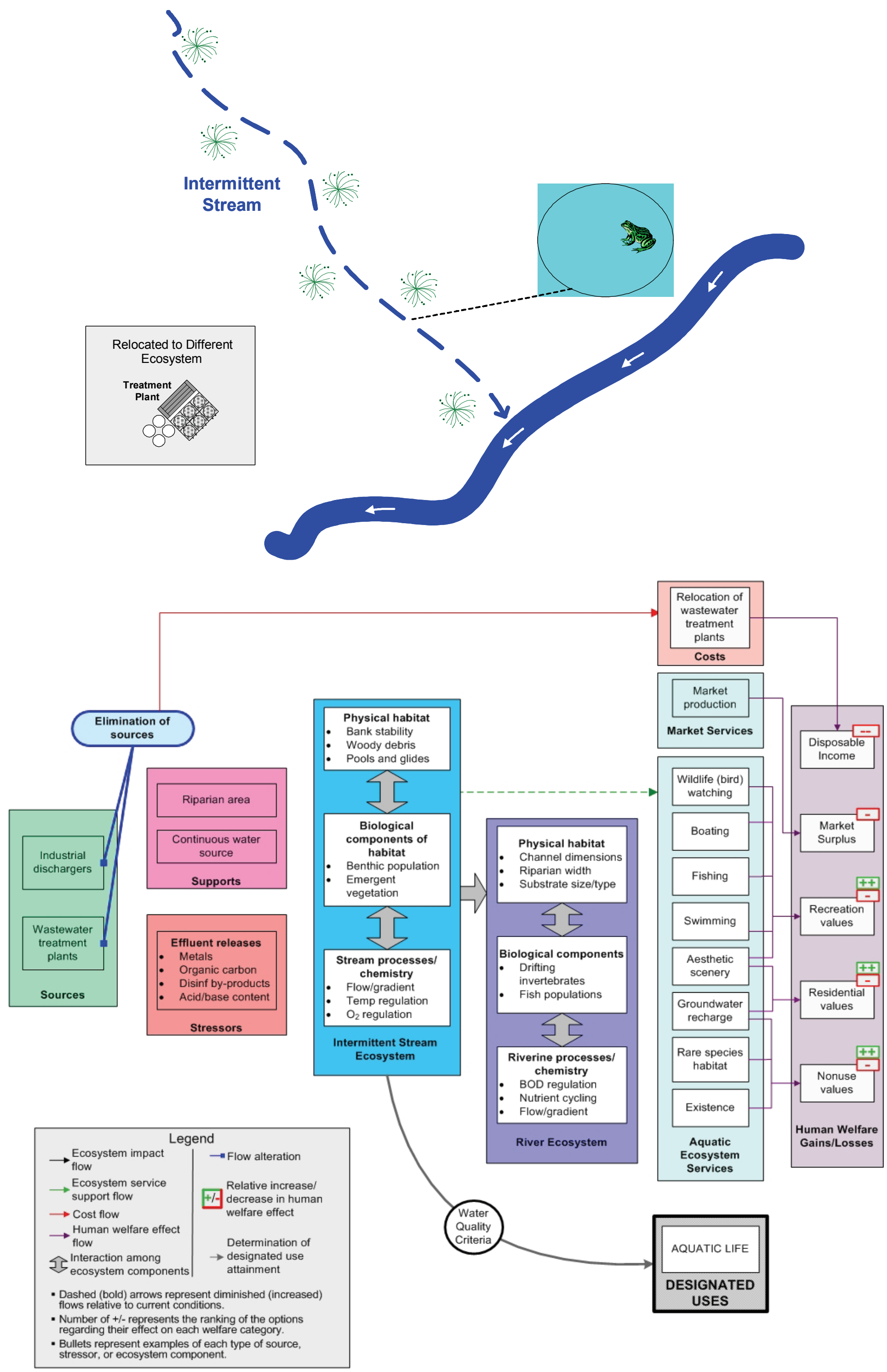

FIGURE 3-19

Management of an Effluent-Dominated Stream:
Option 2: Elimination of Sources of Discharge

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4. UNDERSTANDING THE TOOLS: A SUMMARY OF METHODS FOR CHARACTERIZING THE GAINS AND LOSSES

The purpose of Chapter 4 is to provide the reader with an overview of “social science” methods and a basic understanding of their relative advantages and disadvantages. The descriptions are intended to help the reader gauge which methods might be applicable to his or her situation. Rather than providing detailed instructions on how to apply each method, the chapter references other sources that provide further detail. In most cases, the assistance of qualified experts should be sought to select and implement the most appropriate method for eliciting preferences. The information provided in this chapter, along with the general framework for evaluating management options and the conceptual models described in Chapter 3, can be used to inform and improve the decision-making process for WQS. A common goal of these methods is to help decision-makers better understand the insights, perceptions, attitudes, objectives, and preferences of relevant stakeholders in the affected community and to apply this information to improve policy decisions. Using the term *affected community* implies that decision-makers should consider those individuals impacted by the use-attainment decision. However, according to the *Interim Economic Guidance*, the relevant geographic area must include the water segment under consideration, but no rules exist for defining the community (U.S. EPA, 1995). It is up to the applicant and state, but U.S. EPA must review the decision.

This may not capture the relevant community for the process presented in this report. U.S. EPA (2002) suggests that the community is defined by both the people and the place. The people might be connected by social interaction or a common activity while the place might be based on a geographic setting or political boundary.

In the economic literature, determining the “market area” is a similar problem to determining the relevant community. Freeman (1993) points out that determining the market area is an important research question, but the significance of the resource can help determine the geographic area. Loomis and Gonzalez (1996) examine this empirical question and find that not including nonresident values for reducing wildfires to protect habitat in California and Oregon will understate the total benefits by 80%. Pate and Loomis (1997) find that the extent of the market might be based on total cost of the program and who will bear those costs. Understanding who is in the relevant community is not easy to determine and not likely to have a right answer, but it must be considered part of the process to avoid problems created by the use attainment decision.

This chapter divides the social science methods into two main categories: sociocultural and economic methods. As discussed in more detail in the chapter, the main distinguishing feature of economic assessment methods is that they are based on a common conceptual framework for evaluating the human welfare effects and the benefit-cost trade-offs involved in policy decisions (i.e., for conducting economic analyses). Sociocultural assessment methods, in contrast, provide a number of alternative perspectives and approaches for eliciting, evaluating, and applying community preferences and stakeholder input in the decision-making process.[1] Applying these methods to support WQS decisions is consistent with EPA's stated interest in more fully and effectively using the knowledge base from social and behavioral sciences in environmental decision-making (NRC, 2005).

To present the social science methods, the chapter begins in Section 4.1 by defining a general decision-making process for WQS and identifying the stages in the process where these methods can be applied most effectively. It presents several specific sociocultural and economic methods and describes some of their distinguishing features. Section 4.2 then identifies and describes the information and data collection approaches that are used to support the assessment methods.

Section 4.3 provides more detailed discussion and comparisons of the sociocultural and economic methods. It describes the types of data collection techniques required for each method. It also compares and rates each method according to "cost/complexity"—relating to the time, data, resources, and specialized technical skills required to implement the method. The section then provides a short (one to two pages) description of each method, including a discussion of the advantages and disadvantages of the method, the types of outcomes associated with their application, and a brief example of their use.

4.1. APPLYING SOCIAL SCIENCE METHODS TO THE DECISION-MAKING PROCESS FOR WQS

Figure 4-1 illustrates, in general terms, the decision-making process for setting WQS. It builds on the process illustrated in Figure 3-1 by specifically highlighting areas where social

[1] A key resource for these methods and this chapter was U.S. EPA (2002).

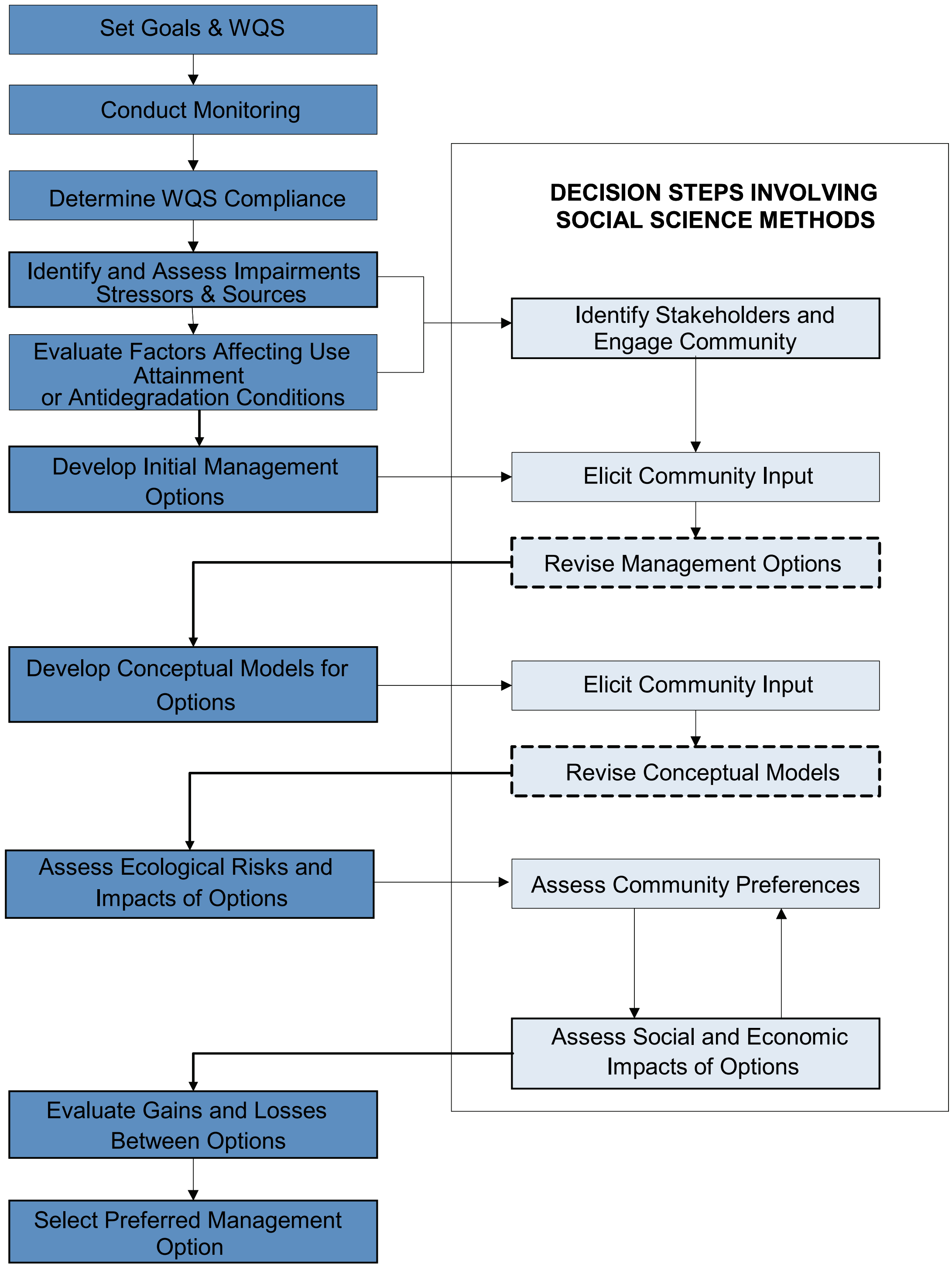

FIGURE 4-1

Incorporating Social Science Methods into WQS Decision-Making science methods can be used to inform and enhance this process. The overall goal of the decision-making process is to select the management option that meets the highest attainable use of the water and best addresses the needs and priorities of the affected community. Throughout this process, social science methods can be used to address three supporting objectives:

(1) involve the community in framing the key elements of the WQS decision,

(2) assess community preferences for different management options to meet the highest attainable use, and

(3) assess the expected social and economic impacts of the different options.

Below we discuss the types of social science methods that are best suited to addressing each of these objectives. This discussion is divided into two sections, the first focusing on sociocultural methods and the second on economic methods.

4.1.1. Sociocultural Methods

Sociocultural assessment methods include a variety of perspectives and approaches for engaging the community in the decision-making process, eliciting input from stakeholders, and assessing and applying community preferences in the decision-making process. Table 4-1 lists several of these methods and distinguishes them according to whether they are “deliberative,” “analytical,” or combined deliberative-analytical techniques. These distinctions are discussed in more detail in the following sections. Table 4-1 also lists the section number later in this chapter where a more detailed description of each method can be found.

4.1.1.1. *Deliberative Sociocultural Methods*

A number of social science methods can be broadly categorized as “deliberative” or “participatory” approaches. Deliberative methods involve the consideration of an issue by an assemblage of stakeholders who ponder, discuss, and collectively assess the issue at hand. They range from large public hearings to representative advisory committees (other examples and descriptions of deliberative methods are provided later in this chapter).

When applied to environmental decision-making, these deliberative methods find their theoretical underpinnings in a wide range of disciplines, including anthropology, conservation

TABLE 4-1

Summary of Sociocultural Methods: Key Characteristics

	Analytic	Deliberative	Section Number With Detailed Description
Mental Model Approaches	✔		4.4
Public Meetings		✔	4.5
Delphi Method	✔	✔	4.6
Multiattribute Trade-Off Analysis	✔	✔	4.7
Multicriteria Decision-Making	✔	✔	4.8
Focus Groups Interviews	✔	✔	4.9
Advisory Committees		✔	4.10
Value Juries		✔	4.11
Opinion and Attitudinal Surveys	✔		4.12
Referenda	✔		4.13
Affective Images	✔		4.14
Narrative	✔		4.15
Damage Schedules	✔		4.16

and ecology, social policy, and sociology. Although the specific theoretical orientations and assumptions of these and other social sciences vary widely, they are largely unified by a holistic, systemic approach that encompasses the complex relations between people and their environments (Moran, 1990). Deliberative social science methods are, as a result, intended for use with a diversity of stakeholder groups and in relation to a diversity of environmental questions and issues. Many of these social science methods also are well suited for examining and addressing environmental equity issues. That is, they can provide useful forums for exploring, and when possible addressing social inequalities in environmental decision-making (Lubchenko, 1998).

In the context of WQS, deliberative methods can strengthen the decision process in several ways, including by helping to define and frame the main elements of the decision. As shown in Figure 4-1, there are at least three points in the decision process where deliberative methods can be used to elicit community input and allow community residents to contribute their unique insights and expertise. First, these deliberative processes can provide policy makers with an initial sense of the public's concern and engagement in a WQS decision and, in so doing, suggest generally appropriate governmental responses. Second, after technical experts develop initial management options, deliberative methods can be used to provide a forum for community members to describe local resource use patterns and priorities, and then the management options could be refined for subsequent discussion and assessment.

Third, these methods can be used to develop and finalize conceptual models for the set of management options under consideration. For example, when holding a public meeting or using focus groups, the participants could help narrow the list of important services or provide important local knowledge about the study area. As described in Chapter 3, these models illustrate the links between affected ecological and human systems and compare, in descriptive terms, the expected ecological and human welfare effects of the different options.

In addition to providing structured approaches for eliciting community input on technical matters, deliberative methods also can be used to elicit and assess community preferences. That is, through organized group discussions such as public meetings or focus groups, they allow community members to express their preferred options (and the specific features of different options they prefer) and the strength of these preferences. The insights gained into community preferences and how they differ across stakeholder groups can help WQS decision-makers improve their understanding of the gains and losses and consequences associated with alternative management approaches.

Finally, deliberative methods offer the advantage of encouraging active community involvement in the decision-making process. When applied early in the process and used to address a controversial resource issue, this engagement of stakeholders can be critical for ensuring that the final decision is acceptable to the affected community.

4.1.1.2. *Analytic Sociocultural Methods*

Sociocultural methods also can elicit and assess community preferences for environmental decisions in the absence of direct deliberation and participation in the decision-making process. In brief, these analytic methods differ from deliberative ones in that data regarding community preferences are structured and analyzed by decision-makers without engaging in dialogue with stakeholders about the process followed. Analytic methods often are typified by a set of standardized and prescriptive methods for reducing data into specific answers to factual questions. These analytical approaches can be used when the options are particularly complex or community residents are unable or unwilling to arrive at a workable consensus in participatory formats. In these situations, certain social science methods can be used to describe the various scenarios available and provide residents the opportunity to indicate the preferred scenario. These methods have the advantage of providing decision-makers with a rigorous and structured set of responses on which they can base their selection of the final WQS management option. Surveys and referenda are examples of such analytic approaches that do not include deliberative or participatory approaches.

4.1.1.3. *Integrated Analytic-Deliberative Sociocultural Methods*

Although deliberative and analytical methods each can contribute independently to a sound analysis, some researchers have advocated decision-making processes that integrate both deliberative and analytic components into socioeconomic assessments. This argument, as well as the distinction between analytic and deliberative methods in general, is detailed in a report issued by the National Research Council (NRC, 1996) entitled *Understanding Risk: Informing Decisions in a Democratic Society*. Table 4-1 introduces several examples of these methods and lists the section number at the end of this chapter where a more detailed description of each method is provided. Focus group interviews or the Delphi method of preference elicitation are examples of methods that can be used to support participatory, deliberative decision-making as well as to provide data for use by social scientists to assess community preferences in subsequent analysis.

Some of these assessment methods can be used or adapted to support economic analyses. For example, multicriteria decision-making, referenda, and damage schedules can be used to collect, measure, and compare monetary values for different options; however, these methods do not necessarily include economic measures, and they are not necessarily or primarily based on the conceptual framework described in Section 4.2. For these reasons, they are not classified as economic assessment methods. Similarly, some of the methods classified as economic assessment methods can be used to gather preference information that is not expressed in monetary or economic terms. For example, conjoint analysis can be used to evaluate preferences in several dimensions, not just in terms of monetary trade-offs. These examples illustrate the fact that the two broad categories of social science methods—economic and sociocultural—are not necessarily mutually exclusive.

4.1.2. Economic Methods for Assessing Preferences and Socioeconomic Impacts

Economic analyses of environmental regulations and related policies are geared toward understanding (1) how society's resources, including its natural resources, are used or exchanged as a result of policy actions and (2) how human welfare (that is, human well-being) is affected by these uses or exchanges. Addressing the first issue requires, among other things, models of human behavior. Market modeling, which simulates the behaviors and interactions of producers and consumers (i.e., supply and demand) under alternative conditions, is one example of the types of tools economists use for this purpose.

Addressing the second issue related to effects on human welfare requires "normative" models. These are models that define measures of well-being and establish corresponding criteria for determining whether society is better off as a result of a policy. Two commonly used criteria in economic analyses are efficiency and equity.

The main questions underlying the efficiency criterion are whether and to what extent the gains to society (benefits) exceed the losses to society (costs) from a given policy. The most efficient policy is defined as the one for which the difference between benefits and costs (net benefits) is the greatest. The efficiency criterion is therefore also the basis for BCA (Arrow et al., 1996; Freeman, 1993; U.S. EPA, 2000). As discussed briefly in Chapter 2 of this report, BCA is a widely used economic analysis method for assessing the overall impact of a policy on society's well-being. It involves identifying, quantifying, and valuing the positive and negative impacts on society's well-being that result from policy changes.

The main questions underlying the equity criterion have to do with how the gains and losses are distributed across society (U.S. EPA, 2000). In particular, who are the "gainers" and who are the "losers" as a result of a policy? Analyses of equity impacts are also often focused on distinct subpopulations, such as disadvantaged or particularly vulnerable individuals. They examine how these groups of individuals are specifically affected by policies. In contrast to the efficiency criterion, for which there is a generally accepted core measure of human welfare effect (net benefits) and a main assessment method (BCA), there is no generally agreed upon measure of equity or a corresponding assessment method (although U.S. EPA [2000] provides a framework). Nevertheless, the process of developing and conducting BCA often requires separate estimation of different types and sources of benefits and costs, which also can be useful for informing equity concerns.

In practice, most economic assessment methods for evaluating environmental policies have been designed to support efficiency analyses and BCA. Actions taken to protect environmental quality (e.g., water quality) typically will involve both benefits and costs. By enhancing the flows of environmental services, they ultimately will have positive effects on human welfare (benefits). However, by diverting resources from other valued activities in order to control pollution, they also will have negative effects on human welfare (costs). In other words, the impacts of these actions, both the benefits and costs, ultimately will be experienced as changes in well-being for households/individuals. This idea is represented in simplified terms in Figure 4-2, which depicts interactions between three "systems:" household, market production, and environmental systems. Human welfare is shown as emanating from household systems because this is where individuals primarily reside. However, households also are closely connected with the other systems. They buy and sell goods, services, and labor through interactions with market systems. As described in detail in Chapter 3 of this report, they also receive important services from environmental/ecological systems. Moreover, some of the services from the environment are experienced indirectly by individuals through their

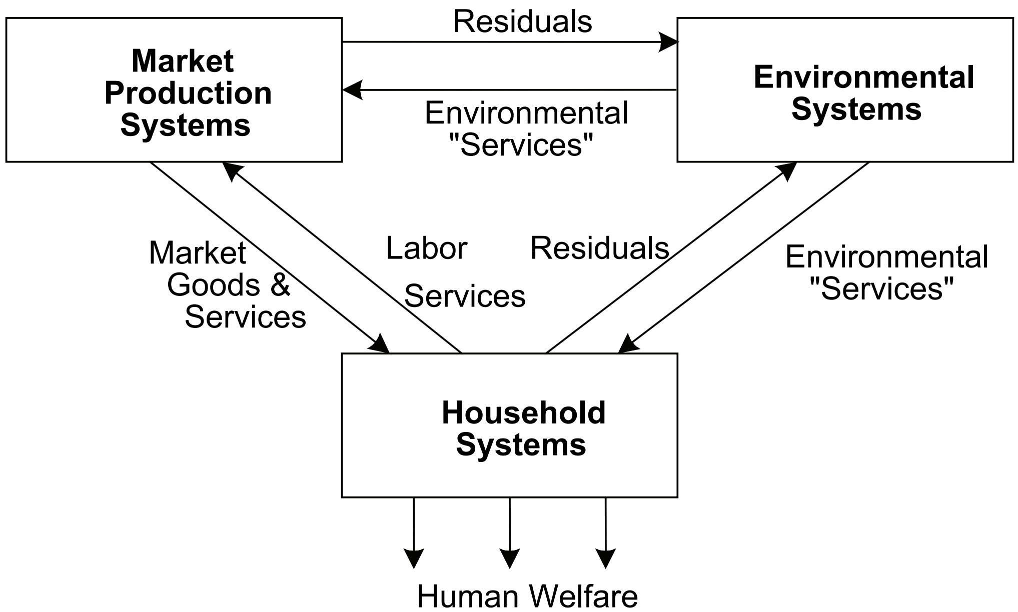

FIGURE 4-2

Interrelationships Between Market, Environmental, and Household Systems and Their Contributions to Human Welfare interactions in market systems. For example, aquatic ecosystems support commercial fishing and aquaculture, which are in turn sources of food and livelihood for individuals. Figure 4-2 also shows that potentially harmful residuals are released to the environment from both household and market production activities. To some extent, environmental systems can absorb and break down these residuals, which, as described in Chapter 3, is one of the important services provided by these systems. However, when releases of residuals exceed the absorptive capacity of the environment, they cause impairments in environmental systems and degrade the other services they provide.

One of the main challenges in applying BCA to evaluate environmental policies related to meeting WQS, is that it requires methods for expressing human welfare changes in money terms (see, e.g., Freeman, 1993). In certain instances, this process is relatively straightforward because the changes are experienced by humans as monetary gains or losses. For example, if producers are required to install systems that reduce pollutant loads to surface waters, these additional expenditures are likely to reduce their profits, which economists term their "producer surplus." The dollar value of these reductions in producer surplus is a measure of costs. Furthermore, if some of the expenses for installing these systems are passed on to consumers in the form of price increases, then it also reduces consumer welfare. The dollar value of these reductions is referred to as a change in "consumer surplus," and is also a measure of costs.

In other instances, welfare changes are not directly associated with monetary gains or losses. As discussed in Chapter 3, such "non-market" changes might, for example, include the welfare gains from improved recreational opportunities at a water body. In these cases a surrogate measure of gains or losses must be used. Economists and other practitioners of BCA generally accept "willingness to pay" (WTP) as the conceptually correct measure for valuing changes in individuals' welfare.[2] WTP is the maximum amount of money that an individual would be willing to pay for a specified change (i.e., what someone is willing to give up to receive something else). As such it is the monetary equivalent of the welfare gain from the change. For instance, if water quality changes improve fishing conditions at a lake, the anglers who use the lake experience an increase in well-being. The dollar value of this welfare change—

[2] Willingness to accept (WTA) is the minimum amount an individual is willing to accept to forego the change. Both WTA and WTP are correct measures for valuing changes. However, to simplify, we only use WTP in this report. Freeman (1993) provides information on the differences between WTA and WTP and how to choose the appropriate measure.

the benefit to anglers—can be expressed as the maximum amount they would be willing to pay for the change if they could only acquire it by paying. Notice that WTP is constrained by the individual's income.

Economists have developed a wide variety of methods for assessing these different components of human welfare changes associated with policy changes. Table 4-2 lists several commonly used economic assessment methods. These methods are geared mainly toward expressing these changes in a common metric (i.e., dollars) so that the benefit-cost trade-offs involved in policy making can be compared directly. In many instances, these methods also can be used or combined to address equity-related issues, by measuring how costs, benefits, and other economic impacts are distributed across the affected population.

TABLE 4-2

Summary and Comparison of Economic Assessment Methods: Key Characteristics

	Preference Elicitation	Preference Revelation	Other	Section Number With Detailed Description
Contingent Valuation	✔			4.17
Conjoint Analysis	✔			4.18
Hedonic Property Value		✔		4.19
Recreation Demand		✔		4.20
Averting Behavior		✔		4.21
Market Models			✔	4.22
Replacement/Restoration Cost			✔	4.23
Benefit Transfer			✔	4.24
Economic Impact Analysis			✔	4.25

Most of the economic methods developed for assessing the benefits (rather than the costs) of environmental policies are described as nonmarket valuation methods because they measure values for things that generally are not exchanged in markets. These methods can be classified broadly as either preference elicitation or preference revelation methods. The discussion below begins by describing these two general nonmarket valuation approaches and then describes other related economic assessment methods. Table 4-2 also distinguishes methods according to whether they are primarily preference elicitation (stated preference) or preference revelation (revealed preference) methods or whether they cannot be classified in this way ("other"). In addition, it lists the section number later in this chapter where a more detailed description of each method can be found.

4.1.2.1. *Preference Elicitation (Stated Preference) Methods*

These methods predominantly use surveys to elicit preferences from individuals. Although several different variations of these methods have been developed, most are similar to or fall broadly within two categories: contingent valuation (CV) and conjoint analysis. Because markets for changes in environmental quality typically do not exist, values for these changes cannot be measured directly from market prices and quantities. Stated preference surveys allow researchers to present respondents with hypothetical choices that are similar to market purchase decisions. One of the main advantages of these methods is that they give the researcher substantial flexibility for framing the choice and defining the change to be valued. Based on individuals' responses to these hypothetical scenarios, it is possible to directly elicit or to infer their WTP for the defined change. Another important advantage is that these methods are capable of capturing both use and nonuse values related to the defined changes. As discussed in Chapter 3, individuals may benefit from ecosystem services in ways that are unrelated to their use of the ecosystem. Nonuse values for these services are therefore not revealed in their use of the ecosystem, but they can be expressed in responses to stated preference surveys.

The main drawback of these preference elicitation methods is the difficulty of verifying whether respondents are providing truthful and accurate preference information. In some cases, respondents may respond strategically, either overstating or understating their WTP or choices if they perceive that they can favorably influence the policy outcome by doing so. In other cases, responses may be biased by the format or context of the questions or by the interviewer's technique. The hypothetical nature of the questions may result in responses that are not carefully thought out by respondents. Many of these limitations can be addressed at least partially through careful design and thorough pretesting of the stated preference survey instrument.

4.1.2.2. *Preference Revelation (Revealed Preference) Methods*

These methods use data on human behaviors in actual rather than hypothetical conditions to infer their values for specific changes. They assume that individuals always act to optimize their own welfare; therefore, their actions reveal how much they value things they cannot purchase directly. For example, by paying more for a home that is next to a less polluted water body, individuals reveal their value for cleaner water. To measure these values, hedonic property value methods are often used to estimate the specific effect that differences in local water quality have on housing prices. Another example is where individuals reveal their values for safer drinking water through purchases of water purifiers or bottled water. Averting behavior methods examine these types of behaviors to measure these values. In a third example, individuals who travel longer distances to recreate at sites with cleaner surface water reveal values for clean water. Recreation demand models examine these types of behaviors.

Although very useful for measuring nonmarket values, revealed preference methods also have a number of limitations. First, because they require data on actual behaviors, these methods offer researchers less flexibility than stated preference methods for framing the choice and defining the change to be valued. Second, because values are implied rather than directly expressed through these observed behaviors, more complex analytical methods often are required to measure values from revealed preference data. Third, revealed preference methods cannot be used to measure nonuse values for environmental resources because by definition these values are not revealed in individuals' use of the resources.[3]

4.1.2.3. *Other Economic Assessment Methods*

Conducting original stated or revealed preference analyses typically requires substantial time and resources. When it is not feasible to conduct a reliable stated or revealed preference study due to time and resource constraints or for other reasons, it may be possible to apply results

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[3] Some of the limitations of stated and revealed preference methods can be addressed by combining the two methods. See Adamowicz et al. (1994) and Kling (1997).

from existing studies to the new policy case, a practice called "benefit transfer." The accuracy of the benefit transfer method for estimating benefits depends on the quality of the original studies and the comparability of the study context with the policy context of interest. Some differences between the two contexts can be overcome by systematically adapting or adjusting the transferred estimates—for example, values may be rescaled to account for price inflation, differences in income, or differences in the size of the effect being evaluated—but this process generally introduces additional uncertainty.

Another method that sometimes is used for approximation in benefits assessment is to estimate avoided replacement/restoration costs. For example, if poor water quality causes damages to wetlands, then one of the benefits of improving water quality may be the avoided costs of restoring the affected wetlands. This type of valuation approach is relatively easy to implement, but it provides, at best, a crude approximation of the value humans attribute to the affected wetlands because it mixes costs and benefits (see, for example, Bockstael et al. [2000] or Section 4.23).

One method that potentially can assess both the benefits and costs resulting from environmental management options is the market models method. A market model simulates supply and demand conditions for a specific good (or service) and shows how the interaction between these two forces determines the market price for the good and the quantity of the good that is bought/sold over a specific time period.[4] More importantly, these models also can estimate how supply and demand conditions change (and prices and quantities adjust) in response to environmental policies. For instance, if the policy requires producers to make new expenditures (e.g., on pollution control equipment), market models can be used to assess the societal costs of the policy. These costs are measured as *reductions* in producer surplus and consumer surplus in the affected market(s). If the environmental resources improved by the policy also directly support market activities—for example, if the affected aquatic resources support commercial fishing—then market methods also can be used to measure specific benefits of the policy. These benefits are measured as *increases* in producer and consumer surplus in the affected market. By distinguishing between changes in producer and consumer surplus, market

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[4] Market models also can vary significantly in their scope and complexity. "Partial equilibrium" market models, which typically include one or perhaps a small number of related markets, commonly are used. In contrast, "general equilibrium" models represent multiple market interactions within an economy and are, therefore, less appropriate for estimating the societal costs of policies that target a small sector of the economy.

methods also can be used to examine the equity-related issues—i.e., how gains and losses are distributed between consumers and producers.

The market models method is designed to provide conceptually valid measures of human welfare changes, which are appropriate for use in BCA. In contrast, economic impact analysis methods are designed to measure policy-related changes in specific economic indicators, such as changes in expenditures and sales, employment levels, incomes, and tax revenues. Although these methods are commonly used to evaluate changes in local or regional economic conditions, they generally do not provide estimates that are directly applicable in BCA. For example, expenditures on fishing trips and related equipment are often used as an indicator of how much a water resource contributes to a local economy; however, these measures do not specifically capture changes in producer or consumer surplus, which are more appropriate measures of human welfare changes. Nevertheless, economic impact analyses can provide useful insights into the economic and equity implications of different actions, including how both positive and negative impacts are expected to be distributed across the affected community.

4.2. DATA COLLECTION TECHNIQUES FOR SOCIOCULTURAL AND ECONOMIC ASSESSMENTS

All the social science methods discussed in this chapter require one or more forms of data collection regarding the affected community. In many cases, they require primary data collection, which entails gathering original data directly from community members or stakeholders. In other cases, they require secondary data collection, which relies on existing sources of data. Several of the most commonly used methods for primary and secondary data collection are described below.

4.2.1. Primary Data Collection

For the purposes of this discussion, primary data collection techniques are grouped in the following four categories.

4.2.1.1. *Individual Interviews*

In individual interviews, answers are elicited from individuals one at a time either in person or over the phone (see, for example, U.S. EPA [2002]). Individual interviews can vary in many ways (such as format, question structure, and level of formality) depending on the desired results. This technique allows for in-depth analysis of topics of interest, such as a thorough description of the experiences and emotions tied to the recreational services provided by an aquatic ecosystem in the community. Speaking directly to individuals also allows for insights not garnered using other techniques. However, it is important to note that information gathered through an individual interview can be biased by a respondent's tendency to say what he or she thinks the interviewer wants to hear or by design flaws that can affect data quality. Adequate training of interviewers, pretesting of interview scripts, and a representative sample can limit these problems.

4.2.1.2. *Surveys*

Surveys are lists of predetermined questions presented to respondents in the form of a questionnaire. The survey may be physically handed to respondents, mailed, sent electronically, given in a group, or in some other way delivered to the respondent, the respondent typically interprets the items on the questionnaire without assistance from the researcher. Surveys can gather demographic information on the respondent as well as perceptions, opinions, values, and behaviors related to the ecosystem. This technique allows data to be gathered from a large number of respondents by a small number of researchers at a relatively low cost per response, providing more representative data than with other techniques. Surveys allow more complicated questions to be asked, such as those requiring repetitive questions used in rankings. The absence of interview bias and the anonymity of the respondent may provide more accurate information as long as the questionnaire is not flawed. The researcher has no control over how the respondent interprets the questions. The overall cost of surveys can be high, partially because of the need for the services of survey methodologists and other professionals adept at survey design and sampling. The entire process also can be time consuming, and there is always the potential of low response rates due to problems with the survey instrument design, delivery method, or the interest level of the population (for more information on surveys, see Dillman [1978]). In addition, if the views of those who complete the survey are systematically different from those who do not, response bias could affect the results.

4.2.1.3. *Group Deliberations*

Group interviews can be used to elicit community perceptions and to facilitate deliberations. They vary in the level of information provided to participants, the criteria by which group members are recruited, depth of the desired response, and the extent to which the group members interact. Group interviews allow information to be obtained from many people at one time and also allow individuals to modify their opinions based on feedback from other group members. This technique generally is not as time consuming as individual interviews. However, one or a few members of the group may dominate the conversation, not allowing the opinions of all group members to be expressed equally. Adequate training of group interview moderators can limit this problem. Consensus may be difficult or impossible to achieve in a group setting, although consensus is not always the goal.

4.2.1.4. *Observation*

Observation involves collecting data on the community through observing day-to-day activities and interactions rather than asking the community members directly, as researchers do during interviews (see U.S. EPA [2002]). This technique may provide unanticipated insights about the values and behavior of the community that may be useful in preparing interviews or surveys. It takes time to fully observe the community, and some behaviors are unobservable. Researchers may need insider knowledge (such as that elicited during interviews) to understand the motivations behind some behaviors.

4.2.2. Secondary Data Collection

A wide variety of secondary data sources also can be used to support and conduct socioeconomic assessments. Many forms of demographic and economic data are readily available through written and electronic sources, such as information available in town halls and libraries. Data collected by the Bureau of Census, which includes information on population, housing, and economic characteristics can be particularly useful for identifying and characterizing the potentially affected community. Data on property values and characteristics, recreational activities, and consumer expenditures and prices are available from a number of sources, and they can also provide useful insights into the behaviors, values, and preferences of community members. Geographic data, for example, information on buildings, roads, elevation, and the location of affected populations in relation to the physical landscape and other populations, also can be useful for characterizing and better understanding the community. These data can be represented in maps, which provide visual representations of the layout of the community, and they can be spatially linked to other data sources (e.g., through geographic information systems [GIS] techniques) to support more advanced analyses of community characteristics, behaviors, and preferences. In addition, published research findings regarding the community (or similar communities) often are available in journals, books, and fact sheets, and they also can serve as important secondary sources of information (additional information can be found in U.S. EPA [2002]).

4.3. SUMMARY AND COMPARISON OF SOCIAL SCIENCE METHODS

In Section 4.1, we identified 22 of the more commonly used sociocultural and economic assessment methods. This section provides additional descriptions and comparisons of these methods. At the end of this chapter, more detailed one-page descriptions are provided for each of the 22 methods.

Table 4-3 distinguishes the sociocultural and economic methods according to the types of data collection techniques that are most integral and most commonly used to apply these methods. As this table shows, most of the methods (and all of the sociocultural methods) require primary data collection. Although not specifically shown in the table, all of the methods can use secondary data productively; however, in most cases these data play a less prominent role than primary data. For example, demographic and economic data sources are often used as a first step in developing surveys or in structuring the make-up of an advisory committee.

As shown in Table 4-3, the primary data collection process most commonly employed is a key variable by which to differentiate the sociocultural methods described here. The mental model approach is the only sociocultural method described in this report that relies on data collected through individual in-depth interviews to develop the mental modeling coding scheme. The majority of the methods—public meetings, Delphi methods, multiattribute trade-off analysis, multicriteria decision-making, focus groups, advisory committees, and value juries—employ group discussions and deliberations to collect primary data for analysis. The Delphi method employs both group deliberations and surveys. The remaining sociocultural methods—opinion and attitudinal surveys, referenda, affective images, narrative, and damage schedules—

TABLE 4-3

Summary and Comparison of Social Science Methods: Main Data Collection Techniques Used

	Primary Data Collection			Secondary Data Collection			
	Individual Interviews	Surveys	Group Deliberations	Demographic Data	Economic Data	Geographic Data	Published Research
Sociocultural Assessment Methods							
Mental Model Approaches	✔						
Public Meetings			✔				
Delphi Method		✔	✔				
Multiattribute Trade-off Analysis			✔				
Multicriteria Decision-Making			✔				
Focus Groups Interviews			✔				
Advisory Committees			✔				
Value Juries			✔				
Opinion and Attitudinal Surveys		✔					
Referenda		✔					
Affective Images		✔					
Narrative		✔					
Damage Schedules		✔					
Economic Assessment Methods							
Contingent Valuation	✔	✔					
Conjoint Analysis		✔					
Hedonic Property Value				✔	✔	✔	
Recreation Demand		✔				✔	
Averting Behavior		✔		✔	✔		
Market Models				✔	✔		
Replacement/Restoration Cost					✔		
Benefit Transfer							✔
Economic Impact Analysis				✔	✔		

all rely on survey data. Finally, because all the sociocultural methods described in this report rely on preferences elicited from stakeholders, observations of relevant behaviors on the part of community residents may provide an important reality check on responses elicited, as well as suggest areas for further investigation. Prospective users of these methods would do well to review the section describing these various primary data collection strategies when deciding which method or methods to employ.

Most of these sociocultural methods provide strategies researchers can use to collect and reduce attitudinal and behavioral data into a set of discrete analytic units, or codes. These codes, often bundled under descriptive headings such as "recreational values" or "economic values," can create structure and order out of the complex assemblage of concerns and comments received from community members. To some extent, they allow for interpersonal comparison and generalization in the same way as economic indicators or other conceptual units operate in economic models. However, the coding schemes often differ from those used in economic methods in that many of these methods are by and large data-driven. That is, the collection of attitudinal and behavioral data precedes the development of the scheme by which the data are parsed and organized.

All of the economic assessment methods are inherently analytic, and in contrast to many of the sociocultural methods, they typically use little, if any, deliberative processes. Instead, many of the economic methods, in particular the preference elicitation techniques such as contingent valuation and conjoint analysis, require collecting data through surveys or, in certain circumstances, personal interviews. Also in contrast to the sociocultural methods, most economic assessment methods require some secondary data collection. For example, the hedonic property value method requires data on housing prices, housing characteristics, and local conditions, most of which can be acquired through existing data sources. Another example is the benefit transfer method, which by definition uses secondary data from existing economic studies.

Table 4-4 rates each of the sociocultural and economics methods according to cost/complexity which refers to the costliness and/or complexity of the method, in terms of time, data, and specialized technical skills required to implement it. This dimension is rated on a 5-point scale ranging from very low to very high. It must be noted that these ratings are subjective (based on the consensus of the report's authors) and require generalizations. Many of the methods can vary significantly in cost/complexity, depending on the context in which they are

TABLE 4-4 Summary and Comparison of Social Science Methods: Cost/Complexity					
	How Costly/Complex to Implement?				
	Very Low	Low	Moderate	High	Very High
Sociocultural Assessment Methods					
Mental Model Approaches			✔		
Public Meetings		✔			
Delphi Method		✔			
Multiattribute Trade-off Analysis					✔
Multicriteria Decision-Making				✔	
Focus Groups Interviews	✔				
Advisory Committees				✔	
Value Juries			✔		
Opinion and Attitudinal Surveys			✔		
Referenda		✔			
Affective Images			✔		
Narrative				✔	
Damage Schedules			✔		
Economic Assessment Methods					
Contingent Valuation				✔	
Conjoint Analysis					✔
Hedonic Property Value				✔	
Recreation Demand					✔
Averting Behavior		✔[a]			✔[b]
Market Models			✔		
Replacement/Restoration Cost		✔			
Benefit Transfer		✔			
Economic Impact Analysis		✔			

[a] Averting expenditure approach
[b] Household production approach

used and the level of resources devoted to applying the method. Nevertheless, these ratings are included here to provide the reader with a broad understanding of the relative advantages and disadvantages of the different methods. They are intended to help the reader gauge which methods might be applicable to his or her situation. More detailed descriptions and comparisons of the methods are provided below and in the descriptions at the end of this chapter. Additional references for the sociocultural assessment methods can be found in U.S. EPA (2002) and additional details on the economic assessment methods can be found in Mäler and Vincent (2005) and Champ et al. (2003).

4.4. MENTAL MODEL APPROACHES

Type	Sociocultural Assessment Method
Description	Mental model and other cognitive mapping approaches have been used in a variety of environmental management contexts. In contrast to opinion polls (Section 4.12), which require that respondents answer fixed questions, the protocols used in a mental model interview allow participants to express themselves in their own terms. All participants discuss a common set of issues but are given substantial flexibility to focus on those issues of greatest concern. The primary goal is to identify those factors that most influence how a person thinks about the issues at hand and why different people may agree or disagree about what matters most or about preferred options.
Advantages	The techniques of mental mapping are flexible and user-friendly, in that the interviewer follows a script but is allowed to vary from this to the extent that the participant wants to discuss some items in more detail. Models also can be revised easily to incorporate new ideas that develop over the course of discussions and can be adapted to reflect the views of individuals, groups, or communities at large. Results are transparent and easily lend themselves to visual communication (through drawings of personal perceptions).
Disadvantages	The flexibility of a mental map can also be a liability, in that the information obtained from participants can range widely and, thus, provide less help than expected in terms of the actual decisions facing policy makers. Mental models involve relatively small numbers of participants to provide a picture of how people think about a policy option and why: they provide neither a number (i.e., for valuation purposes) nor a quantitative comparison of alternatives. Mental models also require that the terms and language used by participants is carefully defined to ensure that models accurately reflect the views of those interviewed and misunderstandings do not occur. To our knowledge, the technique has not yet been used to study community preferences for water quality.

4.4. MENTAL MODEL APPROACHES cont.

Type	Sociocultural Assessment Method
Outcomes	The outcome of a mental model process is an improved understanding of the factors determining people's thinking about the issue. One example is an expert model, which loosely follows the form of an influence diagram showing how key management actions are linked to measures of system performance. The model provides a visual tool for showing which variables are considered to be relevant and how these variables are connected. The technique is compatible with either qualitative analyses (e.g., through visual use of arrows showing pathways that link variables) or quantitative analyses (e.g., where knowing the value of the variable at the tail would influence estimates of the variable at the head).
Example	Morgan et al. (2002) used a mental models approach to study public understanding of global climate change. Interviews revealed confusion about the meaning of basic terms (e.g., climate change, greenhouse effect) and misconceptions about the physical mechanisms underlying global climate change (such as a confusion between ozone depletion and climate change and a lack of emphasis on carbon dioxide emissions). Respondents' views on the likely effects of climate change were more accurate. Gregory et al. (2003) used mental model interviews to develop a formal expert model of the factors determining the impacts of various transmission rate structures for electricity and the influence of the regulatory process producing these effects; this work facilitated the development of proposals that were technically sound and widely accepted.
References	Gregory, R., B. Fischhoff, S. Thorne and G. Butte. 2003. A multi-channel stakeholder consultation process for transmission deregulation. Energ. Policy 31:1291-1299. Morgan, G., B. Fischhoff, A. Bostrom and C. Atman. 2002. Risk Communication: A Mental Models Approach. Cambridge University Press, New York, NY.

4.5. PUBLIC MEETINGS

Type	Sociocultural Assessment Method
Description	In this method, a forum of community members meets to discuss issues or make decisions. The gathering is often highly structured. Attendees are allotted a specific amount of time to speak and may even prepare their statements beforehand. Researchers observe meetings to gain insight on the community. A facilitator runs the meetings while a recorder takes notes.
Advantages	Data are collected from large numbers of people at one time and can be particularly enlightening in terms of intra- and intersegment perceptions and concerns. The open-ended format allows people to express an array of views and sentiments on a specific topic.
Disadvantages	Unequal contribution by individuals may lead to some ideas dominating over others, resulting in a discussion not reflective of the group's values as a whole. Mediation of large groups can be difficult. Comments often range outside the scope and deal with broader issues. Interpreting people's comments may be problematic.
Outcomes	Conducting public ("town hall") meetings can be used as a communication tool while also allowing community members to sense that they are part of the project. Meetings can inform different steps of a project, from conveying problems that need action to informing the public of decisions that have been made and gaining feedback. Transcripts of the meeting may be consulted even if the researcher is not in attendance at the meeting.
Example	McComas (2003) describes the responses of participants in a series of public meetings in upstate New York who were debating the expansion of an existing solid waste landfill and remediation of an adjacent waste site. These responses also are compared with those of nonattendees in terms of comparative changes in risk perceptions and the credibility ratings of experts.
References	Cole, R.L. and D.A. Caputo. 1984. The public hearing as an effective citizen participation mechanism: A case study of the general revenue sharing program. Am. Polit. Sci. Rev. 78:405-416. McComas, K.A. 2003. Public meetings and risk amplification: A longitudinal study. Risk Anal. 23(6):1257-1270.

4.6. DELPHI METHOD

Type	Sociocultural Assessment Method
Description	The Delphi method is a structured, iterative process using questionnaires (filled out individually by each group member) to elicit consensus on a topic from a group of knowledgeable experts or community members. Experts or stakeholders are encouraged to revise their recommendations based on summary responses from the rest of the group.
Advantages	Different views of the issue are incorporated, progressing toward an agreement that systematically addresses all opinions. Anonymity can be maintained to persuade all members of the group to express their opinions, thus eliminating some of the problems associated with face-to-face group meetings.
Disadvantages	Which experts or stakeholders to include is not always apparent and can vary depending on how the issue is defined. Consensus is not always possible. This method can be time consuming depending on the number of iterations. Some respondents may drop out before all iterations are complete, thus affecting the validity of the results.
Outcomes	This method produces organized data in the form of questionnaire responses from multiple respondents. A consensus on the issue is the ultimate goal of the Delphi method.
Example	A Delphi survey of expert opinion on reservoir fisheries was used to aid in river basin reservoir management of the water resources claimed by both Georgia and Alabama.
References	Taylor, J.G. and S.D. Ryder. 2003. Use of the Delphi method in resolving complex water resources issues. J. Am. Water Resour. Assoc. 39(1):183-189.

4.7. MULTIATTRIBUTE TRADE-OFF ANALYSIS (MATA)

Type	Sociocultural Assessment Method
Description	Multiattribute trade-off analysis (MATA) methods facilitate trade-offs across the different ecological, economic, health and safety, and social objectives associated with alternative actions. Applications of MATA differ from multicriteria decision-making (Section 4.8) in terms of the emphasis on values elicitation through a sequence of steps to help participants understand their objectives in the context of a management problem and to use this information in selecting a preferred action. These steps include structuring the problem, defining key objectives, developing performance measures (attributes) for these concerns, estimating the anticipated consequences and associated uncertainty of actions in terms of the objectives, and evaluating alternatives in terms of their ability to satisfy the expressed objectives.
Advantages	MATA techniques highlight the multiple values held by different stakeholder groups. They provide decision-makers with information on these varied perspectives and the likely sources of support for, or opposition to, a policy. They are transparent, facilitate the involvement of multiple participants through use of a level playing field, and are well supported by both theory and practice. In the context of community-based water quality choices, MATA methods can be used to facilitate structured dialogue and understanding among participants with diverse backgrounds.
Disadvantages	Use of MATA can force stakeholders to break an issue down into too many discrete elements and, thus, lose sight of how some elements are interrelated. Practitioners also need to be aware that the approach carries with it a specialized vocabulary and that more quantitative applications (i.e., a “full” MATA, as opposed to a partial MATA), therefore, carry the risk of alienating participants who are more comfortable with qualitative approaches to valuation.
Outcomes	Multiattribute methods can be used to provide quantitative measures of the value placed on an environmental action, or they can be used to help structure community objectives and management or policy alternatives. The focus is on developing insights about preferred options, rather than developing a number (e.g., for use in a benefit-cost analysis); often, this type of “value-focused” help in framing a choice and ranking options is what decision-makers need to make more informed decisions about different levels of water quality or other environmental choices.

4.7. MULTIATTRIBUTE TRADE-OFF ANALYSIS (MATA) cont.

Type	Sociocultural Assessment Method
Example	Borsuk et al. (2001) used decision analytic methods to model nutrient management problems in the Neuse River (North Carolina) as part of an effort to reduce undesirable environmental conditions in the lower river and estuary. The main focus of the study was to link scientific models, expressed in terms of biophysical variables such as dissolved oxygen, to the economic, social, and procedural concerns of stakeholders. Construction of a probabilistic model relates proposed management actions to stakeholder interests by showing anticipated changes in the conditional values of endpoints. Gregory and Keeney (1994) used the value-focusing aspects of multiattribute methods to provide insight to decision-makers about the environmental, economic, and social concerns of stakeholders in the context of a proposed mining development that would alter a relatively pristine forest environment. This information was then used to help create novel and widely accepted management alternatives. Keeney et al. (1996) describe the use of the fundamental values of decision-makers to guide long-term wastewater planning at Seattle Metro, a major utility district. Multiattribute value assessment methods were used to elicit the objectives of decision-makers and provided a basis for quantitative evaluation of alternatives based on identifying the key trade-offs.
References	Borsuk, M., R. Clemen, L. Maquire and K. Reckhow. 2001. Stakeholder values and scientific modeling in the Neuse River watershed. Group Decis. Negot. 10:355-373. Gregory, R. and R. Keeney. 1994. Creating policy alternatives using stakeholder values. Manage. Sci. 40:1035-1048. Keeney, R., T. McDaniels and V. Ridge-Cooney. 1996. Using values in planning wastewater facilities for metropolitan Seattle. J. Am. Water Resour. Assoc. 32:293-303. Ohlson, D., T. Berry, R. Gray, B. Blackwell and B. Hawkes. 2006. Multi-attribute evaluation of landscape-level fuel management to reduce wildfire risk. For. Pol. Econ. 8:824-837.

4.8. MULTICRITERIA DECISION-MAKING (MCDM)

Type	Sociocultural Assessment Method
Description	Multicriteria approaches have been developed to examine the performance of different alternatives when compared with multiple objectives. The aim is to incorporate the value judgments of those considered to be legitimate participants into the assessment of management options; economic objectives (such as efficiency) or ecological ones (such as sustainability) will be incorporated only to the extent that they matter to decision-makers in the specific decision context. The theoretical basis for multicriteria decision-making (MCDM) approaches is well established and similar to that of other multiattribute methods (such as multiattribute trade-off analysis, Section 4.7).
Advantages	The main advantage of MCDM (or other multiattribute) approaches, including well-known methods such as the analytical hierarchy process (AHP), is their ability to provide direct insight into the selection of preferred environmental management options in terms of the factors important to decision-makers. The basic techniques (e.g., use of ratio scales) are quite user-friendly, the general approach is transparent, and the logic can be clearly shown in either verbal or mathematical terms.
Disadvantages	The validity of an MCDM is only as good as the selection and definition of objectives (i.e., to what extent have analysts faithfully captured and described the concerns of decision-makers?) and the choice of relevant alternatives (e.g., involving the use of criteria to screen unrealistic options or those outside the mandate of the preference elicitation process). MCDM approaches also can be viewed by community participants as overly quantitative and reductionist.
Outcomes	By combining information on preferences and on probabilities, MCDM approaches assign a utility function to different outcomes so that decision-makers should prefer the alternative that shows the highest expected utility. MCDM approaches have been applied to environmental management contexts involving the choice among different strategies for dealing with environmental and economic risks under conditions of substantial uncertainty.
Example	Ananda and Herath (2003) used AHP methods as an aid to stakeholder involvement in developing forest management policies in Australia that could address the complexity and uncertainty associated with policy options. The use of AHP helped incorporate stakeholder preferences by making explicit some of the primary multidimensional gains and losses decision-makers faced.

4.8. MULTICRITERIA DECISION-MAKING (MCDM) cont.

Type	Sociocultural Assessment Method
References	Ananda, J. and G. Herath. 2003. The use of analytic hierarchy process to incorporate stakeholder preferences into regional forest planning. Forest Policy Econ. 5:13-26. Saaty, T. 1991. Multicriteria Decision-Making: The Analytic Hierarchy Process. RWS Publishers, Pittsburgh, PA.

4.9. FOCUS GROUP INTERVIEWS

Type	Sociocultural Assessment Method
Description	In this method, a small group of people (typically 7 to 12) discuss topics presented by a moderator. Multiple focus groups often are conducted on the same topic. The meeting structure is highly organized with the purpose of obtaining detailed information on the topic of interest. Once the topic of the focus group has been determined, community members are chosen based on predetermined criteria (such as members of a cultural subgroup or age range). Focus group questions are typically simple and open-ended; moderators use the same questions for each set of focus group interviews on the topic. A focus group moderator asks the questions during the interview and is responsible for ensuring that the group stays on task.
Advantages	Many aspects are controlled by the researcher, including the topics discussed and the members of the group. However, flexibility not provided in a structured questionnaire is present, allowing in-depth discussion of certain topics. Specifically, interactions and discussions among participants can reveal important social dynamics, issues, and preferences that might be missed with individual interviews or surveys.
Disadvantages	A researcher skilled in moderating focus group interviews is needed to monitor the meetings. Opinions are derived from only a small group of people who may not represent the opinions of the community. Even if the focus group is carefully chosen to represent the community, outspoken participants may dominate the meeting and not allow the views of all participants to be spoken. Focus group interviews require a large amount of effort and funds for planning, conducting the meetings, and analyzing the results.
Outcomes	Results from the focus group are used as an approximation of the opinions of the community. This method can be used to develop survey instruments or inform planning for other methods. Results of the focus group interviews are documented in notes and/or audio or videotapes of the meeting, making them available for future reference. If multiple focus groups are conducted, a report summarizing and combining the results from all meetings may be useful.
Example	Desvouges and Smith (1988) discuss the use of focus groups as an aid to communicating risks, including the exploration of risk perceptions and the design of risk-mitigation policies. They explore the use of focus groups in a study of the use of risk ladders to elicit the perceived risk from hazardous waste exposure.

4.9. FOCUS GROUP INTERVIEWS cont.

Type	Sociocultural Assessment Method
References	Desvousges, W. and V.C. Smith. 1988. Focus groups and risk communication: The "science" of listening to data. Risk Anal. 8:479-484. Krueger, R.A. 1994. Focus Groups: A Practical Guide for Applied Research. 2nd ed. Sage Publications, Thousand Oaks, CA.

4.10. ADVISORY COMMITTEES

Type	Sociocultural Assessment Method
Description	Advisory committees consist of a group of people chosen to guide a project on the behalf of another group, such as the community affected by the project. Members interact with one another, potentially modifying their own ideas based on the input from other group members. The composition of an advisory committee can be iterative, adding people after one or two sessions to fill identified gaps.
Advantages	Members of a well-chosen advisory committee can provide perspective on the community's position on an issue, such as whether the community is likely to accept or reject a water management decision. Committees that are truly representative, including members of the sponsoring agencies and scientists as well as community representatives, can be extremely helpful.
Disadvantages	Scheduling a time that all committee members are available to meet may be difficult, especially if the committee is made up of community leaders. Staying on topic and reaching a consensus can be problematic and time consuming. If the advisory committee does not represent all views or subgroups of the community, it may be necessary to employ additional methods to determine these other viewpoints.
Outcomes	Advisory committees may guide the entire project or specific elements of a project. For example, an advisory committee may help plan a public meeting, review a draft survey instrument, or recommend a management policy from a list of alternatives.
Example	Gregory and Wellman (2001) discuss the use of structured facts- and values-based elicitations from the members of a representative advisory committee (as well as community participants) as part of their description of a multiattribute methodology used at the Tillamook Bay national estuary program site. An evaluation workbook was developed that provided insight to decision-makers about the management choices favored by participants and the key gains and losses across objectives that led to these choices.
References	Gregory, R. and K. Wellman. 2001. Bringing stakeholder values into environmental policy choices: A community-based estuary case study. Ecol. Econ. 39:37-52. MacRae Jr., D. and D. Whittington. 1997. Expert Advice for Policy Choice Analysis and Discourse. Georgetown University Press, Washington, DC.

4.11. VALUE JURIES

Type	Sociocultural Assessment Method
Description	Value juries and so-called "science courts" are a relatively new approach to evaluating environmental services. Modeled after the widely recognized jury system, the approach seeks to allow participants the time and information needed to understand a complex environmental issue and to make informed judgments about proposed policy or regulatory actions. As in a court of law, stakeholders are given the opportunity to hear opposing views and often to question witnesses, either directly or through a representative (i.e., equivalent to a defense or prosecution lawyer).
Advantages	Value juries follow a familiar and widely respected element of our society; as a result, they tend to carry substantial legitimacy and support. The approach works well as a way to develop a more informed citizenry, particularly when the environmental issue is complex, and it can also facilitate dialogue between scientists or agency representatives and less technically trained community members. Output can be tailored to the specific policy needs of decision-makers, resulting either in rankings of alternative options or detailed information about the reasons why participants favor or oppose specified plans.
Disadvantages	The successful conduct of a citizen value jury requires that people are able to set aside the time (often 2 or 3 days) needed to engage in such deliberations and that funds are available to bring in the requisite experts. This is sometimes difficult, particularly since participation usually is voluntary and can be viewed as a time-consuming nuisance (in contrast to court cases, which are mandatory and broadly seen as a citizen responsibility). Also, the results of citizen juries typically take the form of recommendations and have no legal standing, which can frustrate participants in those cases where politicians or other decision-makers may override the jury's recommendation.
Outcomes	The usual outcome of a value jury is a decision to proceed or halt a proposed environmental action. In some cases, value juries also have been used to help set damage awards, for example, in the case of stakeholders harmed by pollution.
Example	Brown et al. (1995) set out the conditions and requirements for using value juries as an aid to making defensible resource management decisions. The approach has been used to study a variety of environmental problems, including land management and water conservation options in Colorado.
References	Brown, T., G. Peterson and B. Tonn. 1995. The values jury to aid natural resource decisions. Land Econ. 71:250-260.

4.12. OPINION AND ATTITUDINAL SURVEYS

Type	Sociocultural Assessment Method
Description	Opinion surveys can involve either verbal or written questionnaires. They have been widely used to report how people think about environmental and water quality risks and have received broad coverage in the popular press. Usually, opinions are provided about the relative importance of a potential ecological improvement or damage (e.g., in comparison with other environmental problems or other health, social, or economic issues) or the influence of components of environmental concerns rather than as quantitative responses. One application of attitudinal surveys is to study the perceptions of ecological risks, in which psychometric techniques make use of specified characteristics underlying participants' psychological responses to develop a profile of how participants think about an environmental risk.
Advantages	Opinion surveys can be relatively inexpensive to administer and the results are user-friendly and easily understood by a wide range of citizens. Opinion surveys also can be fine-tuned to address the specific policy questions of concern to decision-makers, and both the level of detail and the number of participants (which, in turn, has implications for the statistical validity of results) can be varied.
Disadvantages	Opinion survey results depend greatly on specific and often highly specialized aspects of how questions are asked in terms of concerns such as wording, order, and (intentional or unintentional) emotional cues. Results do not reflect detailed evaluative information and often are limited to a single dimension of a problem (e.g., costs, risks). Little time is provided for thinking through a more complex problem and, as a result, responses often are uninformed and colored by judgmental biases (e.g., anchoring and availability) or cues introduced by the interviewer or questionnaire. Because the opinions provided usually are those of an individual, little opportunity is provided for dialogue or discussion with peers.
Outcomes	Rankings of environmental or economic concerns associated with water quality, for example, may show how important a proposed action is compared to other alternatives or focus on the reasons why a proposed environmental action is supported or opposed. Psychometric techniques probe subjects' reasons for thinking a potential source of environmental change is either benign or worrisome and the implications for regulations or other management options.

4.12. OPINION AND ATTITUDINAL SURVEYS cont.

Type	Sociocultural Assessment Method
Example	McDaniels et al. (1997) examined lay and expert perceptions of the ecological risks associated with human activities that could adversely affect water resources. Psychometric techniques are used to characterize human health risks in terms of specified characteristics; these underlying factors, including benefits, knowledge, and controllability, explain a great deal of the variability in lay judgments about ecological risks and their perceptions of the need for regulation or specific actions.
References	McDaniels, T., L. Axelrod, N. Cavanagh, P. Slovic and R. Dunlap. 1997. Perception of ecological risk to water environments. Risk Anal. 17:341-352. Schuman, H. and S. Presser. 1996. Questions and Answers in Attitude Surveys. Sage Publications, Thousand Oaks, CA.

4.13. REFERENDA

Type	Sociocultural Assessment Method
Description	Many different types of referenda or voting procedures have been used to estimate values for water quality and other environmental services. In a typical case, the residents of an area are asked to vote for or against a proposed action that is described in terms of its anticipated benefits, costs, and risks. A vote in favor of the action means that the person values the initiative, for example, an improvement in water quality in a local river, at least as highly as the cost he or she is asked to sacrifice.
Advantages	Referenda are commonly used and are viewed as a familiar approach to valuation. The problem context can be described in some detail, alternative policies can be provided (e.g., people can be asked to vote yes or no for one option or they can be asked to vote for their favorite among many actions), and it is relatively easy to compare results across different time periods. In contrast to most survey techniques, referenda often involve large numbers of people, thus lending themselves easily to statistical analyses and having the potential to provide a genuinely representative point of view.
Disadvantages	As with other questionnaires, a referendum is subject to biased interpretation as the result of question order or wording or the presence of accompanying information (e.g., photos, intentionally leading descriptions). Because of the large numbers of people involved, referenda can be quite expensive to undertake. Referenda also can take many forms, from carefully structured approaches to more casual questions, so it can be difficult to interpret whether the results of a vote should be considered legitimate.
Outcomes	A common outcome is an understanding of the percentage of people who favor or are opposed to the described action(s).
Example	McDaniels (1996) used a structured referendum, based on the techniques of decision analysis, to examine the choice among three options for treating sewage from the mid-sized coastal city of Victoria, Canada. Based on the results of small-group discussions, all three options were described in terms of their anticipated impacts on environmental, health, aesthetic, and economic objectives. About 34,000 voters participated in the actual referendum, in which the status quo (no treatment) option was identified as the preferred risk management scheme.

4.13. REFERENDA cont.

Type	Sociocultural Assessment Method
References	Magelby, D. 1984. Direct Legislation. Johns Hopkins University Press, Baltimore, MD. McDaniels, T. 1996. The structured value referendum: Eliciting preferences for environmental policy alternatives. J. Policy Anal. Manage. 15:227-251. McDaniels, T. and K. Thomas. 1999. Eliciting preferences for land use alternatives: A structured value referendum with approval voting. J. Policy Anal. Manage. 18:264-280.

4.14. AFFECTIVE IMAGES

Type	Sociocultural Assessment Method
Description	The positive and negative images associated with policy options can be used to gain insights about why, and to what extent, people value different environmental and water quality actions. Questionnaires using these images are particularly helpful when people's perceptions reflect poorly understood fears, hopes, and worries that may correctly or incorrectly be associated with a proposed initiative.
Advantages	Images are easy for people to work with and it is not difficult to elicit responses. The approach is relatively inexpensive to implement and can readily yield useful information about some of the factors likely to influence community feelings about a proposed environmental management initiative.
Disadvantages	The ease of responding to affective images can lead to problems because the gut-level responses may easily be biased or they may refer to a broader set of issues and concerns than the ones supposedly under consideration. Thus, it may be difficult to tie the results of an image-based survey to the specific policy question or initiative under study.
Outcomes	The usual outcome of an image-based survey is a ranking of the various possible components that might underlie perceptions of the merit of an initiative. Such rankings, for example, on a 1 to 7 scale from "least" to "most," can provide a useful understanding of the affective and cognitive reactions that underlie responses to a proposed action.
Example	Slovic et al. (1991) used images associated with people's negative perception of nuclear risks to demonstrate how the siting of a nuclear repository could lead to negative economic and social impacts. The approach linked perceptions of risk, stigmatization, and the potential for socially amplified reactions to images of the site and to how participants' expressed psychological and attitudinal responses could affect behavioral variables such as employment, tourism, and retirement decisions.
References	Loewenstein, G., C. Hsee, E. Weber and N. Welch. 2001. Risk as feelings. Psychol. Bull. 127:267-286. Slovic, P., M. Layman, N. Kraus, J. Flynn, J. Chalmers and G. Gesell. 1991. Perceived risk, stigma, and the potential economic impacts of a high-level nuclear waste repository in Nevada. Risk Anal. 11:683-696.

4.15. NARRATIVE

Type	Sociocultural Assessment Method
Description	Narrative methods use the familiar act of telling stories as a way to provide a useful perspective on understanding community preferences for water quality or other environmental concerns. Often using the first person, narrative approaches set the decision context by telling about or quoting an individual's experience, often comparing past to current conditions, and then asking participants to either report their emotional response (e.g., after reading a selected passage) or to engage in a valuation exercise.
Advantages	The advantage of a narrative approach is that it is familiar and can help capture the more affective dimensions of an environmental valuation problem, thus having the potential to help decision-makers gain a more complete understanding of the relevant value dimensions. Stories also occupy a central place in many nonscientific and nonwestern cultures, so narratives can prove to be particularly effective when community stakeholders include aboriginal representatives (e.g., Native Americans) or participants from nonwestern cultures.
Disadvantages	Although there is a strong theoretical basis for including narratives as an approach to understanding community attitudes, there are few practical rules to help the analyst in setting up an effective or defensible narrative context. This is problematic because the down side of narration's ability to tap into emotions is its ability to bias; thus, different stories generally will lead to different evaluations, and frequently there is little normative basis for selecting a preferred narrative context. In addition, making a link between attitudes expressed using narrative approaches and policy-relevant values can be difficult.
Outcomes	The result of a narrative judgment can take the form of a ranking or rating attitudinal expression, which then can be linked to values through a paired comparison (Section 4.16) or willingness-to-pay or other judgment task. These attitudes and valuations are based on the context established as part of the narrative description of the problem and can be designed to emphasize different aspects of the management context.

4.15. NARRATIVE cont.

Type	Sociocultural Assessment Method
Example	Satterfield et al. (2000) used narrative techniques to examine participants' responses to proposed environmental policy changes involving trade-offs between hydroelectric power production and salmon populations in a river. Modified narrative story techniques were compared with more utilitarian descriptions of the problem, such as those that might be used as part of a contingent valuation context. Narrative techniques were shown to be better able to help participants consider relevant value information and apply this knowledge to a complex policy environment; the authors conclude that this is in part due to the ability of story-based methods to more fully capture the affective and emotional dimensions of many environmental policy contexts.
References	Satterfield, R., P. Slovic and R. Gregory. 2000. Narrative valuation in a policy judgment context. Ecol. Econ. 34:315-331. Shanahan, L., L. Pelstring and K. McComas. 1999. Using narratives to think about environmental attitude and behavior: An exploratory study. Soc. Natur. Resour. 12:409-419.

4.16. DAMAGE SCHEDULES

Type	Sociocultural Assessment Method
Description	Damage schedules use surveys that present respondents with a relatively simple judgmental mechanism of paired comparisons to provide estimates of the gains and losses and relative (not necessarily monetary) value of various nonmarket ecological services and/or natural resource damages. The resulting rating "schedules" are similar to those used by the courts in personal injury cases, for example, to establish the relative value of nonpecuniary losses associated with different injuries.
Advantages	Provides an accessible and easily understood mechanism for estimating the relative value of nonmarket environmental services or natural resource damages. The judgmental task of making paired comparisons of value is relatively easy and the parallel with standard "workmen's compensation" and other procedures lends legitimacy to the approach. The method does allow internally consistent judgments from selected participant groups to be linked to policy responses, incentives, and proposed compensation or mitigation options.
Disadvantages	The resulting damage schedule is limited to the specific resource losses, services, and/or policy options included in the analysis. Therefore, the results may be difficult to generalize to other losses, services, and policy options.
Outcomes	A schedule that provides a scale for the relative value of different resource losses, services, and policy responses based on structured input from community members.
Example	Chuenpagdee et al. (2001) used damage schedules to help determine the relative value of potential environmental and economic losses to important fisheries habitats in Thailand. Both expert and lay participants were asked to make paired-comparison judgments that, in turn, helped develop a schedule of sanctions, restrictions, and damage awards that provided a measure of the relative importance of different water-based environmental resources and provided input into feelings about proposed changes in their availability and quality.
References	Chuenpagdee, R., J. Knetsch and T. Brown. 2001. Environmental damage schedules: Community judgments of importance and assessments of losses. Land Econ. 77:1-10.

4.17. CONTINGENT VALUATION (CV)

Type	Economic Assessment Method
Description	Contingent valuation (CV) uses survey questions to elicit individuals' values, in monetary terms, for specified "commodities" (e.g., goods, services, or changes in conditions) that are typically not available for purchase in existing markets. To make up for the absence of an existing market, this method presents respondents with a hypothetical situation in which they have the opportunity to buy the commodity. CV surveys usually consist of three main parts: • a detailed description of the "commodity" and a hypothetical set of circumstances under which it could be purchased • questions to elicit the maximum amount individuals would be willing to pay for the commodity, and • questions about respondents' characteristics or opinions, which might influence or be related to their WTP (e.g., income, age, concern about stormwater runoff).
Advantages	The CV method is very flexible and can be adapted to estimate individuals' values, in monetary terms, for a wide variety of commodities. It is particularly useful for measuring values for "nonmarket commodities," such as improvements in environmental conditions, which are typically not available for individuals to purchase. It is also particularly useful for capturing nonuse values (i.e., values that are not associated with individuals' use of or interaction with the commodity). Compared with conjoint analysis (Section 4.18), it is also particularly useful for measuring values for commodities when one is interested in the value of the commodity as a whole, rather than values for different subcomponents of the commodity. It is also useful when the commodity to be valued is relatively unfamiliar to the respondent and, therefore, requires significant introduction and description.
Disadvantages	The values expressed through CV surveys are difficult to validate because they are based on hypothetical scenarios. The values may also be influenced by the way in which the survey is constructed and administered. WTP estimates can be biased (overstate or understate true WTP) if survey participants act strategically in their responses or if they inadvertently respond differently, depending on how the commodity or CV scenario is presented to them. These potential biases can best be avoided through careful, well-researched design and extensive pretesting of the survey instrument.

4.17. CONTINGENT VALUATION (CV) cont.

Type	Economic Assessment Method
Outcomes	CV survey data can be used to estimate how WTP for the defined commodity varies across the studied population and how it depends on characteristics of the population. Depending on how the survey is constructed, it also may provide information on how WTP varies with respect to different levels or features of the commodity. These values can be used to quantify (in monetary terms) and directly compare the benefits (and/or costs) of defined changes resulting from, for example, watershed management policies.
Example	In one of the pioneering applications of the CV method, Smith and Desvousges (1986) administered a survey to a random sample of adults in southwestern Pennsylvania and elicited their WTP for three defined changes in water quality in the Monongahela River: (1) preventing water quality from falling to below-boatable levels, (2) improving water quality from boatable to fishable levels, and (3) improving water quality from fishable to swimmable levels. Their analysis provides average WTP estimates for each type of change, for both users and nonusers of the water resource.
References	Bateman, I.J., R.T. Carson, B. Day et al. 2002. Economic Valuation with Stated Preference Techniques: A Manual. Edward Elgar, Ltd., Northampton, MA. Mitchell, R.C. and R.T. Carson. 1989. Using Surveys to Value Public Goods: The Contingent Valuation Method. Resources for the Future, Washington, DC. Smith, V.K. and W.H. Desvousges. 1986. Measuring Water Quality Benefits. Kluwer-Nijhoff, Boston, MA.

4.18. CONJOINT ANALYSIS

Type	Economic Assessment Method
Description	Conjoint analysis uses surveys to estimate the relative importance and value that individuals associate with different attributes of a commodity. For this method, a commodity is defined strictly in terms of its main components—a list of attributes. For example, a house would be described strictly according to its features, such as its age, size, number of rooms, and distance to local amenities. A conjoint survey presents respondents with commodities that differ only in the levels of each attribute that are present (e.g., a 15-year-old house that has six rooms and is 2 miles from a school or a 50-year-old house that has eight rooms and is 3 miles from a school). It asks respondents to compare and state their preferences for the described commodities. It then uses the survey responses to infer preferences and values for the separate attributes of the commodity. Like contingent valuation (Section 4.17), it can be used to estimate dollar values for commodities and/or attributes that are typically not available in existing markets, such as the various environmental changes resulting from a watershed management policy.
Advantages	The conjoint analysis method is very flexible and can be adapted to estimate individuals' values for a wide variety of commodities and attributes. It can be used to estimate the relative importance of and trade-offs individuals are willing to make among different attributes of a commodity. Consequently, it is particularly useful for measuring preferences for commodities that have multiple attributes and for nonmarket commodities. Conjoint surveys usually present respondents with a series of commodity choices; therefore, they can be used to collect extensive preference information from each respondent. In principle, they also can be used to estimate values for commodities or attributes that include nonuse values.
Disadvantages	The values expressed through conjoint surveys are difficult to validate because they are based on comparisons of hypothetical commodities. Designing an appropriate conjoint instrument typically requires specialized technical expertise and extensive pretesting of the instrument. Because conjoint surveys ask respondents to compare commodities with multiple dimensions (attributes), they are less appropriate when the individual attributes being evaluated are themselves complex and difficult to describe to respondents. Estimating monetary values based on conjoint survey data also requires specialized technical expertise.

4.18. CONJOINT ANALYSIS cont.

Type	Economic Assessment Method
Outcomes	Conjoint data can provide estimates of WTP and individuals' rates of trade-off for a wide variety of attributes and commodities, and it can be used to estimate how these values and trade-offs depend on characteristics of the population. These estimates can be used to quantify and directly compare the benefits (and/or costs) of multiple changes resulting from, for example, watershed management policies.
Example	Conjoint methods have been used to estimate values for regional changes in several dimensions of water quality (Magat et al., 2000; Viscusi et al., 2004). Using a computer-based instrument, respondents from across the country were asked to compare communities (the "commodity") that differed with respect to the following attributes: (1) cost of living, (2) percentage of waters safe for fishing, (3) percentage of waters safe for swimming, and (4) percentage of waters that support aquatic life. Analysis of the survey data provided WTP estimates for percentage changes in each of the water quality attributes.
References	Bateman, I.J., R.T. Carson, B. Day et al. 2002. Economic Valuation with Stated Preference Techniques: A Manual. Edward Elgar, Ltd., Northampton, MA. Louviere, J., D. Hensker and J. Swait. 2000. Stated Choice Methods: Analysis and Application. Cambridge University Press, New York, NY. Magat, W.A., J. Huber, W.K. Viscusi and J. Bell. 2000. An iterative choice approach to valuing clean lakes, rivers, and streams. J. Risk Uncertainty. 21(1):7-43. Viscusi, W.K., J. Huber and J. Bell. 2004. The value of regional water quality improvements. Discussion Paper No. 477. The Harvard John M. Olin Discussion Paper Series.

4.19. HEDONIC PROPERTY VALUE

Type	Economic Assessment Method
Description	The hedonic property value method uses data on housing prices and attributes of properties to decompose prices and estimate separate values for each of the property attributes. These attributes typically include structural characteristics (e.g., lot size, square footage, number of rooms), but they can also include various neighborhood and local amenity or environmental characteristics.
Advantages	The hedonic property value method uses data resulting from human behaviors in existing, well-established markets rather than from hypothetical market scenarios. It can be used to estimate households' WTP for small changes in a wide variety of local conditions (including environmental conditions) as long as these conditions differ to some extent across the properties used in the analysis, can be measured in quantitative terms, and can be observed or perceived by home buyers.
Disadvantages	This method requires extensive and rather specialized data, which may not be available for the area or issue of interest. Moreover, conducting the data analysis and estimating appropriate monetary values requires specialized technical expertise. For example, this method provides a set of marginal WTP coefficients on each explanatory variable (i.e., the marginal WTP for a unit increase in water quality improvement) which is not trivial to take and estimate a total WTP for a community contemplating a large change in water quality. It cannot be used to estimate nonuse values because these values are not reflected in (i.e., capitalized into) property values.
Outcomes	Hedonic property value analyses can provide estimates of individuals' WTP for changes in local conditions, including the level of environmental quality and the provision of local public services, amenities, and disamenities. These estimates can be used to quantify and directly compare the benefits (and/or costs) of multiple changes resulting from, for example, watershed management policies.
Example	The hedonic method has been applied in several studies to estimate values for changes in local water quality conditions. Using local housing prices and attribute data for properties near specific water bodies, these studies have found that prices are positively related to water quality measures, such as the clarity (visual depth) of the water. The measured effect of water quality on housing prices provides an estimate of local households' average WTP for improvements in water quality.

4.19. HEDONIC PROPERTY VALUE cont.

Type	Economic Assessment Method
References	Boyle, K.J., P.J. Poor and L. Taylor. 1999. Estimating the demand for protecting freshwater lakes from eutrophication. Am. J. Agri. Econ. 81(November):1118-1122. Leggett, C. and N. Bockstael. 2000. Evidence of the effects of water quality on residential land prices. J. Environ. Econ. Manage. 39(2):121-144. Palmquist, R.B. 2005. Property value models. In: Handbook of Environmental Economics, Vol. 2: Valuing Environmental Changes. K. Mäler and J.R. Vincent, Eds. Elsevier, New York, NY. p. 763-820.

4.20. RECREATION DEMAND

Type	Economic Assessment Method
Description	Recreation demand methods use data on observed recreation behaviors to estimate individuals' demand and values for specific recreational resources. They also are used to estimate how demand and values are affected by the characteristics of the available resources (including environmental quality) and of the studied population. In these models, the price of recreation is measured as the dollar value of time and other spending required to travel to the resource.
Advantages	Values from recreation demand methods are based on actual human behavior rather than stated behaviors from a hypothetical context. They are useful for measuring values for recreational services from natural resources and for measuring how these values depend on the environmental quality and other characteristics of the resources.
Disadvantages	This class of methods often requires extensive and rather specialized data. Data on human behavior and characteristics must usually be collected through surveys and then matched with other data on the characteristics of the recreational resources. Moreover, conducting the data analysis and estimating appropriate monetary values requires specialized technical expertise. Models that include all of the relevant recreation choices (i.e., whether, where, when, and how often to recreate) can be particularly complex to estimate. Linking recreation demand WTPs to water quality levels can also be complex; WTP estimates must range across the water quality levels and researchers must have enough data to control for other variables. Recreation demand methods can be used to estimate only those values associated with recreational activities; therefore, for example, it cannot be used to estimate nonuse values. Estimated values often are very sensitive to the modeling assumptions, such as the assumed dollar cost assigned to travel time.
Outcomes	Recreation demand methods can be used to estimate the value individuals' receive from having access to specific recreational resources (i.e., recreation sites). They also can provide estimates of how these values are affected by changes in the characteristic of the resources (including environmental quality) and by the characteristics of the individual as well. These estimates can be used to quantify and directly compare the recreation-related benefits (and/or losses) of changes to recreational resources resulting from, for example, watershed management policies.

4.20. RECREATION DEMAND cont.

Type	Economic Assessment Method
Example	Recreation demand modeling has been applied in several studies to estimate recreation-based values for changes in water quality conditions. Using a variety of survey methods to collect data on recreation behaviors and personal characteristics, and combining with data on water quality conditions at potential recreation sites, many studies have found an association between recreation choices and water quality. Based on individuals' observed trade-offs between time of travel to recreation sites (cost) and experiencing better water quality (benefits), these studies estimate the value associated with better water quality. For example, Parsons and Hauber (1998) estimated a recreation site choice model for freshwater anglers in Maine, and using this model, they estimated benefits to anglers of cleaning all Maine lakes to meet EPA standards.
References	Parsons, G.R. and B. Hauber. 1998. Spatial boundaries and choice set definition in a random utility model of recreation demand. Land Econ. 74(1):32-48. Phaneuf, D.J. and V.K. Smith. 2005. Recreation demand models. In: Handbook of Environmental Economics, Vol. 2: Valuing Environmental Changes. K. Mäler and J.R. Vincent, Eds. Elsevier, New York, NY. p. 671-762.

4.21. AVERTING BEHAVIOR

Type	Economic Assessment Method
Description	To protect themselves from environmental risks, individuals often engage in behaviors to reduce their exposures. Averting behavior methods study these behaviors to measure individuals' values for reducing these risks. Simpler versions of these methods measure how much is spent on these behaviors and how these expenditures vary with respect to external conditions (averting expenditure methods). In certain cases, observing how much individuals reduce their averting expenditures in response to an improvement in the quality of their tap water may not be a good estimate of their WTP to improve their tap water (e.g., if WTP includes pain and suffering or change in productivity losses). More complex versions also measure the extent to which these behaviors reduce individuals' risks (household production methods).
Advantages	Values estimated with these methods are based on actual human behavior rather than stated behaviors in a hypothetical context. They are particularly useful for measuring values for reducing potentially harmful environmental exposures to humans. The simpler averting expenditure methods can be relatively easy and inexpensive to implement because they mainly require information on how much individuals spend on these behaviors (e.g., bottled water purchases) in relation to environmental conditions, whereas the more complex behavior methods provide more exact measures of WTP because they include estimates of how these behaviors affect exposures and risk.
Disadvantages	Although relatively inexpensive, the simpler averting expenditure methods do not provide very accurate estimates of WTP to reduce risks. The more complex averting behavior methods provide more accurate estimates of WTP; however, they require more extensive and specialized data and more complex analysis methods to estimate WTP. Averting behavior methods are useful in situations where individuals actively engage in the behaviors and it is possible to measure the dollar cost of these behaviors. Also, if these behaviors produce other benefits (e.g., bottled water provides better tasting as well as safer water), then it is much more difficult to use these methods to specifically isolate values for reducing harmful exposures. Finally, values based on these methods assume that subjects have a reasonably good understanding of what is being averted. If risks are not well understood, then averting behaviors may not give a good indication of value.

4.21. AVERTING BEHAVIOR cont.

Type	Economic Assessment Method
Outcomes	Averting behavior methods can provide estimates of the value individuals place on reducing potentially harmful or damaging environmental exposures, including damages to health or property. They also can provide estimates of how these values are affected by personal characteristics. These estimates can be used to quantify and directly compare the benefits (and/or losses) of changes in environmental exposures resulting from, for example, watershed management policies.
Example	Averting expenditure methods have been used widely to estimate losses that could be avoided by preventing drinking water contamination. For example, Collins and Steinback (1993) surveyed almost 900 households in rural West Virginia with wells that tested positive for bacteria and other contaminants. They estimated average costs for filtering/treating or using alternative sources of water ($42 in 2004 dollars). This value is best interpreted as a lower-bound estimate of the average household's value for eliminating the observed contamination. Unfortunately, no applications of the more complex household production methods are reported in the literature estimating values for reduced water contamination.
References	Abdalla, C.W., B.R. Roach and D.J. Epp. 1992. Valuing environmental quality changes using averting expenditures: An application to groundwater contamination. Land Econ. 68:163-169. Collins, A.R. and S. Steinbeck. 1993. Rural household response to water contamination in West Virginia. Water Res. Bull. 29:199-209. Dickie, M. and S. Gerking. 1991. Valuing reduced morbidity: A household production approach. South. Econ. J. 57(3):690-702.

4.22. MARKET MODELS

Type	Economic Assessment Method
Description	This method measures changes in consumer surplus and producer surplus in markets affected by specific policies or changes in environmental conditions. When these policies or changes in environmental conditions directly affect production costs or the demand for specific market goods/services, then producers and consumers in the market experience gains or losses. This method estimates these gains and losses by modeling the market (i.e., price and quantity) adjustments that occur as a result of such a change.
Advantages	This method uses observed behaviors in actual markets to infer values for things that are not exchanged in markets (e.g., environmental quality changes). It is particularly useful when the nonmarket changes to be evaluated are strongly linked to an existing market, either because they directly affect the production costs or the demand for the market good or service. The method can be applied using existing data on prices and quantities in the affected market. Once the market model is established, measuring consumer and producer surplus changes is relatively straightforward.
Disadvantages	The method can be used only to estimate gains or losses that are experienced through the modeled market. Estimating the supply and/or demand relationships in the market and how they are affected by changes in environmental conditions can require specialized technical expertise. The method is considerably more complicated if the market to be modeled is not competitive or is affected by external price or quantity controls.
Outcomes	The method provides estimates of consumer surplus and/or producer surplus changes in an affected market. These dollar estimates can be directly compared or added to other benefits or cost estimates resulting from, for example, watershed management policies.
Example	Anderson (1989) modeled the market for Virginia hard-shell blue crabs using available market data for the period 1960 to 1987 and also estimated the effect of changes in seagrass habitat on supply conditions. Using this model, he estimated the changes in producer surplus for commercial crabbers and changes in consumer surplus for consumers of blue crabs that would result from policies to restore seagrass habitat.
References	Anderson, E. 1989. Economic benefits of habitat restoration: Seagrass and the virginia hard-shell blue crab fishery. N. Am. J. Fish. Manage. 9:140-149.

4.23. REPLACEMENT/RESTORATION COST

Type	Economic Assessment Method
Description	This method estimates losses associated with environmental degradation as the costs of replacing, restoring, and/or repairing damaged ecosystems or physical property. Correspondingly, it measures gains from environmental improvements as the replacement/restoration costs that would be avoided.
Advantages	The method requires less data, resources, and specialized expertise than most other economic valuation methods. The method is most appropriate when there is a high likelihood that the assumed replacement/restoration activities will occur as a result of damage. If individuals are willing to incur the expenses to repair the damages, it implies the value they associate with the damage is equal to or greater than these expenses (otherwise they would not voluntarily incur the expense). In other words, it implies that the replacement/restoration costs are a lower-bound estimate of actual losses.
Disadvantages	The method often requires strong assumptions about the types of changes humans would make as a result of environmental degradation. In particular, it assumes that specific restoration/replacement activities would occur in response to the degradation (e.g., flood-damaged properties would be repaired or replaced). If it is not actually known whether these activities are likely to occur, then the method is less appropriate because the costs of the activities will provide little information about individuals' values or preferences.
Outcomes	The method typically estimates the number of relevant units that are damaged (e.g., acres of wetland or number of homes) and the average cost of replacing or restoring the unit based on available market prices. The product of these two components provides an estimate of total damages.
Example	Ragan et al. (2000) used this method to estimate the benefits of reducing the salinity in the water supply in the Arkansas Valley of Colorado. The benefits were measured as the avoided costs to households of repairing and replacing appliances that are damaged by high salinity levels.
References	Ragan, G.E., R.A. Young and C.J. Makela. 2000. New evidence on the economic benefits of controlling salinity in domestic water supplies. Water Resour. Res. 34(4):1087-1095.

4.24. BENEFIT TRANSFER

Type	Economic Assessment Method
Description	This method relies on results from existing economic studies to estimate the benefits of improving environmental conditions and/or ecosystem services. It adapts and transfers value estimates from the location or context of the existing studies and applies these estimates to the policy location or context of interest.
Advantages	This method generally requires little if any primary data collection; therefore, it is relatively inexpensive to apply. It does not require the same level of technical expertise that is typically required for conducting original stated or revealed preference analyses. It generally is most appropriate for providing rough or first-cut benefits estimates when time and resources are limited. It also is most appropriate when value estimates are available in the literature, are of good quality, and measure values for changes and contexts that are similar to the policy changes and context of interest.
Disadvantages	Benefit transfers rely entirely on what is available in the existing literature, and they are directly limited by the quality and accuracy of the existing results. They also are limited by the amount of relevant data and information reported in the existing studies. They are less reliable and appropriate when there are significant differences between the context of the existing studies and the policy context of interest. Values based on benefit transfer also may be viewed as less acceptable by community members, if the estimate that is used is derived from elsewhere and is transferred to their situation.
Outcomes	Most benefit transfers use information from existing studies to estimate an average "unit value" (e.g., value per fishing day, per acre of wetland, per health effect avoided). These unit values are then multiplied by corresponding estimates of the number of units that change as a result of the policy to estimate the aggregated benefits of the policy.
Example	Morgan and Owens (2001) used results from an earlier study (Bockstael et al., 1989) to estimate the aggregate benefits of observed improvements in Chesapeake Bay water quality. Bockstael et al. previously used revealed and stated preference methods to estimate average WTP per person (beach users, boaters, and bass fishers) for a 20% improvement in Bay water quality. Morgan and Owens rescaled these estimates to apply to a 60% improvement and multiplied them by updated estimates of the number of beach users, boaters, and bass fishers.

4.24. BENEFIT TRANSFER cont.

Type	Economic Assessment Method
References	Bockstael, N.E., K.E. McConnell and I.E. Strand. 1989. Measuring the benefits of improvements in water quality: The Chesapeake Bay. Mar. Res. Econ. 6:1-18. Brander, L., R. Florax and J. Vermaat. 2006. The empirics of wetland valuation: A comprehensive summary and a meta-analysis of the literature. Environ. Resour. Econ. 33(2):223-250. Morgan, C. and N. Owens. 2001. Benefits of water quality policies: The Chesapeake Bay. Ecol. Econ. 39(2):271-84. Rosenberger, R. and J. Loomis. 2003. Benefit transfer. In: A Primer in Nonmarket Valuation, P. Champ, K. Boyle and T. Brown, Eds. Kluwer Academic Publishers, Norwell, MA.

4.25. ECONOMIC IMPACT ANALYSIS

Type	Economic Assessment Method
Description	This method is designed to measure policy-related changes in specific economic indicators, such as changes in expenditures and sales, employment levels, incomes, and tax revenues. It rarely has anything to do with preferences or welfare as interpreted in economics; rather, this method measures indicators such as expenditures/sales, profits, and employment in sectors of the economy that are directly related to the resource. Economic impact models vary in geographic scope (e.g., local, state, and/or region) and the number of different economic sectors included; however, they are usually based on assumed "input-output" (I/O) relationships between the selected sectors. They begin by measuring direct effects (i.e., changes in the economic indicators for the sector most directly affected by the program or policy). They then use the assumed I/O structure to measure indirect effects (i.e., changes in economic indicators for other sectors, in particular those that buy from or sell to the directly affected sector). They also measure induced effects (i.e., changes in the economic indicators that result from changes in income and, thus, expenditures) by households.
Advantages	The data and analytical requirements for this method are typically low compared with other methods. The resulting estimates are easy to communicate and interpret.
Disadvantages	The economic indicators used in this method are often not conceptually valid measures of preferences or human welfare. For example, expenditures/sales provide a gross measure of economic activity, which does not account for the direct or indirect costs associated with the activity. These methods also usually do not measure how the economic indicators are related to the extent or quality of the resource. Moreover, the I/O structures used in these models are usually quite rigid and do not account for changes in market prices or how these price changes are likely to affect market transactions. For these reasons, economic impact models are generally not used in BCA.
Outcomes	Aggregate measures of changes in economic activity related to a specific program or policy, or aggregate measures of economic activity in sectors directly related to a natural resource.
Example	The Greeley-Polhemus Group (2001) conducted a study for the Maryland Department of Natural Resources that estimated expenditures on recreational activities and commercial values of coastal properties for the coastal bays in Worcester County, MD.

4.25. ECONOMIC IMPACT ANALYSIS cont.

Type	Economic Assessment Method
References	The Greeley-Polhemus Group, Inc. 2001. An Assessment of the Economic Value of the Coastal Bays' Natural Resources to the Economy of Worcester County, Maryland. Final Report. Prepared for the Maryland Department of Natural Resources.

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5. WORKING THE PROCESS: BUILDING AN APPROACH FOR COMMUNITIES TO UNDERSTAND THE ECOLOGICAL RISKS, COSTS, AND BENEFITS OF WATER QUALITY MANAGEMENT DECISIONS

In this report, we describe a process for WQS that is designed to help decision-makers understand the full environmental, economic and social implications of alternative water quality goals. It emphasizes community involvement throughout the decision process and provides a general framework for evaluating the relevant gains or losses. Each of the previous chapters played a specific role in describing and developing the decision process. For example, we connected the process to the analysis of whether attaining the use is "feasible" under 40 CFR 131.10, or whether changing the current use in an AR is necessary for important economic or social development under 40 CFR 131.12(a)(2). Questions that may trigger the process for a UAA might be what are the benefits of attaining a use that is not currently being attained? Or, for an AR, the relevant question might be, if we allow the degradation being considered, what are the damages (e.g., lost ecological benefits) produced? Because the process required complying with the current regulatory framework, we introduced the CWA and WQS regulation in order to provide some context (Chapter 2). To link use-attainment decisions and their effects on ecosystems, we suggested using expanded conceptual models based on concepts from ecological risk assessment, stressor identification, and socioeconomic analyses (Chapter 3). Finally, we described and compared various social science methods that could either provide quantitative or qualitative information to support the decisions (Chapter 4).

The purpose of this chapter is to provide a concise description of how the proposed approach can be implemented in practice, using the methods and tools described in the previous chapters. The decision process is illustrated again in Figure 5-1. This figure outlines the same steps described in Figure 4-1; however, it emphasizes three main phases: (1) framing the WQS decision, (2) comparing the advantages and disadvantages of the different management options, and (3) making the decision (selecting the option).

This chapter is organized according to these three phases. For each phase, it describes the main components of the process and the techniques that can be used to address each component. It also uses two of the hypothetical case studies described in Chapter 3—the combined sewer overflow (CSO) example and the acid mine drainage (AMD) example—to illustrate specifically

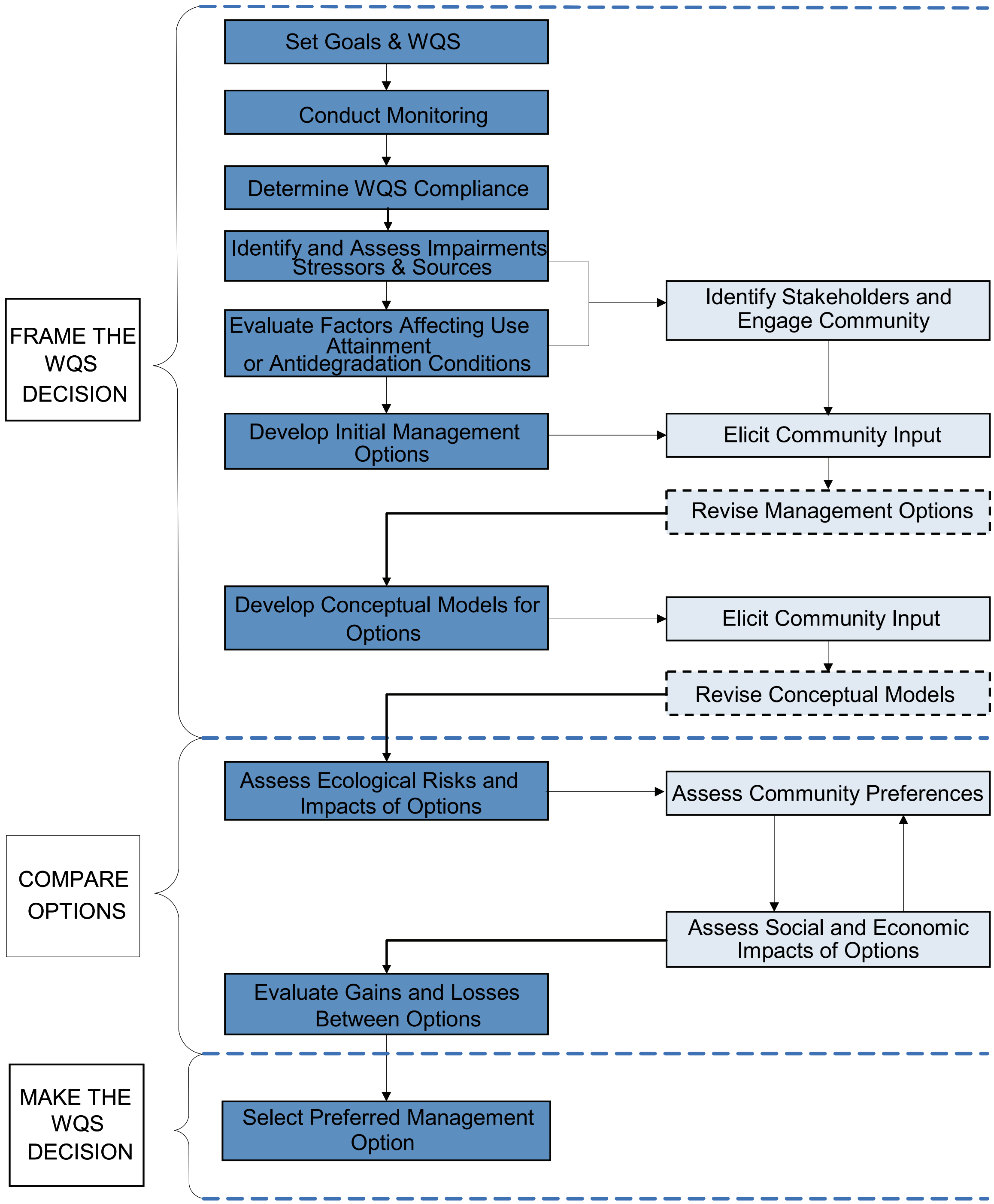


FIGURE 5-1

Three Phases of the Decision Process Framework how the methods and tools described in the previous chapters can be applied to inform and strengthen each stage of the decision-making process.

The proposed decision process described in Figure 5-1 and the example applications described in this chapter were developed using input from invited participants who attended a workshop sponsored by U.S. EPA/Office of Research and Development/National Center for Environmental Assessment on November 14–15, 2006. The objectives of the 2-day workshop were to (1) critically examine and develop recommendations for revising an earlier draft of this report (Chapters 1 through 4), (2) employ hypothetical case studies of use-attainment problems to evaluate a draft decision process and (3) hold discussions with practitioners and stakeholders to develop recommendations for incorporating community preferences into water quality management decisions. The workshop brought together 20 experts from various parts of U.S. EPA, from state and local organizations, and from RTI International.[1] A roster of participants and the workshop agenda are provided in Appendix C. It is important to emphasize that the decision process and methods described in this chapter represent the authors' best efforts to incorporate a wide variety of recommendations and opinions expressed during the workshop; however, they do not necessarily fully reflect the views of each participant.

5.1. FRAMING THE WQS DECISION THROUGH COMMUNITY INVOLVEMENT

As illustrated in Figure 5-1, the first phase of the decision process involves framing the relevant decision. This means identifying the key water quality impairments, along with the related sources and stressors, and determining the set of feasible options available for addressing the impairment. It also means recognizing and engaging community residents in initial discussions of how they are likely to be affected by both the impaired water and the options available for addressing the impairment. As discussed below, group deliberative methods can be used in several ways to involve the community in framing the decisions, including (1) identifying community priorities, concerns, and constraints; (2) revising and defining the most practical set of management options; and (3) revising and finalizing conceptual models that illustrate the key linkages between environmental conditions and human welfare and the gains and losses involved in the decision-making process.

[1] RTI International is a trade name of Research Triangle Institute.

5.1.1. Identifying Key Stakeholders and Engaging the Community

Involving community stakeholders early in the decision-making process using deliberative approaches can help identify and explain unexpected barriers or benefits to specific management options. It also can begin the important process of establishing a rapport and gaining the trust of community residents and stakeholders. This initial stage of community involvement can be a two-way communication process whereby decision-makers introduce the WQS problem and decision-making process to the public and residents in turn can provide information on local conditions, priorities, and perspectives. By selecting a broad base of community representatives early in the process, decision-makers can make the WQS process more acceptable to the community as a whole and engage those who may feel less informed about or less qualified to address the issues at hand. At this stage, rather than recruiting specific stakeholder input from the community, decision-makers should be providing an organized and accessible conduit for decision-makers and community members to introduce themselves and present their perspectives going into the process. The level of public participation is likely to vary throughout the process; therefore, this initial stage can serve to identify stakeholders who are particularly invested in the WQS decision and who are most likely to play an active role in subsequent stages of the process. It also can help identify issues of particular concern to all community residents.

5.1.1.1. *The AMD Case Study Example*

In this hypothetical case study example, which is described in detail in Section 3.4.3.1, drainage from abandoned surface mines has caused serious impairments in 3 miles of a tributary stream and 8 miles of a river. These impairments have reduced the size and variety of ecological services available from these water bodies, in particular recreation and aesthetic services for local residents and for recreational boaters, hikers, and anglers. For reasons described in Chapter 3, the focus of the UAA is on options that control AMD discharges to the tributary.

Even before an initial set of management options has been defined, group deliberative methods can be used to engage the community and to begin framing the decision in a way that is understandable and hopefully acceptable to the affected community. In this case, the main stakeholders are likely to include local landowners, recreationists, watershed protection groups, local government, and local businesses.

Because the affected geographic area and the size of the immediately affected population are relatively small, holding one or two public meetings within the local community may be adequate as an initial step. These meetings, which by definition are open to the public, can be used in several ways. First, they can be used to present the findings of environmental and ecological assessments to the community. The information conveyed in this setting would include descriptions of the AMD sources, the types of water quality impairments resulting from these sources, the requirements and goals of the WQS program in relation to these impairments, and the factors affecting use attainment. Second, the meetings would provide stakeholders with an opportunity to identify themselves, to state their own objectives and concerns, and to provide their own perspectives and knowledge regarding the AMD-related impairment. For example, it might allow local land and business owners to describe their main experiences with AMD-related impairments and what their expectations are regarding clean up. Third, public meetings can be used to identify individuals who are willing and best positioned to serve on an advisory committee. In this case, one or two individuals from each stakeholder group might volunteer or be selected to serve as representatives on the committee, which would have a more regular and active role in the next phases of the decision-making process.

5.1.1.2. *The CSO Case Study Example*

In this hypothetical case study example, which is described in detail in Section 3.4.3.2, the water quality of a large river is impaired by pollution for CSOs. An interstate Basin Commission is responsible for improving water quality of this river, which flows through multiple states and is currently not attaining water quality standards for primary contact recreation during wet weather. The Basin Commission must determine the best way to address the nonattainment of the designated use. First, stakeholders and other interested parties should be identified. Stakeholders include those who use the river for recreation, derive a value from the existence or aesthetics of the river, and/or would be affected by higher sewer rates. Potential stakeholders include local communities, recreationalists, states, local businesses, economic development groups, and watershed groups. Public meetings could be used to inform stakeholders of the problem, to present potential solutions, to obtain feedback about the options, and to begin to determine community preferences. The location and announcement of these meetings should be targeted toward key stakeholder groups, and the meetings should be easy for them to attend and offer a variety of methods for providing their input. It is important to determine if the meeting is successful at getting information from the targeted stakeholders. If not, other methods should be considered to reach the stakeholders who were not represented.

5.1.2. Identifying and Defining the Most Relevant Management Options

Community residents' knowledge of local conditions and resource uses can be invaluable in the initial process of refining the prospective management options for application in a specific setting. Specialized knowledge of local conditions and constraints (both physical and social) may help decision-makers in an initial assessment of the management options. First, community residents can identify barriers that preclude the application of certain management options. These may include local conditions, patterns of resource use, or just strongly held local attitudes. Second, community residents can identify factors that might facilitate the use of certain management options with minor adaptations to better fit the local conditions or needs of the community. Finally, community residents can identify completely new management options.

As with the prior phase in the WQS process, the deliberative methods described in Chapter 4 are particularly useful for eliciting input from the community regarding the various management options under consideration. The deliberative process has the added advantage of providing decision-makers with key insights into underlying values and perspectives that shape the preferences expressed by community residents, which are discussed further in Section 5.2. Analytical approaches could play an important role at this phase, for example, if the management options are particularly complex or community residents are unable or unwilling to arrive at a workable consensus in participatory formats.

5.1.2.1. *The AMD Case Study Example*

In this case study, the state has initially determined, based primarily on environmental and engineering analyses, that two main management options are available for addressing the AMD-related impairments to the tributary and the river—a limestone channel or a constructed wetland. Before assessing community preferences for these options, it may be useful to use group deliberative methods to acquire other types of community input (see Table 4-1). For example, through their participation in an advisory committee (Section 4.10), individuals with specialized knowledge of local conditions may be able to suggest adaptations of the limestone channel that would make it less of an eyesore to local homeowners. Similarly, they might be able to identify ways of adjusting the placement of the wetland that would increase its attractiveness to local recreationists, without decreasing its effectiveness for addressing AMD discharges.

5.1.2.2. *The CSO Case Study Example*

Based on an assessment of sources, stressors, and impairments and factors affecting use attainment, and with initial input from the community, the interstate Basin Commission described in this case study proposed two feasible alternatives to address nonattainment of the river for primary contact recreational use. Option 1 will attain the primary contact recreational use eliminating 95% of the CSO structures, in addition to other upgrades with an estimated three-fold increase in sewer rates. Option 2 will attain a wet weather limited use subcategory for primary contact recreation by eliminating 75% of the CSO structures; this would require a 50% increase in sewer rates.

At this stage, group deliberative techniques could be used in several ways to elicit input from the community on the set of feasible management options. For example, public meetings (Section 4.5) with local communities and watershed groups might lead to suggestions for ways to reduce stormwater flow, which would decrease the number of CSO events and improve water quality. Such reductions might be accomplished by residents installing rain gardens and/or cisterns to capture runoff from their roofs during storm events instead of allowing it to flow into combined sewers. This option would require widespread implementation to be effective and would not address runoff from roads and commercial and industrial properties.

Similarly, public meetings involving local businesses and economic groups might lead to additional options, such as an off-line underground storage facility that could store excess runoff during storm events and be released for treatment during dry weather. These groups might believe that this type of option would cause less disruption of service/business and also might achieve the 75% reduction in CSOs.

To examine the feasibility of the proposed options, the Commission could then form an advisory committee, based on the groups represented at the public meetings (and any additional groups that were identified). This committee could, for example, include representatives from the local communities (residents and businesses), state governments, and water quality scientists.

5.1.3. Developing and Refining Conceptual Models of Management Options

In this phase of the WQS process, the specialized knowledge offered by community residents may help decision-makers refine the conceptual models of the various management options under consideration. These diagrams depict, in qualitative terms, the fundamental relationships between pollution sources, ecosystem processes, and human welfare, and they illustrate how the management options alter these relationships (see Section 3.4). Thus, they frame the main gains and losses involved in selecting between management options. By including resident knowledge and perspectives on local aquatic resource use and preferences, community participation in refining these models could, for example, provide unexpected (to the decision-makers) linkages between ecosystems and ecosystem services.

Decision-makers also might find the perspective of community residents useful in identifying ways to employ a simplified version of the conceptual models as a decision aid. A simple conceptual model clearly illustrating the linkages between stressors, aquatic ecosystems, and ecosystem services and the consequences of the various management options on those linkages could help community residents conceptualize and compare the available management options. Decision-makers can elicit comments and questions from community residents serving as members of advisory committees or boards to develop simple conceptual diagrams for use in community hearings or in other venues with large numbers of residents and stakeholders. Thus, these stakeholders can assist in eliciting broader community preferences for the options available.

For this phase of the process, both deliberative and analytic sociocultural methods can be used (see Table 4-1). Deliberative methods can elicit specific input from community residents on the diagrams' utility. Analytic methods can be used to review comments and questions offered by participating residents to identify potentially problematic components of the diagrams for revisions or modification.

5.1.3.1. *The AMD Case Study Example*

In this example, it is assumed that, after input from the community, the two primary management options are adapted versions of the limestone channel and the constructed wetlands. These revised options are the ones described in Section 3.4.3.1. One of the benefits of a deliberative process for revising and refining these options is that it provides members of the community (in this case, the advisory committee in particular) with an opportunity to further familiarize themselves with the sources, stressors, ecological impacts, and use-attainment conditions on the tributary and the river and with the expected changes that would occur with the two management options. Using this gained understanding, the advisory committee would then also be well positioned to participate in developing and revising the conceptual models.

Figures 5-2 through 5-7 illustrate how the conceptual models for this case study can be constructed in stages, using input from the advisory committee. Building these diagrams gradually through a participatory process with community representatives offers several advantages, including the following: (1) it takes advantage of the participants' understanding of local conditions and (2) it provides models that are easier for the lay public to understand. For example, Figure 5-2 provides a simple representation of the current conditions at the case study site. It identifies the main sources of impairment, the stressors, the affected ecosystems, and the linkages between them. This type of flow diagram, combined with the physical representation of the site, could be initially developed by water quality experts and presented to the advisory group as a way of generating discussion, eliciting feedback, and establishing a common understanding of the main water quality problem to be addressed. The deliberative process could then be used to revise and expand the model. As shown in Figure 5-3, input from community representatives could be used to identify and represent the main ecosystem services affected, and water quality managers could use the diagrams as a way of illustrating to these participants the key designated use impairments. Diagrams for the management options also could be constructed in a stepwise fashion, as shown in Figures 5-4 to 5-7. For instance, water quality managers and engineers participating in the project could use the diagrams to illustrate for other participants how the limestone channel and the constructed wetland would affect the flow of stressors from the AMD sources, and they could use the diagrams to describe the expected costs of the options and their expected implications for designated use attainment on the tributary and river. Then, through deliberations with the community participants, they could identify and add to the diagrams the

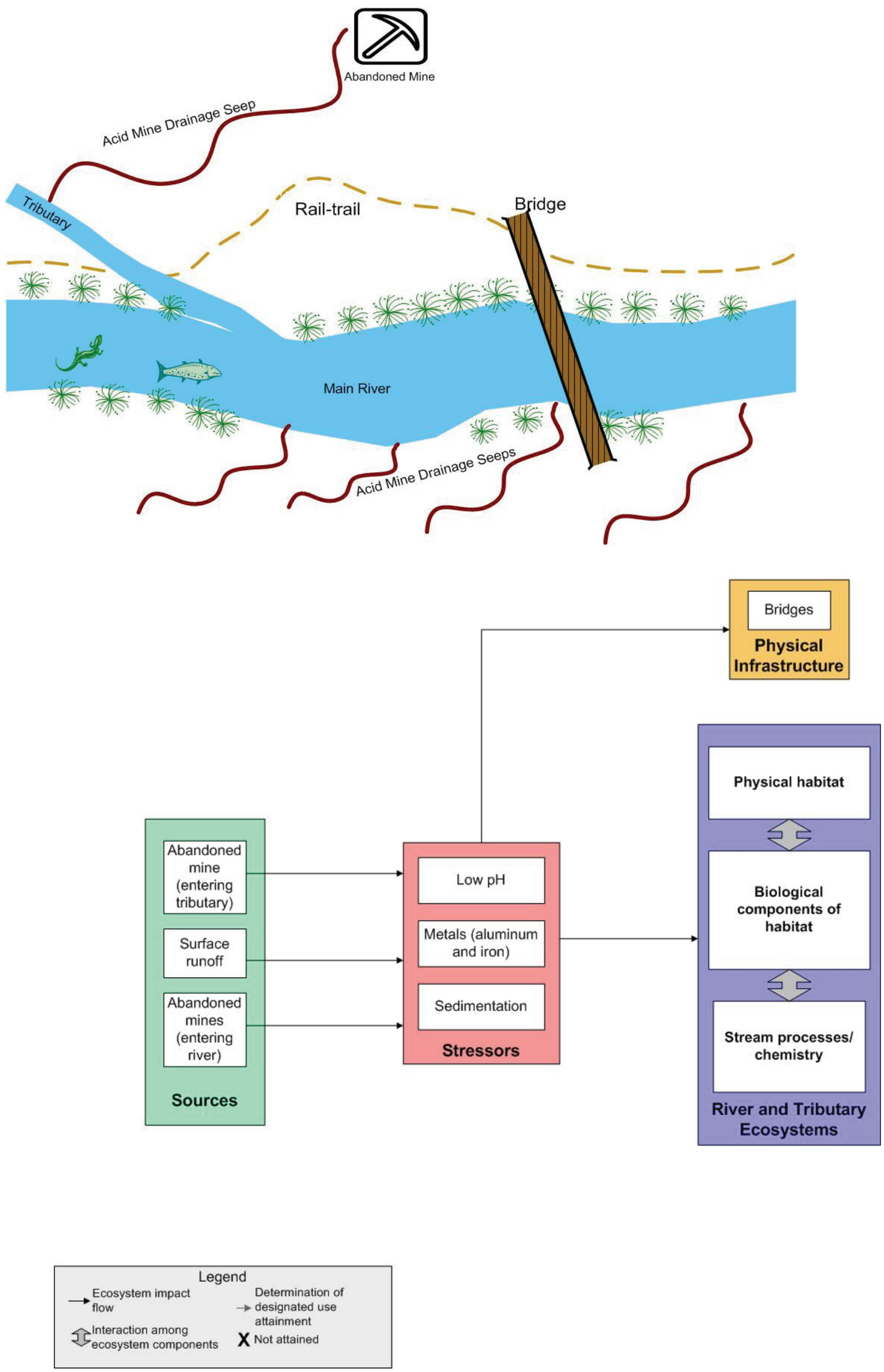


FIGURE 5-2

Mitigating Acid Mine Drainage Impacts on a Tributary and River: Current Conditions (Version 1)

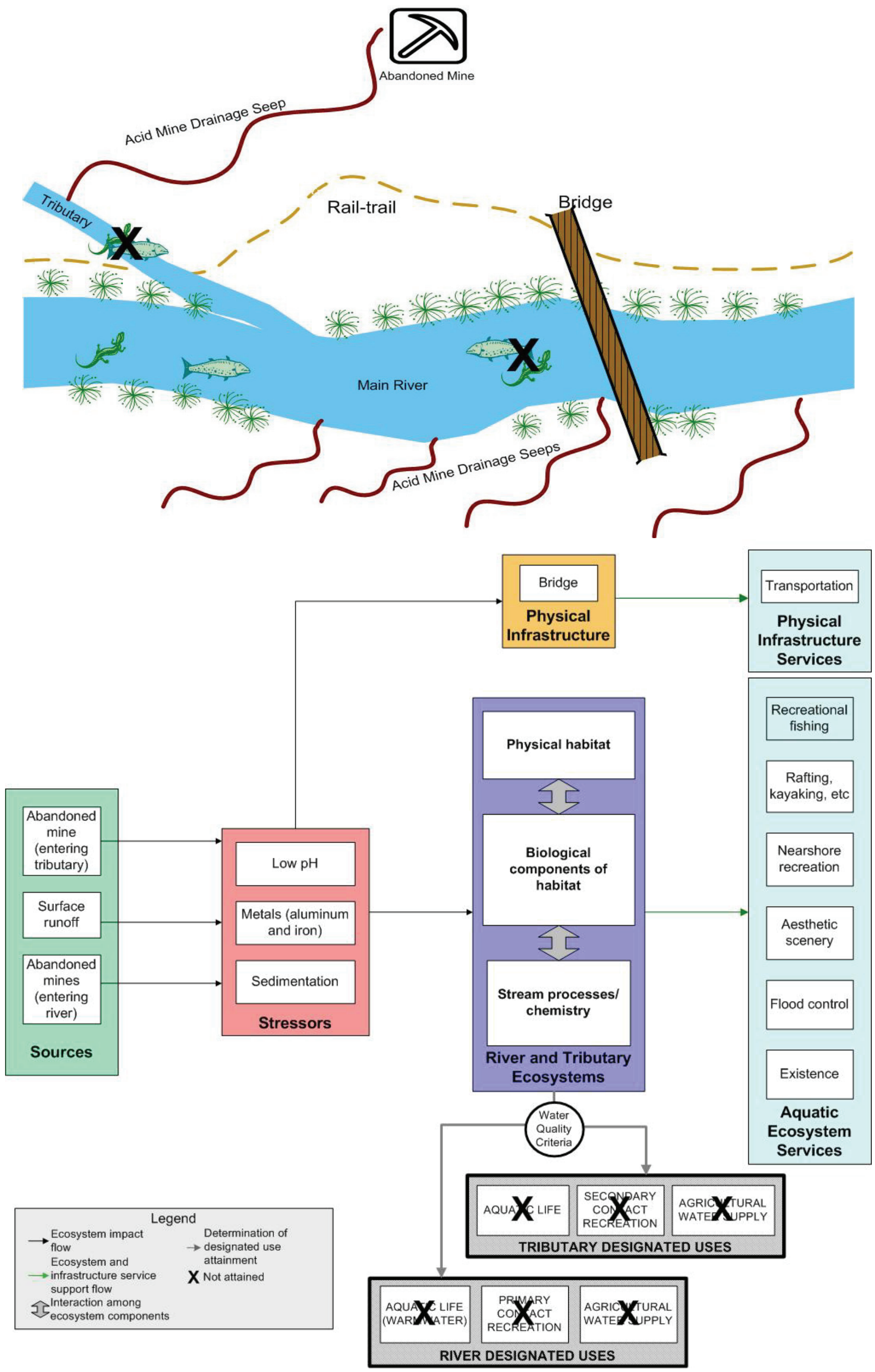


FIGURE 5-3

Mitigating Acid Mine Drainage Impacts on a Tributary and River:
Current Conditions (Version 2)

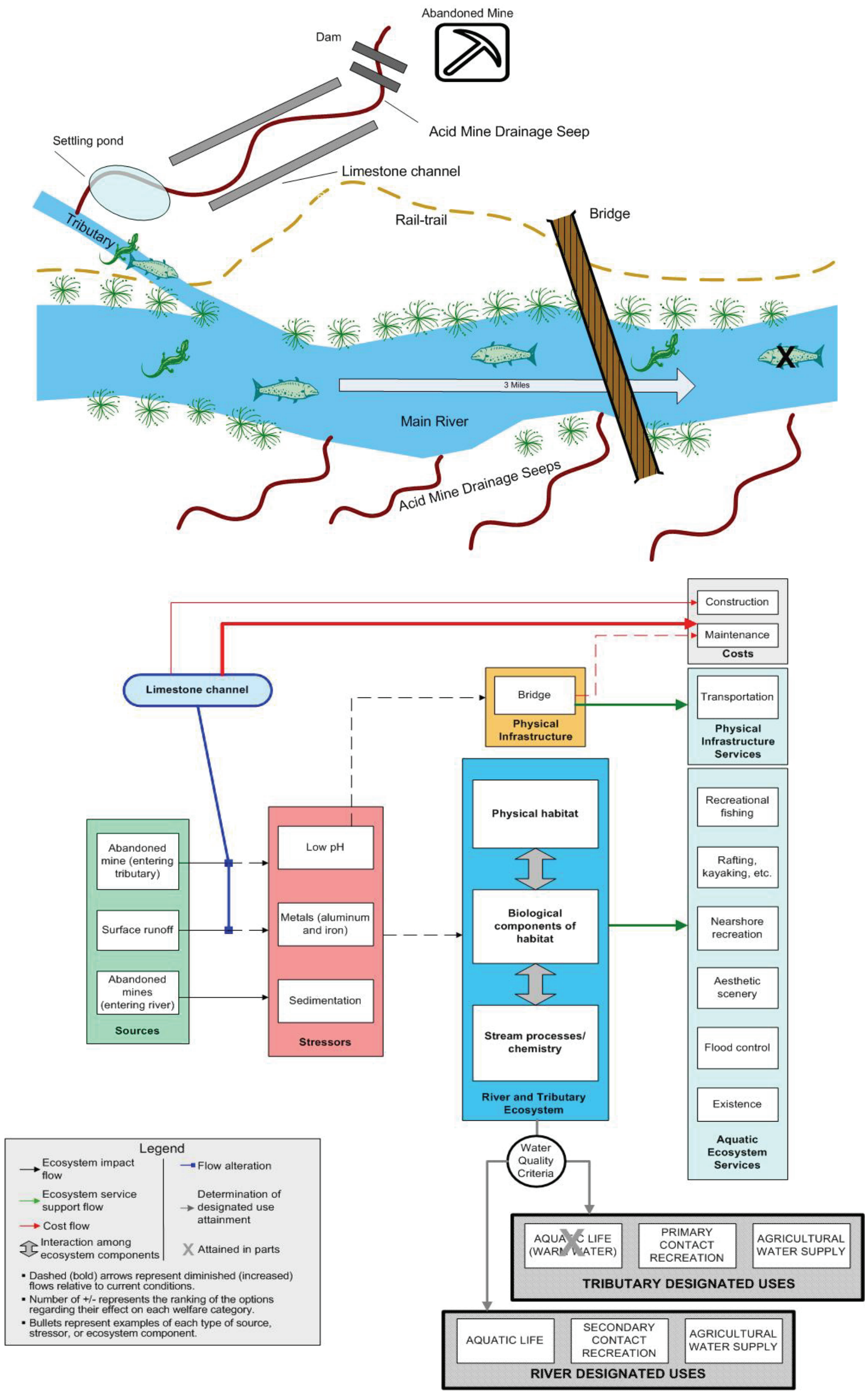


FIGURE 5-4

Mitigating Acid Mine Drainage Impacts on a Tributary and River
Option 1: Create Limestone Channel (Version 1)

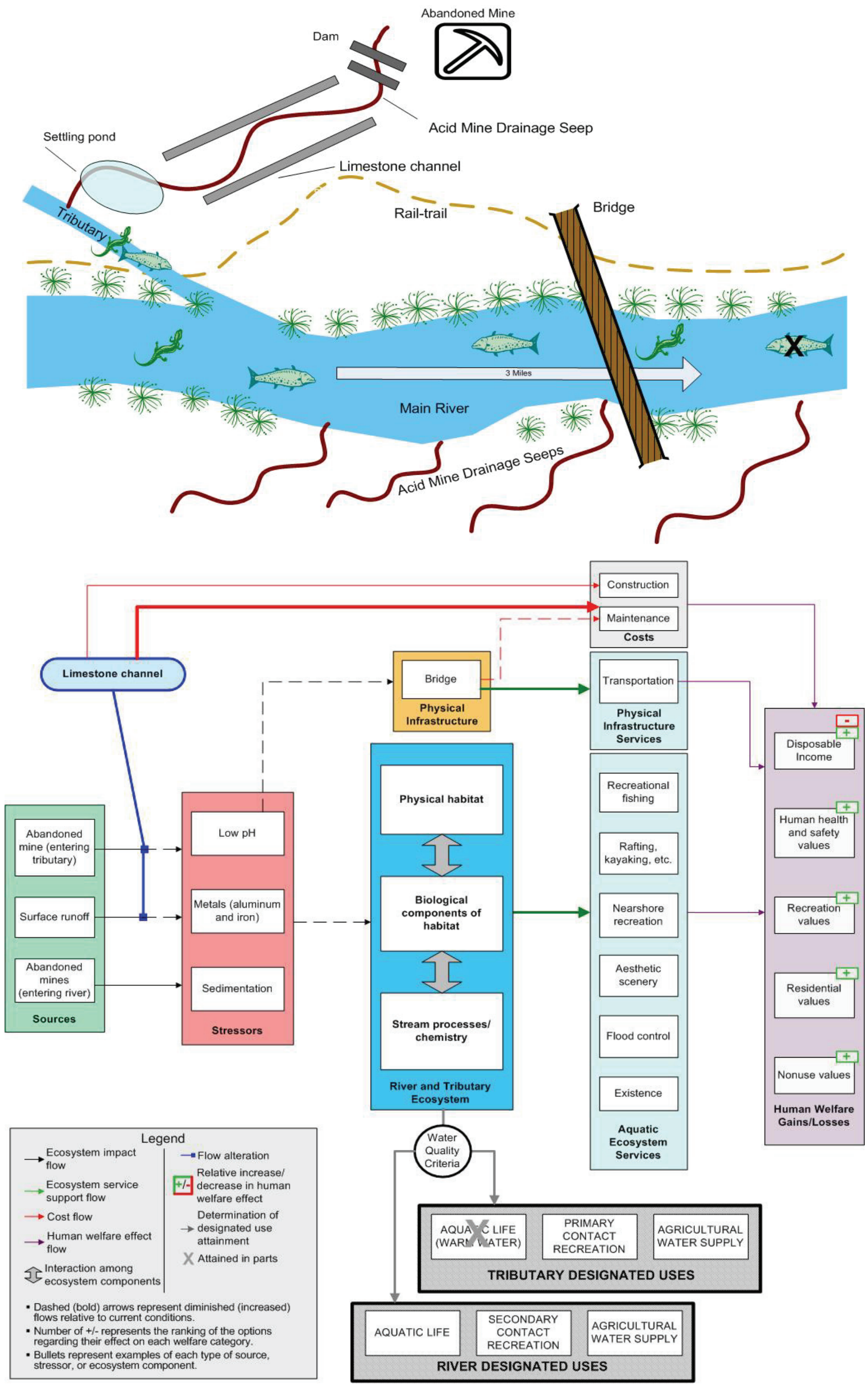
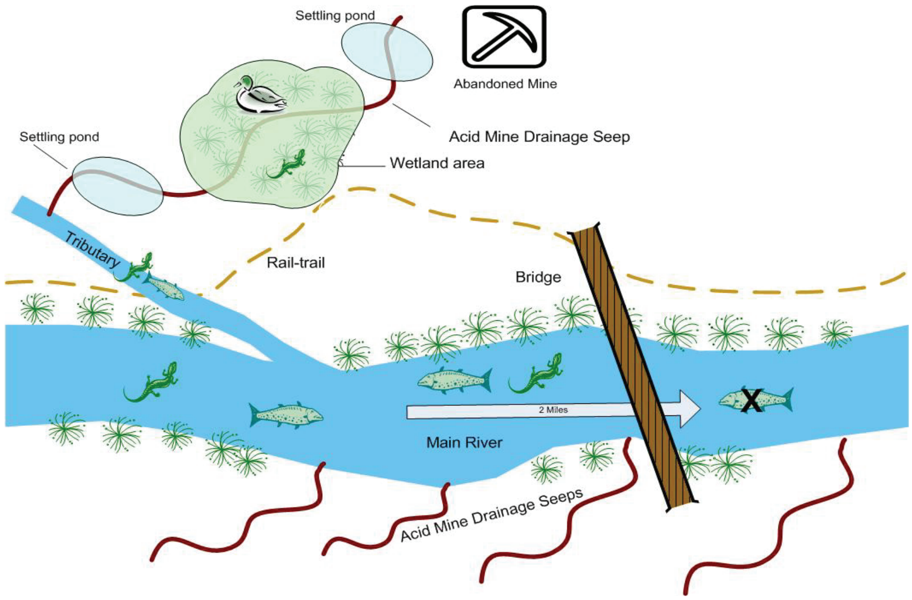


FIGURE 5-5

Mitigating Acid Mine Drainage Impacts on a Tributary and River
Option 1: Create Limestone Channel (Version 2)



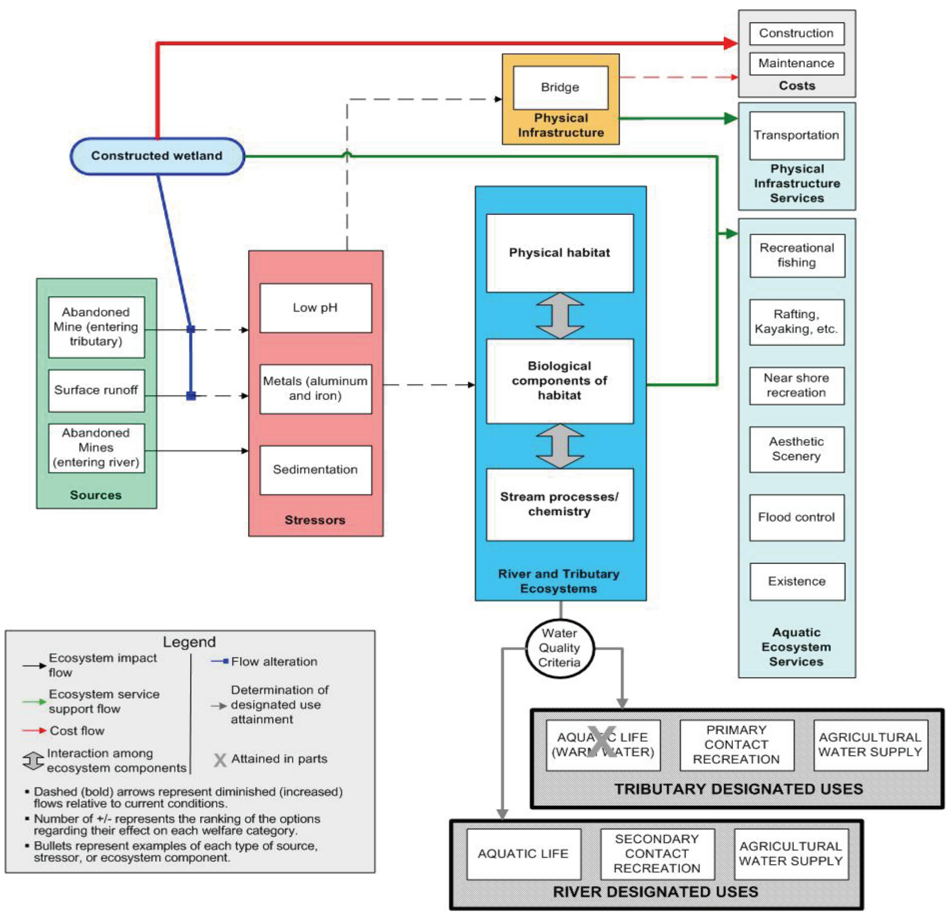


FIGURE 5-6

Mitigating Acid Mine Drainage Impacts on a Tributary and River
Option 2: Create Wetland Area (Version 1)

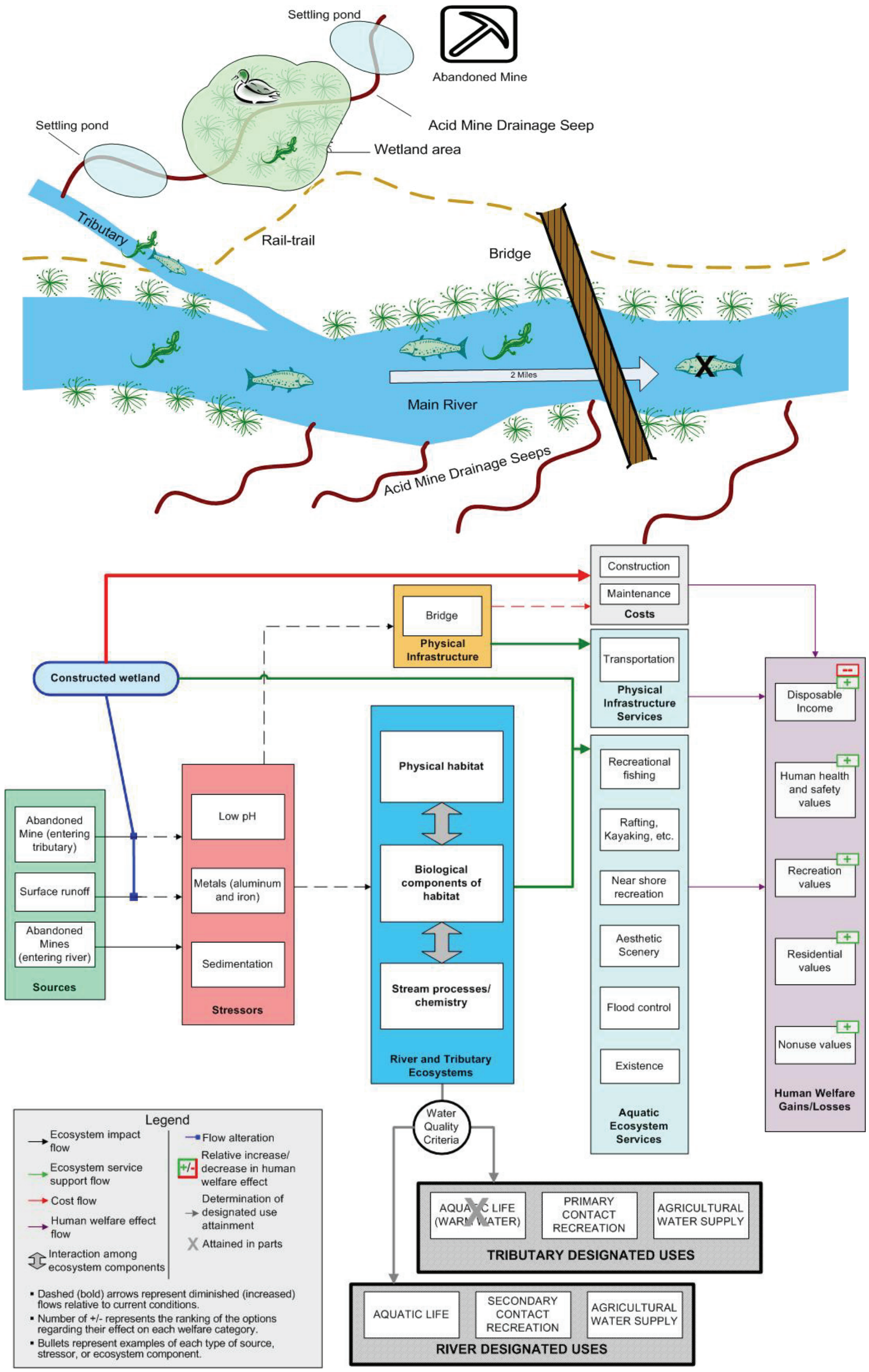


FIGURE 5-7

Mitigating Acid Mine Drainage Impacts on a Tributary and River
Option 2: Create Wetland Area (Version 2)

main human welfare gains and losses expected to result from the two options (Figures 5-5 and 5-7).

At this stage, compared with the diagrams reported in Section 3.4 for this case study, the diagrams in Figures 5-2 through 5-7 include less detail regarding the complex relationships between sources, stressors, aquatic ecosystems, ecosystem services, and human welfare changes. Thus, these intermediate-level diagrams may be useful as tools for communicating the water quality management problem to the broader public in the affected community. Parts of these diagrams could, for example, be used in public meetings as a way of walking the community through the issues and trade-offs involved in addressing the AMD sources and as a way of eliciting further feedback from the public. In contrast, the more detailed and complex diagrams shown in Figures 3-5 through 3-7 could be developed through further deliberations with the advisory panel and with other experts, such as ecologists and economists. These detailed conceptual models are likely to be most useful for the water quality managers as a way of framing the decision problem.

5.1.3.2. *The CSO Case Study Example*

In this example, the Basin Commission presented two primary management options focused on developing a special wet weather use category for primary contact. These options are described in Section 3.4.3.2. As in the AMD example, one of the benefits of this process for revising the options is to provide stakeholders an opportunity to understand the sources, stressors, and ecological impacts of the options. In this case, the process provided the Commission with an opportunity to learn about localized efforts that could contribute to the solution and allowed stakeholders to feel ownership in the problem and the solution.

With input from the advisory committee, it is possible for the Basin Commission to develop conceptual models that incorporate the knowledge and perspectives of the affected community. Using a similar stepwise procedure as the one described above for the AMD case study, the advisory committee, including stakeholders and water quality experts, could participate in the process of developing the conceptual models shown in Figures 5-8 through 5-10. By constructing these models collaboratively, water quality managers and stakeholder representatives can evaluate all of the proposed options to determine how applying them would address stressors, the river ecosystem, and eventually the designated uses of the river. The

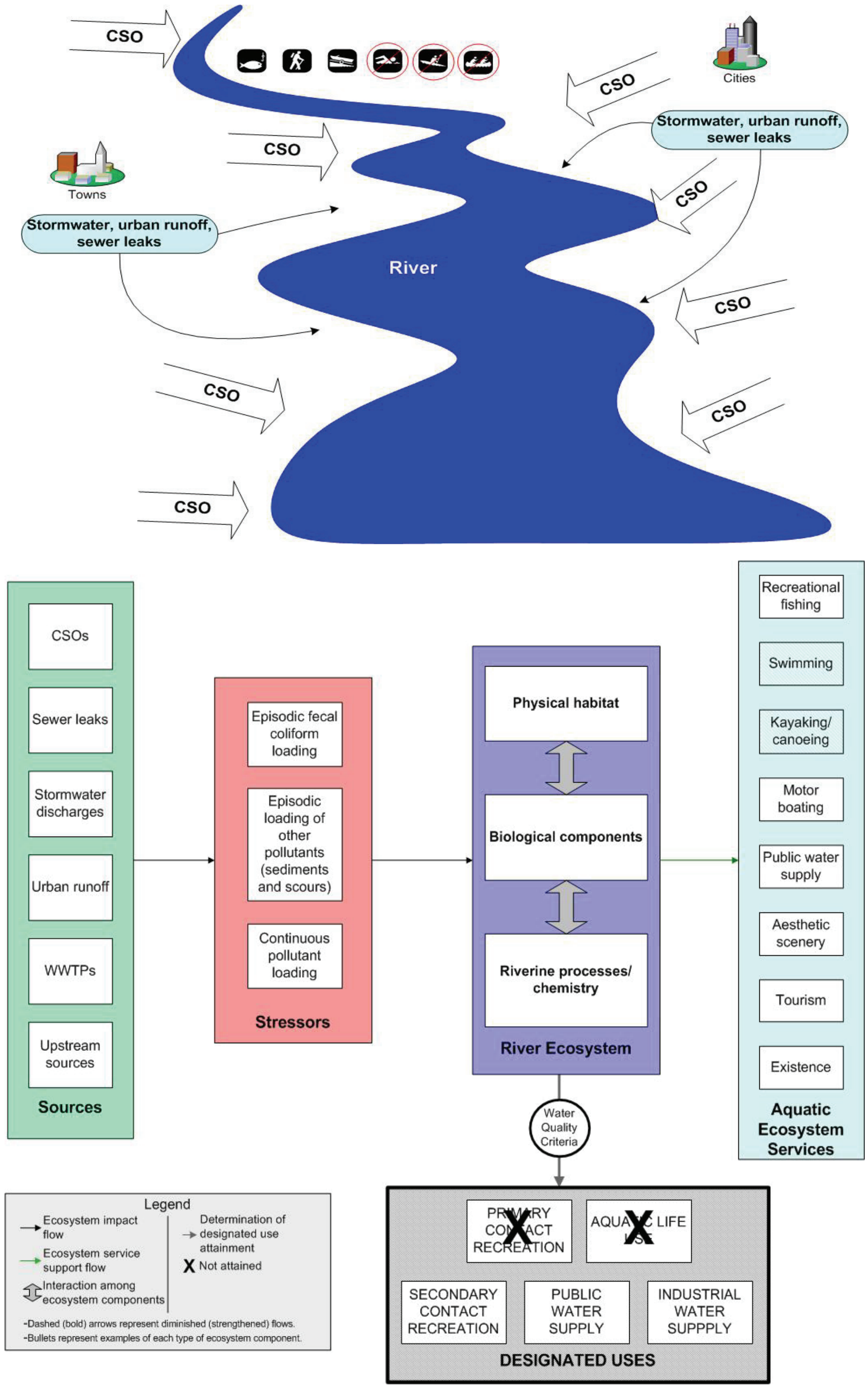


FIGURE 5-8

Mitigating CSO and Stormwater Impacts on a River System:
Current Conditions

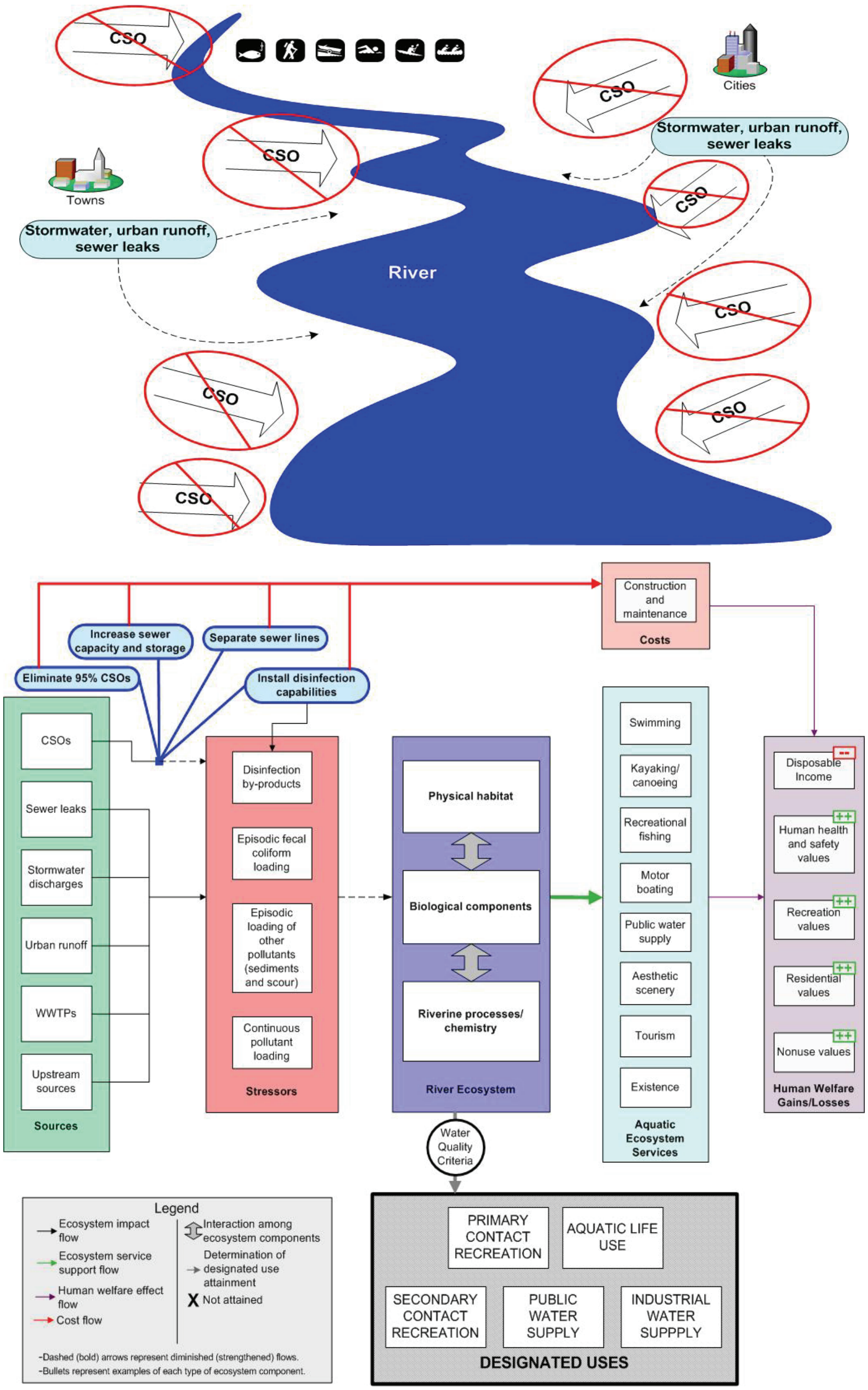


FIGURE 5-9

Mitigating CSO and Stormwater Impacts on a River System
Option 1: Eliminate 95% of CSOs and Implement Other System Improvements

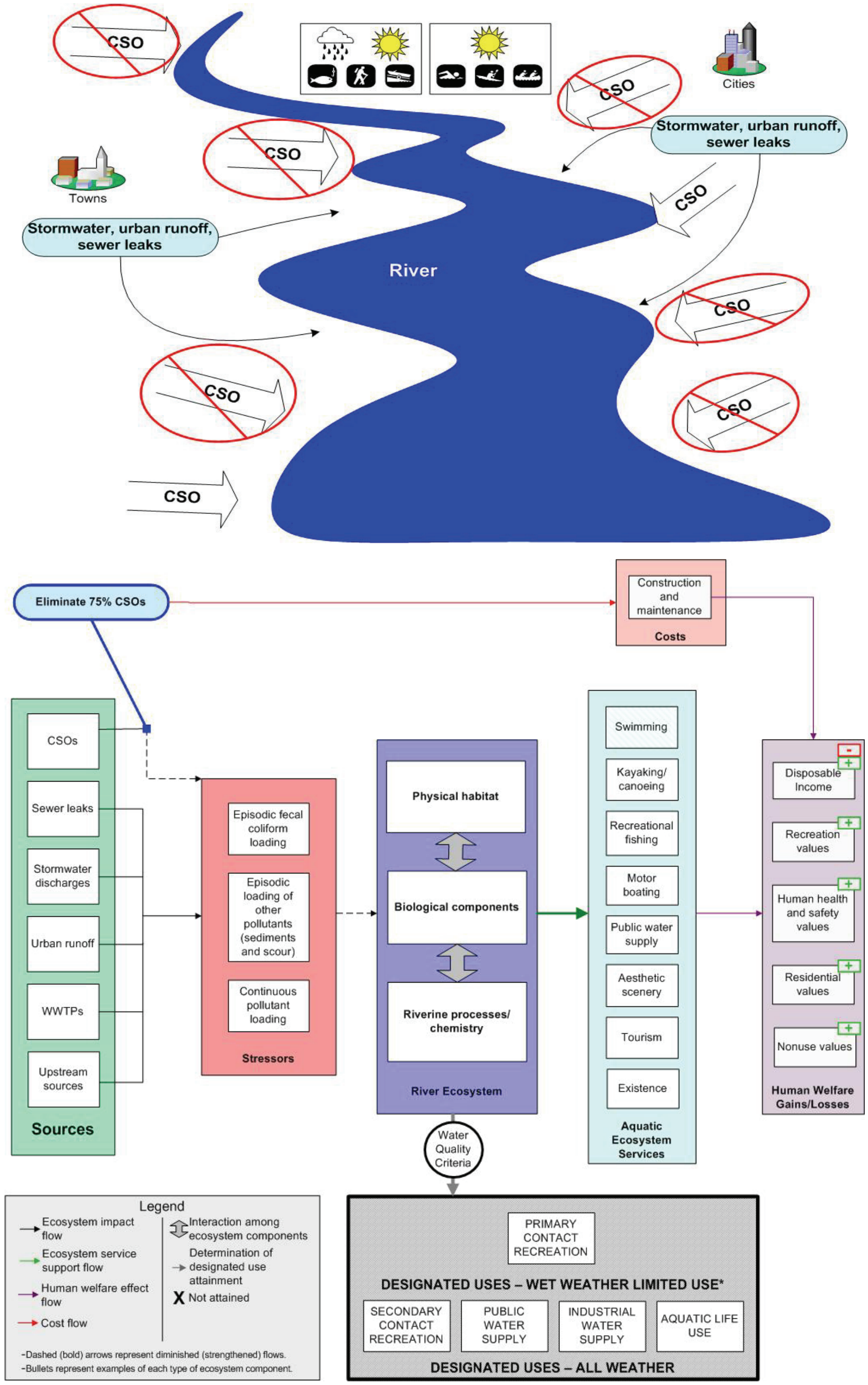


FIGURE 5-10

Mitigating CSO and Stormwater Impacts on a River System
Option 2: Eliminate 75% of CSOs and Apply Limited Use Designation

participation of the advisory panel can help ensure that all ecosystem services and human welfare effects are accounted for in the framework. Working with water quality experts, they also can help identify the main stressors and their impacts on the river ecosystem.

The process of assisting with the development of the conceptual models could also help members of the advisory panel better understand the relevant gains and losses. For example, the process might help clarify for them what the additional costs of Option 1 would provide to the community in terms of improved health and recreational services. The resulting intermediate-level models shown in Figures 5-8 through 5-10 also might serve as a resource for educating the general public about the WQS issue and the relevant gains and losses.

5.2. COMPARING OPTIONS THROUGH THE ASSESSMENT OF COMMUNITY PREFERENCES AND SOCIOECONOMIC IMPACTS

After the decision has been appropriately framed by determining the main management options and, as appropriate, constructing conceptual diagrams, decision-makers need to evaluate the advantages and disadvantages of the options. In addition to conducting ecological risk assessments for the options and evaluating their respective environmental impacts, the decision process can be enhanced by assessing community preferences. This entails gathering information from the community to assess how different segments of the affected population regard and value different features of the options. Chapter 4 of this report discusses several sociocultural and economic approaches that can be used to elicit or measure preferences. With this information, it is then also possible to estimate the social and economic impacts of the different options. For example, estimates of stakeholders' WTP for different improvements in ecological services can be used to inform a cost-benefit analysis of the options. In other words, the results of the preference assessment can help decision-makers gauge, for each option under consideration, how the overall well-being of the community is likely to be affected. In addition, they can help evaluate how the gains and losses from the different options are distributed across various segments and stakeholders in the community.

As shown in Figure 5-1, the process relating the assessment of preferences and the assessment of economic and social impacts can be an iterative one. Assessing preferences for the options may require some initial understanding of their expected socioeconomic implications. For instance, estimates of how the costs of the management options will be distributed across the community may influence individuals' preferences for the different options; therefore, preliminary estimates of this distribution may help community members better determine and express their preferences.

Regardless of how they are organized, the purpose of all these activities—ecological risk assessment, preference assessment, and the assessment of economic and social impacts—is to acquire and organize information that can be used to evaluate the trade-offs between the options. In some cases, this information may be quantitative estimates of risks, preferences, and impacts, and in other cases, the information may be more qualitative findings regarding the community's attitudes, preference, and concerns. In all cases, however, they should be designed to help decision-makers understand and anticipate the implications of alternative management approaches.

5.2.1. The AMD Case Study Example

In this example, the decision-makers must decide between a limestone channel and a constructed wetland to address the AMD-related impairments of the tributary. Both options also would improve conditions on the river. As highlighted in the conceptual diagrams, this decision requires a careful consideration of whether the additional ecological services provided by the wetland and its lower annual operating and maintenance costs are sufficient to offset the lower capital costs of the limestone channel, along with its ability to reduce impairment on a longer (by 1 mile) stretch of the river.

Given the relatively small scale of this WQS issue (compared, for example, with the CSO case study), a fully quantitative benefit-cost analysis (BCA), particularly one involving extensive primary data collection, is most likely beyond its scope. Nevertheless, a number of less resource-intensive possibilities exist for eliciting and assessing community preferences and using this information to examine the differences between the two management options. In the previous chapter, Table 4-4 identifies several methods that tend to be "low" or "very low" cost compared with other methods. Even though these methods generally provide less detailed information about community preferences, they nonetheless may be informative enough to address the needs of this case study assessment.

One approach would be to conduct focus groups with the advisory panel and with other small groups of local residents and stakeholders. In these deliberative group settings, participants first would be presented with the WQS issue being addressed, the management options under consideration, and the expected costs and ecological impacts associated with the alternatives. Ideally, this presentation would use parts or all of the conceptual model diagrams to help frame the decision context for the participants. Through a structured group discussion, preferably led by a trained focus group moderator, the participants then would be asked to discuss their perspectives on the expected advantages and disadvantages of the options and to indicate the direction and strength of their preferences for one option over another. Because most of this input would be qualitative in nature, the focus group setting also could be used to collect somewhat more quantitative measures of preferences. For example, participants could be asked to rate different dimensions of the options on a numeric scale in a type of opinion survey. They could be presented with a list of affected ecological services and asked to rate their perceived importance of each of these services and the perceived effectiveness of each option in improving these services.

As illustrated in Section 4.9, an inherent limitation of the focus group approach is that the preference information is collected from a small subset of the affected population; therefore, it is difficult to know how well the participants represent the preferences of the broader community. Nevertheless, by including participants from different segments of the population and from different stakeholder groups, these deliberative processes should enhance decision-makers' understanding of where the key concerns lie in the community and which factors are most important in assessing the gains and losses. For instance, the focus groups discussions may strongly suggest that improving local water-based recreation services is paramount for most segments of the community, in which case the comparison of options should focus primarily on how well the two options enhance these services.

Another approach would be to conduct a simplified economic analysis that approximates some of the benefits and costs of the two options. Whereas most of the costs of implementing the options are relatively well defined, the benefits from increased ecological services, in terms of recreation, residential, health, and nonuse values, are more difficult to quantify. As shown in Table 4-4, a new stated preference survey or revealed preference analysis (see Section 4.1.2) would likely be too costly to implement in this case; however, one practical alternative is to use a benefit transfer approach to approximate benefits. For example, a limited number of existing published studies have applied stated preference methods to assess the benefits of reducing AMD damage on streams in West Virginia and Pennsylvania (Collins et al., 2005; Farber and Griner, 2000). Although these studies address changes on different streams and for other populations, they may provide estimates of WTP that can be adapted or serve as approximations for the affected case study population. Similarly, a number of studies have estimated the monetary value of wetlands' benefits (see, for example, Woodward and Wui [2001], Brouwer et al. [1999] and Boyer and Polasky [2004]), which may provide useful approximations for the constructed wetlands option. Ideally, applying these types of benefit transfer approaches would involve experts in economics and aquatic ecosystems to ensure that the results from existing studies are properly interpreted and adapted to the case study context.

The effectiveness of this approach for understanding community preferences and comparing the costs and benefits of the two options depends importantly on how applicable and adaptable the benefits information is from existing studies. Since benefit transfers mean that preference information is drawn from different populations and/or water resource impairments, these differences should be accounted for either quantitatively (e.g., by adjusting the WTP estimates to better correspond to local conditions) or qualitatively (e.g., by describing the uncertainties and potential biases associated with transferring estimates). As discussed in Section 4.24, one of the possible limitations of benefit transfer is that community members may be less likely to accept benefit estimates that are derived from other areas or contexts, in which case it is especially important to address differences in populations and water resource impairments. It also may be the case that monetary estimates for certain subcategories of benefits (e.g., residential values) are not available in the literature. In these cases, it may be necessary to combine both quantitative and qualitative assessments of costs and benefits to evaluate the options (see, for example, Button et al. [1999]).

5.2.2. The CSO Case Study Example

Once the advisory committee has refined the conceptual models, the Basin Commission is in a position to assess community preferences for the two options. Because this example involves a large, multistate population with diverse stakeholder groups and interests, a combination of several methods likely would be used to determine overall community preference. This process likely will be an iterative one, conducted over a fairly long time frame to reach a final determination of community preferences.

If the commission determines that it is interested primarily in a sociocultural assessment of community preferences, then the public meetings and representative advisory committee that were used in framing the decision also can serve as the beginning of a sociocultural assessment process. In addition to gathering qualitative information from the community, these deliberative methods could be used to plan more extensive data collection and analysis efforts. For example, the advisory committee could help draft and develop a region-wide survey to elicit community preferences. As discussed in Chapter 4, a number of preference elicitation survey methods may be suitable for addressing the needs of the commission. For instance, as shown in Table 4-4, opinion or referendum surveys offer relatively less costly approaches that could be used to present the community with the main options under consideration and get structured feedback on preferences. Depending on the elicitation approach selected, a number of different survey administration methods are possible, including surveys that are mailed directly to sewer customers and local businesses, phone surveys, and surveys that are made available on a Web site. Alternatively, more complex and costly survey instruments that explore individuals' preferences regarding specific attributes of the options could be developed to support multiattribute trade-off analyses (see, for example, Gregory and Wellman [2001]) or conjoint analyses. For example, respondents could be presented with and asked to choose between management options that are characterized in several dimensions, including the numbers of river miles improved, the number of high-bacteria days avoided, the types of methods used to inform the public about high-bacteria conditions, and the annual costs of the options to local households. Although these multiattribute survey-based methods can provide rich characterizations of community preferences, as discussed in Sections 4.7 and 4.18, they also are relatively expensive because they require extensive pretesting and specialized technical expertise for designing and analyzing the survey.

If the commission is interested in conducting a BCA to evaluate the options, then several of the methods outlined in Chapter 4 are possible alternatives. The most direct approach would be to collect WTP information from the community using a stated preference approach, such as a contingent valuation (CV) survey.[2] These types of surveys also require specialized technical expertise for designing the instrument and analyzing the survey results; however, like opinion or

[2] A less direct approach would be to estimate benefits for specific aspects of the options separately. For example, recreation demand methods could be used to estimate recreation values and hedonic property methods used to estimate benefits for nearshore residents.

referendum surveys, they can be administered to households across the river basin using either phone, mail, Internet, or some combination of modes. A CV survey would, for example, present respondents with descriptions of one or more of the options under consideration. Ideally, these descriptions would include easily understandable information about current conditions—sources, stressors, aquatic ecosystem impacts, and ecosystem service impacts—and then describe how the option(s) would alter these impacts. In other words, it would convey much of the same information that is described in Figures 5-8 through 5-10 but not necessarily in the same format. The main objective of the CV survey would then be to elicit respondents' WTP for the options under consideration, using an appropriately designed elicitation technique.

The results of a stated preference survey like CV should provide decision-makers with estimates that can be used to evaluate not only the efficiency but also equity implications of different management options. For efficiency (benefit-cost) analysis, total benefit estimates for each option can be calculated by aggregating average (per respondent) WTP for each option across the population of interest (i.e., the population in the river basin). A stated preference survey also can inform an equity analysis by providing estimates of how benefits are distributed across the population. For example, the results may show whether and by how much average WTP is greater for populations who live closer to the river or who are more active recreational users of the river.

In addition to BCA, the commission might be interested in conducting an economic impact analysis (Section 4.25) of the options to estimate how they might affect economic activity in the region, in terms of industry-level revenues, employment levels, and household incomes. Although the results of this type of analysis would not directly support a BCA, they may nonetheless provide information to help policy makers understand the economic consequences of the options. In particular, they may provide information about the relative magnitudes and distributions of economic impacts across different sectors of the regional and local economy. The results of these analyses might be included as information in preference elicitation surveys of local residents to help respondents understand the expected economic consequences of different options.

5.3. SELECTING THE MANAGEMENT OPTION

The final step, as defined in Figure 5-1, is for the decision-makers to select the management option that best addresses their objectives, the communities' needs, and complies with the CWA and WQS regulation to attain the water body goal. The methods proposed in this report are intended to help decision-makers collect and organize information in a way that best supports these objective and needs. For example, in the AMD case study context, it is likely that a combination of quantitative measures and qualitative factors relating to water quality impairments, community preferences, and socioeconomic impacts will need to be considered in choosing between the constructed wetland and the limestone channel. If these assessments indicate that, in spite of the ecosystem services provided by the wetlands, the community has a strong preference for improving recreation services and eliminating as many miles of impairment along the river as possible, then the decision-makers may decide that the limestone channel is the best option. In the CSO case study context, it is likely that a more detailed and quantitative analysis will be feasible, which will allow for a more thorough assessment of the costs and benefits as well as the equity implications of the two options. For example, the analysis may indicate that the 95% reduction option (Option 1) will provide the higher level of net benefits (i.e., benefits minus costs). However, it may also show that the benefits are concentrated within a small sector of the population (i.e., those living in close proximity to the river) and that the rate increase required to pay for the option will impose a high burden on the lower-income segments of the community. Therefore, unless the rate increases can be redistributed, the decision-makers may decide that the 75% reduction option (Option 2) is the best option.

5.4. CONCLUSIONS

This chapter illustrated how the use of the methods and tools presented in the previous chapters can be implemented in order to support use-attainment decisions while complying with the CWA and WQS regulation. We developed a decision process framework to aid the development of a balanced analysis by revealing how the ecological and socioeconomic trade-offs can be understood, communicated, and weighed in the standard-setting process. A broader analysis—one that analyzes the ecological benefits—could provide important decision support.

The *Interim Economic Guidance* specifically states that the benefit-cost analysis is not required for determining widespread and substantial impacts (U.S. EPA, 1995). However, it explains that certain benefits may accrue to communities from cleaner water. Appendix C in the *Interim Economic Guidance* presents the types of benefits that could be relevant to a use-attainment decision, but it does not explain how to use the benefit estimates. We demonstrate an approach that could assist in determining which benefits to consider and how to use this information for evaluating and selecting a management option.

The purpose of this report is not to suggest the criteria that should be used in making any particular decision, rather it is to propose methods that could help decision-makers better frame and evaluate the options. None of the individual methods described in the report can determine unequivocally which management option is best suited to address a particular WQS issue. However, as we state in the goal of the report, they should enable states and authorized tribes—and the associated communities—to make informed decisions about their water bodies while remaining in the current regulatory framework.

Although the focus of this report is on use-attainment decisions, we believe that there are other opportunities to use this decision process framework. Community preferences could be important for prioritizing watershed-wide planning activities (e.g., see Figure 1-5). For example, the approach presented could improve grant proposals for water quality activities or assist in allocating restoration dollars to different projects in a watershed. Although we do not illustrate any of these examples in the report, we believe the three main phases of the decision process still apply. We suggest that water quality officials, watershed managers, members of stakeholder groups, and other interested individuals consider the importance of ecological benefits to addressing their objectives and the communities' needs and whether a balanced analysis could play an important role in supporting their particular watershed management decisions.

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APPENDIX A
MEASURES USED IN FINANCIAL IMPACT ANALYSIS FOR WATER QUALITY STANDARDS

The Financial Impact Analysis (FIA) described in U.S. EPA's *Interim Economic Guidance for Water Quality Standards: Workbook* (*Interim Economic Guidance*) uses select financial measures to determine whether or not the water quality standards may have a substantial economic impact on a discharger or other entity. U.S. EPA specifies different measures to identify substantial impacts for public-sector and private-sector entities.

A.1. MEASURES USED TO ASSESS FINANCIAL IMPACTS FOR PRIVATE-SECTOR ENTITIES

Before discussing the ratios, the components of the ratios must be understood. Table A-1 succinctly lists all financial data needed about the entity to calculate the ratios as well as a description of each. Data for multiple years should be gathered on each component. If possible, data should be gathered on the entity level. In cases where this data is not available, a common way to estimate the entity's share of company data is to use the proportion of sales for which the entity contributes to overall company sales to determine the proportion of earnings, debt, etc., at the company level attributable to the entity. Additionally, pollution control costs should be estimated for the entity.

Profitability is the primary measure the FIA uses to determine the impact that the costs of attaining the specified pollution control will have on the entity. Liquidity, solvency, and leverage are secondary measures to determine the financial impact on the entity. The ratios specified in the *Interim Economic Guidance* for each of these measures and their components are listed in Table A-2.

A.1.1. Primary

A.1.1.1. *Profitability*

Profitability measures the profit (revenue minus costs) of the entity with respect to its revenue. In other words, it shows the percentage of sales that the entity keeps after paying its bills. The profit rate should be calculated using earnings before pollution control costs have been

TABLE A-1

Data Needs to Calculate Ratios

Component	Description
Revenue	Sales
Earnings Before Taxes	Revenue minus all costs except taxes
Cash Flow	Cash entity has available in a given year
Current Assets	Assets that are or could easily be converted into cash, such as inventories, prepaid expenses, short-term investments, accounts receivable, marketable securities, and cash
Current (or Short-Term) Liabilities	Liabilities that must be paid within the year, such as accounts payable, wages payable, short-term notes payable, accrued expenses, taxes payable, and current portion of long-term debt
Long-Term Liabilities	Liabilities that must be paid in a year or more, such as bonds, debentures, and bank debt and other noncurrent liabilities
Total Debt	Current debt for current year plus long-term debt
Interest	Current financing charges (interest expense) due on debt
Owner's Equity	Difference between total assets and total liabilities, including contributed capital and retained earnings (net stockholder's equity for publicly held entities)

TABLE A-2

Ratios Used in the *Interim Economic Guidance*

Financial Measure	Main Ratio	Supplemental Ratio
Profitability	Profit Rate = Earnings Before Taxes (EBT) ÷ Revenue	NA
Liquidity	Current Ratio (CR) = Current Assets (CA) ÷ Current Liabilities (CL)	Quick Ratio (Acid Test) = [CA—Inventories] ÷ CL
Solvency	Beaver's Ratio = Cash Flow (CF) ÷ Total Debt (TD)	Times Interest Earned (TIE) = Earnings before Interest and Taxes (EBIT) ÷ Interest
Leverage	Debt to Equity Ratio (DER) = Long-Term Liabilities (LTL) ÷ Owner's Equity (OE)	NA

NA = Not Applicable

subtracted and earnings after pollution control costs have been taken into consideration. A substantial change between these two measures may indicate substantial financial impacts on the entity (see Table A-3).

TABLE A-3

Rules of Thumb for Interpreting Ratios

Ratio	*Interim Economic Guidance* Rule of Thumb
Profit Rate	No rule of thumb, compare with other firms in similar lines of business
Current Ratio	Greater than 2—Entity should be able to cover short-term debt
Beaver's Ratio	Greater than 0.20—Entity should be able to pay long-term debt (solvent) Between 0.15 and 0.20—Uncertain Less than 0.15—Entity may go bankrupt (insolvent)
Debt to Equity Ratio	No rule of thumb, compare with other firms in similar lines of business

A.1.2. Secondary

A.1.2.1. *Liquidity*

The capacity of an entity to turn its assets into cash and then use those assets to retire debt is known as liquidity. The current ratio, a common measure of liquidity, gauges the ability of the entity to pay its short-term debt. Care should be taken in interpreting this ratio by analyzing the components that make up the current assets and current liabilities. For instance, an entity with a higher proportion of cash to other current assets may have an easier time paying short-term debt than an entity with a higher proportion of inventories to cash with the same Current Ratio value.

Use of other ratios, such as the Quick Ratio (also called the Acid Test), can be used to distinguish between the two situations described above. The ambiguity associated with the Current Ratio makes it important to concurrently use other financial measures.

A.1.2.2. *Solvency*

The ability of an entity to pay its long-term debt and avoid bankruptcy is referred to as solvency. A solvent entity can pay its long-term debt while an insolvent entity is likely to go bankrupt. Beaver's Ratio determines the solvency of an entity by calculating the amount of cash generated by the entity per dollar of debt. The greater the amount of cash produced to the amount of debt owed by the entity, the more likely the entity will be able to repay that debt and thus, the more the solvent it is.

Another measure, the Times Interest Earned Ratio, demonstrates the ability of the entity's earnings to cover the financing costs of its long-term debt. Literally, the ratio determines the number of times the interest expense could be paid using the entity's current earnings. Unlike the Beaver's Ratio, the Times Interest Earned Ratio uses only the interest expense and not the entire amount of the debt.

A.1.2.3. *Leverage*

Leverage involves acquiring assets through borrowed funds. This tool can be used to determine the entity's ability to secure the debt it needs to grow. The Debt to Equity Ratio measures the entity's balance between the portion of assets that have been funded by debt and the portion of assets funded by the owners (stockholders, if the entity is publicly owned).

A.1.3. Interpretation

Each of these ratios needs to be analyzed in context. Multiple years (*Interim Economic Guidance* recommends at least three years of data) should be used to calculate an accurate estimate of the ratios. If the ratio differs significantly between years, further investigation should be used to determine the reason for the divergence. In many cases, the ratios should be compared to those of similar entities (ideally other dischargers) or industry averages. A large variation between the benchmark ratio and the calculated ratio also warrants further investigation. The *Interim Economic Guidance* suggests some rules of thumb for interpreting the ratios. These general rules are listed in Table A-3.

A.2. MEASURES USED TO ASSESS FINANCIAL IMPACTS FOR PUBLIC-SECTOR ENTITIES

The *Interim Economic Guidance* provides primary and secondary measures to assess whether impacts imposed on public-sector entities are substantial.

A.2.1. Primary

U.S. EPA's primary screening indicator for public-sector impacts is

$$\frac{\text{Average Total Pollution Control Cost per Household}}{\text{Median Household Income}} \qquad \text{(Eq. A-1)}$$

U.S. EPA provides detailed instructions on adjusting dollar values from various years to current year dollars and provides a set of criteria for determining if the primary screener indicates substantial impacts.

- If the ratio is less than 1%, impacts are assumed not substantial
- If the ratio is between 1 and 2%, it indicates mid-range impacts
- If the ratio is greater than 2%, there may be substantial impacts.

Unless the primary screener indicates insubstantial impacts,[1] the analyst should examine secondary screening indicators:

Debt Indicators

- bond rating
- overall net debt as a percent of full market value of taxable property

Socioeconomic indicators

- unemployment rate
- median household income

[1] The *Interim Economic Guidance* (1995: 2-15) states, "Communities with screening results of less than 1.0 but still fairly close to 1.0, however, may still want to proceed to the secondary test."

Financial management indicators

- property tax revenue as a percent of full market value of taxable property
- property tax collection rate.

A secondary screener score is calculated for the community by weighting each indicator equally and assigning a score of 1 to each indicator of weakness, 2 to each indicator that is mid-range, and 3 to each indicator that suggests financial strength, then computing an average (see Chapter 5 of *Interim Economic Guidance* for calculation of secondary screener). The average score is then interpreted to determine if the entity is weak, mid-range, or strong. If the average score is less than 1.5, the secondary screening suggests weakness. If the average score is between 1.5 and 2.5, the secondary screener suggests mid-range conditions. If the average score exceeds 2.5, the secondary screener suggests strength.

The analyst can then use the matrix shown in Table A-4 to combine the results of the primary and secondary screeners to determine if the project will have substantial impacts.

TABLE A-4

Assessment of Substantial Impacts

	Municipal Preliminary Screening Ratio		
Secondary Score	Less than 1.0 Percent	Between 1.0 and 2.0 Percent	Greater Than 2.0 Percent
Less than 1.5	Impact is unclear	Substantial impacts expected	Substantial impacts expected
Between 1.5 and 2.5	Substantial impacts not expected	Impact is unclear	Substantial impacts expected
Greater than 2.5	Substantial impacts not expected	Substantial impacts not expected	Impact is unclear

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APPENDIX B
EXAMPLES OF EXISTING USE ATTAINABILITY ANALYSES AND ANTIDEGRADATION REVIEW ANALYSES USING ECONOMIC CONSIDERATIONS

A literature search identified 13 use attainability analyses (UAAs) and four antidegradation review analyses (ARs) that incorporate economic arguments. Documentation for the examples was obtained from materials that could be downloaded from state agency Web sites and reports submitted by the states to U.S. EPA Regional program offices (Table B-1 lists the examples).

This collection of examples is not meant to be exhaustive. The main goal was to examine examples from different parts of the country that embodied economic analyses of varying sophistication or used different methods in presenting socioeconomic arguments. It should be noted that the vast majority of UAAs do not involve economic arguments. For ARs, many states are still defining their methodologies. This means that ARs involving socioeconomic arguments are not plentiful and assembling documents to develop example analyses was difficult. The "record of decision" process does not usually involve publishing materials into the Federal Register or other readily available national dockets. Also, states tend to submit materials to their U.S. EPA Regional offices to initiate a potentially lengthy series of negotiations. In many cases, technical alternatives to an actual UAA (e.g., site-specific adjustments to criteria for existing uses) are employed to avoid actual changes in the designated uses. Many of these examples, therefore, can be best viewed as ongoing. The status of the review process as of the end of 2003 is noted in the examples, but a large number are best viewed as still in-process or even as draft submissions.

Nevertheless, these examples offer a good illustration of the types of socioeconomic methods and techniques states have applied to these UAAs and ARs. The materials are organized to provide information on the location of the water bodies, the designated uses and pollution stressors of concern, the types of analyses considered, alternatives proposed to address the water quality standards issues. The different stakeholders involved are noted along with information on when the UAAs or ARs were initiated and the current status of the process.

As suggested in Chapter 2, these 17 examples seem to indicate that typically no or very little benefits evaluation is conducted for UAAs and ARs. Where some discussion of economic

TABLE B-1 UAA and Antidegradation Examples		
Example	State	Name
Use Attainability Analyses		
1	CA	Ballona Creek
2	ID	Blackbird Creek
3	VA	Blacks Run Creek
4	MA	Boston Harbor Area
5	OR	Burnt River
6	NY	Cayadutta Creek
7	DE/PA/NJ	Delaware Estuary
8	ME	Gulf Island Pond
9	CO	Lower French Gulch/Blue River
10	NY	Lower Hudson/East River
11	ME	Lower Salmon Falls River
12	CA	Santa Ana River
13	IN	White River
Antidegradation Reviews		
14	ND	Devils Lake
15	WY	Northwest Basins
16	OK	Snake Creek
17	OH	Sycamore Creek

impacts or evaluation was included, most were qualitative or, if quantitative, focused on the costs of the various management options.

B.1. EXAMPLE 1. BALLONA CREEK, CALIFORNIA: USE ATTAINABILITY ANALYSIS

Ballona Creek is located in Southern California (in U.S. Geological Survey subbasin 18070104), where it flows as an open channel for 10 miles from Los Angeles through Culver City before it reaches the Pacific Ocean at Playa del Rey. Except for the estuarine portion of the creek, it is concrete-lined and extends into a series of storm drains that reach into West Hollywood and Beverly Hills. The stream has been classified as supporting a Water Contact Recreation designated use. According to the Los Angeles Basin Water Quality Control Plan, waters with this type "REC-1" use are suitable for recreational activities involving body contact with water, where ingestion of water is reasonably possible. Pathogens are among the pollution issues of concern. A UAA was conducted to determine if the REC-1 designated use assigned to the stream is appropriate.

The available economic analysis materials involve a narrative discussion only. The analysis of economic and social impacts of the recommended alternative (which would de-designate part of the creek for REC-1 use and subdivide the other part as "limited REC-1"), would aim to preserve the actual current and potential future uses of the creek. The study finds that it would impose no incremental costs on the Los Angeles County Department of Public Works or any of the affected municipalities when compared with the existing designations. The study finds that the recommended alternative would not interfere with developing housing in the area. In the available documentation, no specifics of more detailed economic analyses or the underlying economic data are presented.

Alternatives considered included establishing a stream-wide Total Maximum Daily Load (TMDL) for all of Ballona Creek or to change the use for the armored portions of the stream where the original habitat is significantly altered and restrict the TMDL to the estuarine portion. The UAA materials were presented to U.S. EPA Region 9 in 2003.

B.2. EXAMPLE 2. BLACKBIRD CREEK, IDAHO: USE ATTAINABILITY ANALYSIS

Blackbird Creek is located in Lemhi County in the Middle Salmon River-Panther Creek Basin (USGS subbasins 17060203 and 17060203) in east-central Idaho. The stream is about nine miles long and flows into Panther Creek. Blackbird Creek is contaminated with dissolved heavy metals and acid mine drainage from the inactive Blackbird mine. Reports from the 1930s indicate that mine tailings were channeled directly into the creek, and subsequent construction of settling ponds proved ineffective in preventing contamination of the stream due to frequent spills. The UAA work is related to concerns over designated uses involving aquatic life support and secondary contact recreation.

The available economic analysis materials involve a narrative discussion only. The Blackbird Creek UAA summarizes the analyses done to assess feasibility and plan restoration of water quality in Blackbird Creek as well as ongoing efforts to address similar mining-related impacts in the same general area for Big Deer Creek and Panther Creek. The contamination in these creeks results from mining activity in the area over the period from the late 1890s through 1982. A tributary of Blackbird Creek, Meadow Creek, originates and drains through the inactive Blackbird Mine. Blackbird Creek has received dissolved heavy metal loadings from acid mine drainage originating from exposed sulfide-containing ore and waste rock at the mine as well as historic mine waste disposal directly into the creek. The available UAA documentation describes the acid water conditions and high copper and cobalt concentrations in the creek. After undertaking remediation activities, upper Blackbird Creek (above Meadow Creek), Big Deer Creek, and Panther Creek will sustain salmonid spawning, cold water biota, and secondary contact recreation uses. Lower Blackbird Creek, which currently has only the most pollution-tolerant invertebrates and no fish, will only be able to attain secondary contact recreation uses.

Restoration of higher water quality in Lower Blackbird Creek was argued to be technically infeasible. No method of sufficiently reducing copper and cobalt concentrations to a level that would support salmonid spawning or aquatic life biota could be found. For this reason, it was recommended that these designated uses be removed for Blackbird Creek from its confluence with Meadow Creek to the mouth of the stream. Costs of early restoration activities were estimated to be $33 million. Water quality benefits were assessed qualitatively and quantitatively but were not valued. It was estimated that even if the cleanup of the mine was 100% effective that residual fractions of copper and cadmium in area sediments and other nonpoint sources would produce metal loadings in excess of state regulations. No analysis of the economic and social impacts of the restoration was reported because the use was found to be technically unattainable.

Various alternatives were explored to prevent clean water from contacting mining waste, collect and treat mine runoff, upgrade the existing treatment plant, and excavate the mine waste to see if existing designated uses could be met. In the available documentation, no detailed economic analyses or the underlying economic data are presented. Studies relevant to the UAA were initiated in 1983. The UAA materials were presented to U.S. EPA Region 10 in 1997.

B.3. EXAMPLE 3. BLACKS RUN, VIRGINIA: (PRELIMINARY) USE ATTAINABILITY ANALYSIS

Blacks Run is located in northwest Virginia in the South Fork Shenandoah River Basin (USGS subbasin 02070005). Blacks Run drains most of the city of Harrisonburg, Virginia, an urban area of approximately 12,255 acres (19 square miles). Blacks Run flows into Cooks Creek. Neither of these streams is considered to support its current primary contact recreation, secondary contact recreation and aquatic life designated uses due to violations in general (benthic) criteria and fecal coliform bacteria. Pollutants of concern include total phosphorus, suspended solids, biological oxygen demand (BOD), ammonia, pathogens, and other possible unknown pollutants. The sources may include agriculture, municipal wastewater treatment facilities and commercial land uses.

The available economic analysis materials include a narrative discussion included as part of a study related to establishing TMDLs. Sediment and phosphorus loading TMDL analyses have been performed starting in 2002, and the pollution reduction findings from these TMDL loading analyses are deemed appropriate to a wider range of pollutants (e.g., pathogens) of concern on Blacks Run. Sections of these studies exploring TMDL implementation consider the development of a variety of cost-effective best management practices (BMPs) and stress that Virginia’s 1997 Water Quality Monitoring, Information, and Restoration Act calls for, among other analyses, an assessment of costs and benefits of implementation plans for achieving water quality. Such state-mandated studies do not automatically constitute a formal UAA, but Virginia is considering pursuing this option with U.S. EPA Region 3 if the implementation of reasonable BMPs fails to improve or restore the benthic community and additional controls have the potential for widespread social and economic impacts.

B.4. EXAMPLE 4. BOSTON HARBOR AREA, MASSACHUSETTS: USE ATTAINABILITY ANALYSIS

The study area includes Upper and Lower inner Boston Harbor and a series of tidally-influenced estuary and river systems contained in portions of USGS subbasin 01090002. The tidally influenced system includes Chelsea Creek, Island end, the Little Mystic Channels, and the tidal portions of the Mystic and the Charles River. These waters are part of the Massachusetts Water Resource Authority (MWRA) service area, and this sewerage system has combined sewer overflows (CSOs). While the MWRA has pursued remediation approaches to minimize the impacts from wet weather discharges from these emergency outfalls, there have been concerns over the feasibility of attaining a primary contact designated use under the Massachusetts WQS Class A for freshwater or Class SA for estuarine and marine waters due primarily to elevated levels of pathogens during the wet weather CSO releases.

The available economic analysis materials from the Massachusetts Department of Environmental Protection (DEP) submitted to U.S. EPA Region 1 in 1997 involve primarily a narrative discussion based on the argument that improvements in treatment efficiencies beyond certain levels reach a “knee of the curve” from a technical perspective. Apparently other information is presented noting that there could be significant increases in utility rates and other impacts to the local communities that should be viewed as leading to widespread adverse social and economic impacts.

In 1998, U.S. EPA Region 1 approved changes in the designated use for these waters in the Boston Harbor area to reflect a secondary contact recreation status, which would be Class B for freshwater or Class SB for estuarine and marine waters under the Massachusetts WQS. The Region noted that the Massachusetts DEP easily could have developed a more cogent set of arguments by assembling cost figures on likely increases in household utility charges to upgrade the centralized wastewater system to substantially eliminate the wet weather CSO releases. Other figures easily could be assembled related to the impacts of the capital costs for upgrades of this magnitude on the tax bases of local government and likely impacts on the bond rating status for smaller towns such as Chelsea. The Region provided the Massachusetts DEP with examples for the cities of Chelsea and Boston on how utility upgrades to virtually eliminate the CSO impacts would be rated for five factors described in U.S. EPA’s 1995 *Interim Economic Guidance for Water Quality Standards: Workbook* (EPA/823/B-95/002) as indicating widespread adverse social and economic impacts. The Region approved the changes in the designated uses with the understanding that the focus was on impacts from pathogens such as fecal coliform. As part of the triennial WQS review process, the Region encouraged the Massachusetts DEP to continue to study how to apply appropriate numeric criteria to waters in the Boston Harbor area. The Region also stressed that additional justifications would be needed to consider changes related to impacts from toxic pollutants.

B.5. EXAMPLE 5. BURNT RIVER, OREGON: USE ATTAINABILITY ANALYSIS

The Burnt River watershed (USGS subbasin 17050202) covers an area of approximately 1,100 square miles in eastern Oregon. The main tributaries of the Burnt River originate in the Blue Mountains and join the Burnt River mainstem just upstream of the Unity Reservoir. This reservoir stores spring runoff and is used to irrigate crops in the surrounding area. There are concerns involving the present aquatic life designated use involving the temperature criteria for the mainstem of the Burnt River below the reservoir.

The available economic analysis materials involve a narrative discussion only. These materials include a short discussion on socioeconomic issues that summarizes rancher concerns about TMDLs under development to reduce water temperatures in Burnt River. Ranching interest groups have expressed concern that achieving the reductions in water temperature may be technically infeasible and that attempting to achieve them may put their livelihoods at risk. No detailed assessment of these possible economic or social impacts is reported in the available materials. Alternatives being considered include attempting to meet temperature criteria by adding trees and other vegetative shading measures or allowing temperature exceedances in summer. Studies on the Burnt River watershed were initiated in 2000, and UAA-relevant materials were presented to U.S. EPA Region 10 in 2002.

B.6. EXAMPLE 6. CAYADUTTA CREEK, NEW YORK: USE ATTAINABILITY ANALYSIS

Cayadutta Creek is located in central New York and flows into the Mohawk River. The creek drains an area of 62.7 square miles (within USGS subbasin 02020004) that includes urbanized areas in the cities of Gloversville and Johnstone. Tanneries in the area had contributed to increased water temperatures and high concentrations of chromium, ammonia, phosphorus and turbidity. Monitoring also indicated lower dissolved oxygen concentrations below the discharges from the tanneries. Because of this, Cayadutta Creek was assigned a Class D designated use by the state. New York State uses a class system to designate the quality of the state's waters. Class D waters are suitable for fishing and support fish survival but not fish propagation. Class C waters support both fish survival and propagation. A UAA was conducted to determine if it was possible to reclassify Cayadutta Creek as a Class C water.

Work on the Cayadutta UAA started in 1987 and continued through 1996. Information is available on cost data for alternative management approaches. The UAA has considered different ways to attain a more appropriate classification of Cayadutta Creek. During the late 1980s, the publicly owned treatment works (POTWs) on the stream were undergoing a major upgrade to achieve Class D limits. If the stream was reclassified as a Class C stream, additional further wastewater treatment investments would be required, and the tanneries themselves would also incur incremental pretreatment costs prior to discharging their wastewater to the POTW. The UAA analyzes impacts on the POTW, the tanneries, and the local economy. Costs to upgrade the POTW to achieve Class D limits are estimated as $35.1 million, plus $2.7 million for a sewer rehabilitation project; both of those amounts are eligible for federal and state aid, which reduces the local burden to an estimated 15% of that total. To meet Class C limits, the POTW would incur an additional $2 million and would pass through incremental annual costs of $206,000 to the tanneries. The analysis, based on costing estimates from "model" plants, concludes that additional incremental pretreatment costs at the tanneries will result in the tanneries becoming unprofitable and will result in potentially substantial and widespread economic impacts.

The UAA used data collected by U.S. EPA to support development of effluent limitations for the industry; these data are presented as seven model plants. U.S. EPA and the New York Department of Environmental Control (NYDEC) collected some primary data from the tanneries to verify that the model plants were adequately representative. They analyzed the costs of meeting Class C limits (estimated total annualized costs ranging from $59,000 to $1.1 million per plant, depending on wastewater flows) and concluded based on financial analysis that these costs would result in the tanneries becoming unprofitable. Based on an analysis of the role of the tannery industry in the local economy, the UAA concludes (and NYDEC and U.S. EPA concurred) that achieving Class C limits would result in substantial and widespread economic and social impacts. U.S. EPA Region 2 approved this UAA in 1996.

B.7. EXAMPLE 7. DELAWARE ESTUARY IN DELAWARE, PENNSYLVANIA, AND NEW JERSEY: USE ATTAINABILITY ANALYSIS

The Delaware River Basin includes areas of Delaware, Pennsylvania, and New Jersey, with the Delaware River system extending upstream into New York. The basin has a drainage area of over 111,400 square miles. The lower 86 miles of the Delaware River form the Delaware Estuary. The estuary flows through Camden, New Jersey; Philadelphia, Pennsylvania; and Wilmington, Delaware. Discharges from many municipal and industrial wastewater treatment facilities have reduced the dissolved oxygen content of the waters in the estuary. A study was conducted through the Delaware Estuary Program (part of the National Estuary Program) to determine what would be necessary to upgrade wastewater treatment facilities to achieve the designated uses of the estuary.

The available economic analysis materials involve a narrative discussion only. In 1989, the Delaware River Basin Commission undertook studies relevant to a formal UAA as part of the process to complete the National Estuary Program Comprehensive Conservation and Management Plan (CCMP). In the CCMP, the potential benefits of a sustainable approach that combines environmental protection with economic development were discussed in detail with the CCMP also containing a section dealing with Financial Planning for the Delaware Estuary Program (DELEP) Comprehensive Conservation and Management Plan. The financial plan lists numerous potential sources of funding for implementation of the plan, including current programs, donations, user fees, and redirection of penalties collected by U.S. EPA and the states. There are summaries of quantitative measures of the water quality improvements that have resulted from wastewater treatment. No discussion of potential impacts or comparison of costs and benefits was made. Alternatives discussed included upgrading a varying number of municipal and industrial wastewater treatment plants to allow attainment of various designated uses including secondary contact recreation and aquatic life support. Pollution issues of concern include BOD, nutrients, pathogens, priority pollutants in contaminated sediment, and priority pollutants in aquatic food chains that have led to states issuing fish consumption advisories for the protection of public health. Approval of the Delaware Estuary Program CCMP involved both U.S. EPA Region 2 and Region 3. It is not clear that provisions of the UAA-relevant studies completed under this National Estuary Program have been formally adopted into the U.S. EPA-approved WQS of the states of Delaware, Pennsylvania, and New Jersey.

B.8. EXAMPLE 8. GULF ISLAND POND, MAINE: USE ATTAINABILITY ANALYSIS

Gulf Island Pond is an impoundment on the Androscoggin River in southwestern Maine (in USGS subbasin 01040001). The reservoir extends from the towns of Lewiston to Turner. A four-mile segment of Gulf Island Pond upstream of Gulf Island Dam is on the 303(d) list for Maine as an impaired water due to low DO content and yearly algal blooms. The main designated use of concern is primary contact recreation. Discharges from three paper mills and five municipal point discharges upstream of the impoundment contribute to the contamination. There is excessive sediment oxygen demand, so that water escaping the impoundment is low in DO, and removal of the dam would increase the DO content of the Androscroggin River.

The available economic analysis materials present cost data on seven different alternatives to meet WQS. The complete set of alternatives include

(1) no action
(2) status quo cleanup efforts
(3) status quo with nutrient reduction
(4) removing the dam
(5) reducing point sources
(6) status quo with nonpoint source reductions, and
(7) point source reduction with oxygen injection.

Two of the alternatives include a discussion of socioeconomic costs and benefits, and one alternative provides a discussion of estimates for the costs of implementing the alternative. Alternative 3, which proposes removal of the dam in Gulf Island Pond, discusses the loss of power production and recreational opportunities associated with flat-water boating and fishing and the benefit of flowing water opportunities for boating and fishing that would result from dam removal. Dam removal also could release highly organic or toxic sediments to the river below. While the extent of possible damage is unknown, a qualitative evaluation of costs and benefits made this option unattractive. Alternative 7, operating the existing Gulf Island Pond Oxygenation Project and adding a second oxygenation facility with ancillary point source reductions, is listed as the preferred alternative. The economic discussion for the preferred alternative involves a rough estimation of annual implementation costs. No socioeconomic benefits are discussed for this preferred alternative. The UAA studies began in 2000, with subsequent studies submitted to U.S. EPA Region 1 through 2003.

B.9. EXAMPLE 9. LOWER FRENCH GULCH AND BLUE RIVER, COLORADO: USE ATTAINABILITY ANALYSIS

French Gulch is located in central Colorado and is part of the Blue River Basin (USGS subbasin 14010002). The stream flows into the Blue River near the town of Breckenridge. Approximately 80 square miles of French Gulch and portions of Blue River are impacted by acid mine drainage from the former Wellington-Oro Mine site. Designated use concerns focus on aquatic life support. Aquatic life has experienced impacts from high concentrations of zinc and cadmium and destruction of habitat.

The available economic analysis materials involve a narrative discussion only. The UAA process examined proposals to improve water quality and aquatic habitat in Lower French Gulch and Blue River to permit establishment of a brown trout fishery. The UAA studies recommend restoration of water quality and habitat in Blue River but not in all of French Gulch. The expense and potential economic impacts of restoring French Gulch, together with concerns that it might permit upstream migration of nonnative fish that could threaten a population of native Colorado River Cutthroat trout that live in the upper reaches of French Gulch, resulted in a recommendation that water quality be restored to such ambient quality as can be accomplished by upgrading the existing Wellington-Oro treatment facility and that no attempt be made to restore the physical aquatic habitat.

The analysis report estimated costs for upgrading the treatment facility and noted that the value of the native trout population far exceeds the value of a potential brown trout fishery in the lower reaches of the Gulch. While not a demonstration of substantial or widespread social or economic impact, the study does provide a qualitative assessment of costs and benefits of the potential water quality improvements to support its decision. The primary alternatives discussed related to the extent to which the aquatic life use should be restored (throughout the entire reach or in isolated areas to protect native trout populations). The UAA studies began in 2002, with subsequent studies submitted to U.S. EPA Region 8 through 2003. Final U.S. EPA action on the UAA recommendations is still under review.

B.10. EXAMPLE 10. LOWER HUDSON RIVER, UPPER EAST RIVER, AND LONG ISLAND SOUND IN NEW YORK: (PRELIMINARY) USE ATTAINABILITY ANALYSIS

The study area includes the Lower Hudson River, East River, and portions of Long Island Sound located in southernmost New York. These waters drain nearly 16,000 square miles including much of New York City. For many years, these waters were listed as Class D waters. New York State uses a class system to designate the quality of the state's waters; Class D waters are suitable for fishing and support fish survival but not fish propagation. Class C waters support both fish survival and propagation. A UAA was conducted to determine which waters in the area were able to meet criteria associated with Class C or other "higher" use classifications. The primary designated uses of concern involve aquatic life support and primary contact recreation. The major pollutants of interest involved nutrients. The studies summarized in this example were initiated in 2002 and have been shared with U.S. EPA Region 2. These studies are related to the Long Island Sound Study involving states in both U.S. EPA Region 2 and Region 1.

The available economic analysis materials involve a narrative discussion only. The materials are presented as a type of regulatory impact statement and are apparently not intended to constitute a formal UAA. No specific plan of action is recommended for reclassifying bodies of water, but the there is a general discussion of the entire regulatory process. The argument is advanced that reclassification of fresh surface waters in the Lower Hudson River and Upper East River-Long Island Sound Drainage Basins will provide a current basis for water protection and will lead to improved water quality in the long run due to increased protection. The costs associated with reclassification may include increased operation and maintenance costs to meet WQS. The reclassification proposal affects 546 surface water discharge State Pollutant Discharge Elimination System (SPDES) permits, each of which must be reviewed to determine possible cost impacts from reclassification. It was determined that there were no current costs to SPDES dischargers since the higher use classifications were currently supported by their current permit effluent limits. Additionally, potential costs to previously unclassified waters were determined to be negligible. Costs from reclassification (e.g., advertising and holding public hearings) will likely accrue to the regulating agency. While some discussion of the economic impacts of reclassification was provided, no costs were quantified in the use attainability studies associated with this project. No alternatives discussion was provided.

B.11. EXAMPLE 11. LOWER SALMON FALLS RIVER, MAINE: USE ATTAINABILITY ANALYSIS

The Salmon Falls River forms the boundary between Maine and New Hampshire for its entire length of more than 40 miles (in USGS subbasin 01060003). At its lower end, it becomes a tidal estuary, and its name changes to the Piscataqua, which forms the state boundary for an additional 10 miles. Flow for the entire river is regulated at its headwaters at Milton Pond. There are four dams in the first five river miles. Effluent from the town of Milton discharges to the river just below Spaulding Pond at about 20 miles above head of tide. Effluents from the towns of Berwick and Somersworth discharge to the Rollinsford impoundment and the town of Rollinsford's effluent discharges to the South Berwick impoundment. South Berwick's effluent discharges just below the South Berwick dam at head of tide, and the town of Dover's effluent discharges in the estuary about 5 miles below head of tide. In the mid to late 1980's and throughout the 1990's a dissolved oxygen problem became evident on the lower portion of the Salmon Falls River, since sampling always indicated some nonattainment of Maine's Class B dissolved oxygen standards. Dissolved oxygen content is often linked to aquatic life designated uses. Under the CWA, when two states share the same water body, the most stringent WQS applied to the water body should prevail. For this reason, it is necessary for the Salmon Falls River to meet the most stringent applicable water quality criteria. Maine's Class B criteria for dissolved oxygen is 7 parts per million (ppm) with 75% saturation. Maine's Class C dissolved oxygen criteria (5 ppm and 60% saturation) is similar to New Hampshire's Class B criteria (5 ppm).

Materials available describe a set of monitoring and modeling studies combined with cost data for alternatives. The Maine Department of Environmental Protection conducted a UAA because water quality modeling suggested that, after considering available options, Maine's Class B dissolved oxygen goal is unattainable for a 5.5 mile segment of the Salmon Falls River from Berwick (Route 9 bridge) to South Berwick (head of tide). The UAA included a careful examination of the costs of all possible alternatives of river cleanup and concluded that a sub-categorization for that segment was required, due to both physical and economic considerations. It is argued that both dams and point source inputs significantly influence water quality degradation on the Salmon Falls River, and it is not believed that there are any cost-effective or practicable alternatives to meet Class B WQS on the 5.5 mile segment. The UAA summarizes a separate document (not reviewed) that analyzed the economic impacts of five nontreatment and four waste treatment alternatives, ranging in cost from $1.4 million to $18.9 million. Alternatives considered included upgrading the municipal wastewater treatment facilities, removing dams, in-stream aeration, and advanced wastewater treatment. The UAA recommends reclassification from Maine Class B to Class C and implementation of the most cost-effective treatment option, Level 2 advance treatment, that results in attainment of WQS. Level 2 treatment is estimated to achieve WQS, and this facility upgrade would cost about $3.8 million. Higher levels of advanced treatment that were examined are not certain to achieve significant benefits in water quality (model projections of dissolved oxygen and chlorophyll *a*) and would double or triple the costs of Level 2. Implementing Level 2 treatment would increase sewer rates by 1-9% for smaller plants and 15-20% for larger plants. Sewer rates would remain less than 2% of median household income and are, thus, deemed affordable. The UAA studies began in 1994, with subsequent studies submitted to U.S. EPA Region 1 through 1999.

B.12. EXAMPLE 12. SANTA ANA RIVER, CALIFORNIA: USE ATTAINABILITY ANALYSIS

The Santa Ana River (SAR) is located in Southern California and is an effluent-dominated stream that begins in the San Bernardino Mountains and flows southward through urbanized areas. The river discharges into the Pacific Ocean about 50 miles downstream. The river (in USGS subbasin 1870203) was ephemeral prior to industrialization of the area when discharges transformed the lower two-thirds of its length into a perennial stream. In recent years, discharges from municipal water treatment at publicly-owned treatment works (POTWs) have extended hydraulic continuity to the upper reaches of the river. A study was conducted to determine if the uses associated with the stream were appropriate given the fact that the stream is used for flood control and cement-lined in some reaches. The main concerns involve the designated use for aquatic life. Pollutants of concern include toxics such as ammonia, cadmium, copper, lead, chromium, mercury, silver, chlorine, and nitrite.

The available UAA materials include cost data for changes to the current designated uses based on studies conducted to address ammonia and heavy metals concerns and to characterize the SAR for basin-wide management planning. In addition to summarizing assessments of water chemistry, physical parameters, microbiological and biological assessment, biomonitoring, habitat assessment and hydrologic characterization, the UAA includes a socioeconomic impact analysis. The socioeconomic impact analysis examined annual economic costs to ratepayers and citizens of the affected communities. The model analyzed first order impacts such as impacts upon utility rates, employment, earnings, and tax revenues. The UAA analyses, initiated in the mid-1990s, were implemented so that they would generally follow the updated guidelines on the determination of widespread and substantial social and economic impacts in the second edition of U.S. EPA's Water Quality Standards Handbook (EPA/823/B-94/005a). In addition, second order impacts such as the health impact of unemployment, impacts on housing affordability, impacts on fixed and low income households and impacts on bond ratings of local governments also were analyzed. The UAA found that taken together, nitrogen removal, tertiary treatment, metals and total dissolved solids (TDS) removal requirements would cause widespread and substantial social and economic impacts. Particularly, the study projected substantial unemployment as a result of the requirements, which in turn would result in increased morbidity and mortality and increased crime, divorce, and abuse. The study also projected increased utility rates, impacts on public debt and impacts on low and fixed income individuals.

The analysis argues that water quality in one portion (Reach 4) of the SAR does not fully support the potential beneficial aquatic life use due to chlorine, ammonia, and nitrite; present levels of heavy metals do not appear to impact warm water aquatic life, recreational or groundwater recharge beneficial uses. Since the POTWs discharging into the SAR do not significantly contribute to chlorine, nitrate, and ammonia concentrations, advanced treatment at POTWs would thus not yield significant benefits. The health impacts of unemployment are not always considered in these types of impact analysis because there are lingering empirical and statistical issues that have not been resolved. Even without these impacts, however, the UAA appears to make the case that other impacts are potentially significant and widespread and that heavy metals loadings are not as serious an issue in fact as the modeling originally suggested. The alternatives were to remove the flood control protections allowed by the river and establish a streamwide TMDL to meet current aquatic life uses or to change designated uses to a warm water fishery designation for parts of the river system. The UAA was submitted to U.S. EPA Region 9 by 1999, and U.S. EPA has approved the designated use changes.

B.13. EXAMPLE 13. WHITE RIVER, INDIANA, COMBINED SEWER OVERFLOW REVIEW: USE ATTAINABILITY ANALYSIS

The White River is located in south-central Indiana (in USGS subbasin 05120201). It has a drainage area of approximately 11,350 miles and is part of the Mississippi River system. Fall

Creek is one of two major tributaries to the White River. This river system is the primary drinking water source of the City of Indianapolis. The city has approximately 135 combined sewer overflow (CSO) outfalls. Combined sewer systems can back up during rain events and flush untreated sewage through emergency outfalls into receiving waters. The city initiated a study in 2001 to determine ways to reduce the impacts of these events on the waters and to determine the practicality of a primary contact recreation use in these waters. Pollutants assessed as part of the special CSO and UAA studies include pathogens, BOD, PCBs (related to fish consumption advisories), mercury (also related to fish consumption advisories), and metals and other organic toxics in contaminated sediments.

The White River Final Long Term Control Plan Report provides a financial capability assessment, a detailed description of the methods and findings of an assessment of the economic achievability of CSO controls that includes cost data for alternatives. The methods used follow U.S. EPA's 1997 *Combined Sewer Overflows: Guidance for Financial Capability Assessment and Schedule Development* (EPA/832/B-97/004). The analysis examines estimated current and future wastewater treatment, utility, and CSO elimination costs per household as a share of median household income for Marion County, Center Township, and Indianapolis, Indiana. The results indicate that residents of Marion County and Center Township face a potentially high burden, while Indianapolis residents face at least a medium burden. The analysts then examined other potential social and economic impacts and found the potential for losses of retail and manufacturing jobs, reductions in population and housing stock, and possible financial shortfalls for the city and county.

The study examines the affordability and potential for substantial and widespread social and economic impacts resulting from implementation of CSO controls. Alternatives were considered over a range of the percentage of CSOs to be eliminated (0, 85, 92, 96, 98, 99 or 100%) and for special technologies the technologies applied to reduce BOD (e.g., accelerated septic treatment). Arguing that actual impacts depend on the final CSO control schedule negotiated between the city, the Indiana Department of Environmental Management, and U.S. EPA, the study recommends a 20-year implementation schedule. Data and computations used to support the finding that the controls may pose a financial burden are discussed in detail. Description of the analysis of other possible social and economic impacts is more qualitative and includes a demographic and economic characterization of baseline conditions in the affected area, a summary of other financial issues facing the city and county and a discussion of the potential for reduced economic growth if sewer rates increase to disproportionately high levels relative to neighboring counties. These CSO and UAA materials were submitted to U.S. EPA Region 5 during 2001.

B.14. EXAMPLE 14. DEVILS LAKE OUTLET, NORTH DAKOTA: ANTIDEGRADATION REVIEW

Devils Lake is a large natural water body located in east-central North Dakota. This area is called the Devils Lake Basin. This is an isolated basin that has no natural outlet due to geomorphological factors going back to the ice ages. If Devils Lake were a small feature, it would be viewed as a prairie pothole isolated wetland, but Devils Lake and its associated basin are quite large. The watershed measures 3814 square miles, and the lake surface area is approximately 214 square miles. The area has received above-average rainfall from 1993 onward, resulting in a 25-foot increase in lake elevation. An AR was conducted to determine if draining a portion of the lake into the adjacent basin of the Sheyenne River (a tributary of the Red River in Minnesota) would impact water quality in North Dakota, Minnesota, Canada, or tribal lands. Devils Lake has a Tier 2 antidegradation status. The major designated uses of concern are aquatic life and recreation. There are also concerns relevant to other U.S. EPA programs and other natural resources issues involving wetlands, migratory birds, and endangered species. Studies relevant to AR have analyzed such pollutants as TDS and sulfates. The AR process has been an important issue for the local agricultural community and other agricultural interest groups. There are also interests from Manitoba, Canada, and the Spirit Lake Nation Indian Tribe.

There are a variety of documents available about this project, including materials that provide cost data for alternatives. In the analysis performed by the U.S. Army Corps of Engineers, changes in water quality are discussed as one consideration in determining the amount of water that should be released. The impact of the project on economic and social development is not analyzed. The only costs or impacts that are discussed in the reviewed documents are the costs of continued naturally-occurring increases in water levels in Devils Lake. Alternatives considered were to allow a continuation of the present flooding patterns in the area or to partially drain the lake, resulting in possible water quality degradation in the Sheyenne

River. These AR studies were initiated in 2001, with the latest reports submitted to U.S. EPA Region 8 in 2003.

B.15. EXAMPLE 15. NORTHWEST BASINS, WYOMING: ANTIDEGRADATION REVIEW

A study was conducted to determine if proposed discharges from the processing of coal bed methane would impact water quality in surface waters of northeastern Wyoming. The study area covers over 20,000 square miles along the Powder, Belle Fourche, and Cheyenne River Basins in northwestern Wyoming (the "Northwest Basins"). The primary contaminant of concern in this evaluation was barium, which had the potential to impact certain public water supplies. In addition to the drinking water designated use, the AR also took into account possible impacts for other uses such as agriculture, aquatic life, wildlife, and recreation. Antidegradation Tier 2 issues were involved.

The available information included cost data for alternatives and covered three main areas of socioeconomic analysis: (1) Determination of significance, (2) Economic evaluation, and (3) Examination of alternatives. Although variations in watersheds may require different necessary levels of degradation, this review is conducted on an area-wide basis. For the first evaluation step, it was determined that potential degradation due to barium is significant and necessitates economic analysis. The economic evaluation must determine that the degradation is necessary for important economic or social development in the affected area. This report follows the practice of presuming importance unless the public review reveals contrary information. A complete economic analysis was submitted by the Petroleum Association of Wyoming and included estimation of tax revenues from the development of 30,000 coal bed methane wells in addition to an evaluation of the economic significance of the development in terms of capital expenditures and job creation. While the degradation proposal reports a summary of potential tax revenue and capital investment, there is no information on the generation of these numbers. The AR analysis and findings prepared by the Wyoming Department of Environmental Quality (DEQ) correctly recognizes the need to demonstrate that degradation is necessary to permit important economic or social development in the area. The summary report does not provide information about the local economic impacts but does suggest that proceeds to the state from these developments would be almost $2.3 billion. They state that "normally," activities that result in degradation are "presumed important unless information to the contrary is submitted in the public review process." This is not "normal" practice for antidegradation in general, although it may be normal for Wyoming DEQ antidegradation studies.[1] The alternatives discussion was essentially an exercise to determine the barium assimilation capacity of the region's watersheds. U.S. EPA Region 8 has approved the recommendations of this AR.

B.16. EXAMPLE 16. SNAKE CREEK, OKLAHOMA: ANTIDEGRADATION REVIEW

Snake Creek is located in central Oklahoma in Mayes County (USGS subbasin 11070209). It has a drainage area of about 38 square miles and is approximately 15.5 miles long. Snake Creek flows into Spring Creek, which is an Oklahoma High Quality Water (HQW). A tributary to Snake Creek, Little Spring Creek, is also a HQW. A UAA also was conducted to determine if Snake Creek could achieve the same water designation as its tributary. The designated uses of concern involve aquatic life support and a special Oklahoma aquatic life use. Nutrients are the primary pollutants of concerns. Potential pollutant sources include agricultural land uses, mainly related to the ground application of poultry litter from animal feeding operations. This involves a Tier 2.5 (or HQW) AR under the system followed in Oklahoma's WQS.

The available documentation provides only narrative summaries of the AR and the companion UAA. To assess potential economic impacts from changing the designation of Snake Creek to HQW, the Oklahoma Water Resources Board (OWRB) solicited input from all state environmental agencies. The first response, from the Oklahoma Department of Agriculture, Food, and Forestry, referred to the six poultry operations in the Spring Creek watershed. Poultry house litter may be a nonpoint source of pollution in the watershed, and the HQW designation for Snake Creek would prohibit plants from expanding beyond 125,000 birds. However, Snake Creek was incorrectly identified as Little Spring Creek (which is already HQW) on the OWRB 1982 basin map of the area, so the poultry operations will experience no change in operations or cost due to the change in designation. An additional response from the Corporation Commission, Oil and Gas Division, had no opinion on the change. No other impacts were indicated, and the only benefit cited is the protection of Snake Creek water quality and possible remediation of Fort

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[1] According to the Region 8 Antidegradation Guidance (U.S. EPA, 1993, p. 20), "the applicant is required to demonstrate the social and economic importance of the proposed activity." This differs from the applicant presuming importance. Preliminary determination of importance by the Division will depend on the analysis of the applicant (U.S. EPA, 1993).

Gibson Reservoir water quality. This study combines aspects of UAAs with an AR. It includes an appropriate consideration of potential economic impacts, which indicated no incremental economic or social impact due to upgrading the designated use of Snake Creek. Since the impacts would be neither substantial nor widespread, they do not constitute an impediment to designating the Creek as a Cold Water Aquatic Community. The alternatives considered were upgrading designated use or leaving as listed currently. Development of the AR and the trial UAA was initiated in 2001, and the AR materials were submitted to U.S. EPA Region 6 in the same year. U.S. EPA Region 6 has approved the recommendations of this AR.

B.17. EXAMPLE 17. SYCAMORE CREEK, OHIO, WASTEWATER TREATMENT PLANT UPGRADE: ANTIDEGRADATION REVIEW

Sycamore Creek is located in southern Ohio (USGS subbasin 05090202). The creek is about 4.5 miles long and has a drainage area of 25 square miles. The Sycamore Creek wastewater treatment plant (WWTP) discharges into Sycamore Creek 0.25 miles upstream of the creek's confluence with the Little Miami River. A WWTP upgrade was planned to meet existing and future wastewater treatment needs. As part of an AR for upgrading the WWTP, regional solutions were evaluated along with the preferred design, nondegradation and minimal degradation alternatives. The degradation alternatives were evaluated with respect to meeting Ohio WQS associated with the Little Miami River and its designation as an Exceptional Warmwater Habitat and State Water Resource. Designated uses of concern include Agriculture, Aquatic Life Support, Industrial Water Supply, and Primary Contact Recreation. The major pollutants considered in the AR involved BOD, ammonia, total phosphorus, and total suspended solids. This involves a Tier 2.5 (for Exceptional Warmwater Habitat Waters) AR under the system followed in Ohio's WQS.

The available materials summarize economic analysis on the benefits gained and lost as a result of each of three alternatives. The alternatives considered to meet future needs were to remove excess flows from the system, construct retention basins, transport treated flow from the area, or provide a means to split the flow entering the plant during wet weather events. For all three alternatives, the economic and social benefits are discussed in a general sense. The AR argues that the increased recreational value of Sycamore Creek, Little Miami River, and/or their receiving streams (depending on the specific alternative) is the main social and economic benefit. The review indicates that, out of the three alternatives, the preferred design alternative offers the greatest social and economic benefits to the Sycamore Creek watershed and surrounding communities, but there is no economic or quantitative analysis to support this claim. The discussion of benefits lost for each of the three alternatives is likewise qualitative and does not indicate any specific expected losses. Environmental benefits are discussed in technical detail, but there is no quantitative value assigned to expected changes in pollutant loadings. The studies to support the AR were initiated in 1993, with the latest materials submitted to U.S. EPA Region 5 in 2003.

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APPENDIX C
U.S. EPA/NCEA WORKSHOP—AGENDA AND PARTICIPANTS

On November 14–15, 2006, U.S. EPA/NCEA sponsored a workshop entitled “Weighing the Ecological Risks, Benefits, and Costs in Use Attainment Decisions.” The focus of the workshop was an earlier draft of this report (Chapters 1 through 4). The objectives of the 2-day workshop were to (1) critically examine the draft report, (2) employ three case studies of use-attainment problems to evaluate a draft implementation process and (3) hold discussions with practitioners and stakeholders to establish processes and methods for incorporating community preferences into water quality management decisions. The workshop brought together 20 experts from various parts of U.S. EPA, from state and local organizations, and from Research Triangle Institute. The workshop agenda and the roster of participants are included below.

C.1. WORKSHOP AGENDA

WEIGHING ECOLOGICAL RISKS, COSTS, AND BENEFITS IN USE-ATTAINMENT DECISIONS

November 14-15, 2006
Andrew W. Breidenbach Environmental Research Center
26 W. Martin Luther King Drive
Cincinnati, OH 45268

Sponsor: National Center for Environmental Assessment—Cincinnati Office (NCEA-Cin),
U.S. Environmental Protection Agency

General Sessions in Room 130
Case Study #1—Acid Mine Drainage in Room AG-30
Case Study #2—Combined Sewer Overflow (CSO) in Room 138
Case Study #3—Agriculture and Development in Watershed in Room 130

WORKSHOP SCHEDULE

Tuesday, November 14, 2006

8:00 **Registration**

8:30 **Welcome and Opening Remarks,**
Goals and Objectives of the Workshop
Matt Heberling, EPA/NCEA

Review of Workshop Agenda and Ground Rules
David Driscoll, RTI

Introduction of Workshop Participants

Summary Review of the *EPA Report*
Matt Heberling, EPA/NCEA

9:30 **Discussion and Critique of the *EPA Report***

- Discussion of Chapters 1 and 2
  David Pfeiffer, USEPA
  - Q&A

- Discussion of Chapter 3
  Anne Sergeant, USEPA
  - Q&A

- Discussion of Chapter 4
  Hale Thurston, USEPA
  - Q&A

10: 30 ***Break***

10:45 **General Discussion of the 3 Report Critiques**

David Driscoll, RTI

11:15 **Overview of 3 Case Studies for Working Groups**

- Case Study #1—Acid Mine Drainage

  Evan Hansen

- Case Study #2—Combined Sewer Overflow (CSO)

  Jason Heath

- Case Study #3—Agriculture and Development in Watershed

  Adam Schnieders

12:30 ***Lunch***

1:30 **Breakout Session 1: Framing the WQS Problem Using the Expanded Conceptual Model(s)**

3:15 ***Break***

3:30 **General Session: Review of Breakout Session 1**

George Van Houtven, RTI

- Summary of Case Study 1 Framework
  - *Person selected by break out group*

- Summary of Case Study 2 Framework
  - *Person selected by break out group*

- Summary of Case Study 3 Framework
    - *Person selected by break out group*

4:30 **General Discussion of Session 1**

George Van Houtven, RTI

5:00 ***Adjourn***

Wednesday, November 15, 2006

8:30 **Welcome and Opening Remarks for Day 2**

Summary of Issues from Breakout Session 1

George Van Houtven, RTI

9:00 **Breakout Session 2: Applying the Framework and Assessment Tools to Support WQS Decision-Making**

10:45 ***Break***

11:00 **General Session: Review and Discussion of Breakout Session 2**

- Summary of Case Study 1 Process
  - *Person selected by break out group*
- Summary of Case Study 2 Process
  - *Person selected by break out group*
- Summary of Case Study 3 Process
  - *Person selected by break out group*

12:30 ***Lunch***

1:30 **Summary of Issues from Breakout Session 2**

David Driscoll, RTI

1:45 **Discussion of Recommendations and Next Steps**

3:30 **Closing Remarks and Workshop Summary**

4:00 ***Adjourn***

C.2. ROSTER OF WORKSHOP ATTENDEES

Robert Broz
University of Missouri, Extension Faculty
Columbia, MO

Randall Bruins
U.S. EPA, Office of Research and Development, National Exposure Research Laboratory
Cincinnati, OH

Timothy Connor
U.S. EPA, Office of Water, Water Quality Standards Program
Washington, DC

David Driscoll
Research Triangle Institute
Research Triangle Park, NC

Nancy Ellwood
Millcreek Valley Conservancy District
Hamilton, OH

Jacquelyn Ferguson
U.S. EPA, Region 7, Southwest Missouri Field Office
Springfield, MO

Evan Hansen
Downstream Strategies, LLC
Morgantown, WV

Jason Heath
Ohio River Valley Water Sanitation Commission
Cincinnati, OH

Matthew Heberling
U.S. EPA, Office of Research and Development, National Risk Management Research Laboratory
Cincinnati, OH

Tara A. Maddock
Mill Creek Watershed Council of Communities
Cincinnati, OH

Kimberly Matthews
Research Triangle Institute
Research Triangle Park, NC

Matthew Morrison
U.S. EPA, Office of Research and Development, National Risk Management Research Laboratory
Cincinnati, OH

David Pfeifer
U.S. EPA, Region 5
Chicago, IL

Elliot Rosenberg
U.S. EPA, Region 10
Seattle, WA

Adam Schnieders

Iowa Department of Natural Resources

Des Moines, IA

Anne Sergeant

U.S. EPA, Office of Research and Development, National Center for Environmental Research

Washington, DC

Dan Sweeney

U.S. EPA, Region 3

Philadelphia, PA

Hale Thurston

U.S. EPA, Office of Research and Development, National Risk Management Research Laboratory

Cincinnati, OH

Michael Troyer

U.S. EPA, Office of Research and Development, National Center for Environmental Assessment

Cincinnati, OH

George Van Houtven

Research Triangle Institute

Research Triangle Park, NC