A Benefits Assessment of Water Pollution Control Programs Since 1972: Part 1, The Benefits of Point Source Controls for Conventional Pollutants in Rivers and Streams

Final Report

Prepared for

U.S. Environmental Protection Agency
Office of Water
Office of Policy, Economics, and Innovation

January 2000

EPA Contract Number
68-C6-0021

RTI Project Number
6600-4

A Benefits Assessment of Water Pollution Control Programs Since 1972:
Part 1, The Benefits of Point Source Controls for Conventional Pollutants in Rivers and Streams

Final Report

Prepared for

U.S. Environmental Protection Agency
Office of Water
Office of Policy, Economics, and Innovation

EPA Work Assignment Manager

Dr. Mahesh Podar
Office of Water
401 M Street SW (MC4301)
Washington, DC 20460

Prepared by

Tayler H. Bingham, Timothy R. Bondelid
Brooks M. Depro, Ruth C. Figueroa, A. Brett Hauber
Suzanne J. Unger, George L. Van Houtven
Research Triangle Institute
Research Triangle Park, NC 27709

in association with

Andrew Stoddard

Tetra Tech, Inc.
Fairfax, VA 22030

Industrial Economics, Inc.
Cambridge, MA 02140

January 2000

DISCLAIMER

Although the information in this report has been funded wholly or in part by the United States Environmental Protection Agency under Contract 68-C6-0021 with Research Triangle Institute, it does not necessarily reflect the views of the Agency and no official endorsement should be inferred. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ACKNOWLEDGMENTS

The principal project manager for this segment of the model development is Virginia Kibler. In addition, we would like to thank the following EPA staff for critical review and comments: Bill O'Neil, Charles Griffiths, Mahesh Podar, Mathew Clark, and John Powers.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

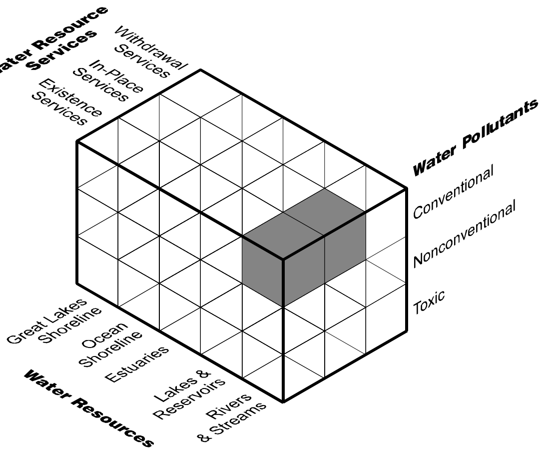
Executive Summary

Since the early 1970s, national water pollution control programs at all levels of government can be largely credited with reversing the centuries-long trend in the degradation of the Nation's waters. Foremost among these programs are those that have been implemented by the U.S. Environmental Protection Agency (EPA) under the Clean Water Act (CWA) of 1972. Prior to these programs, the decline in water quality that accompanied economic industrialization and population growth was epitomized by the day in June 1969 when oil and debris in the Cuyahoga River caught fire. Today, the cumulative impact of the national water pollution programs has been to improve the health of aquatic ecosystems and to expand the share of the Nation's water resources that support various forms of beneficial uses for humans. The purpose of this study has been to develop a preliminary assessment of the national benefits associated with these programs, in particular the CWA.

This analysis represents the first part of an ongoing effort by the Agency to develop a comprehensive assessment of the benefits of the CWA using modern valuation methods. The results of this study must therefore be viewed as partial because they do not yet include all of the facets of water quality benefits. As depicted in Figure ES-1, a comprehensive assessment must fully address the three primary dimensions of water quality improvements. That is, it should address

- all of the **pollutants** addressed by the Agency's programs,
- all of the Nation's surface **water resources**, and

Figure ES-1. Illustration of the Potential Scope of CWA Benefits and Contributions of This Study



- all of the **services** that surface water resources provide to humans.

Our study covers the subset of water quality improvement benefits represented by the shaded area in Figure ES-1. First, it focuses exclusively on the Nation's system of primary rivers and streams. Other important water resources, including the marine coast, estuaries, lakes, and smaller streams, are not included. As a result, the sources that discharge pollutants directly to these other waterbodies are also not included. Second, only conventional pollutants are included in the water quality analysis. Nonconventionals and toxic pollutants are not included. Finally, the monetary estimate of the benefits is confined to a subset of the services provided by water resources. While this coverage is not insignificant, the ultimate goal of future benefits assessments is to cover all the elements in all three dimensions of Figure ES-1.

We estimate that the benefit for the shaded elements in Figure ES-1 is currently about $11 billion annually. This estimate is best interpreted as an approximation of the partial *annual* benefits of current water quality levels relative to what they would have been without the water pollution control programs that have been implemented since the early 1970s, in particular without the CWA.

Although we recognize that it is an oversimplification, for convenience in this report we attribute the benefits of water pollution controls to the CWA. The CWA is the primary Federal law for addressing the Nation's water quality problems. Under the Act the Agency, among other things, establishes industrial and municipal pollution control performance standards for point sources (PS) of conventional, nonconventional, and toxic pollutants. It charges States and tribes with setting specific water quality criteria appropriate for their waters and with developing pollution control programs to meet them. Under the CWA, the Agency also provides funding to States and communities to help them meet their clean water infrastructure needs. These initiatives are likely to be the most significant cause of the water quality improvements achieved since the early 1970s. But they are not solely responsible for the gains.

Other Federal and subfederal legislation and initiatives have contributed to the improvements. For example, the Coastal Zone Management Act addresses NPSs of coastal water pollution. Also, in some cases, pollution controls mandated by State and local agencies can be more stringent than Federal guidelines. Even legislation directed toward other media has contributed to water quality improvements. The Clean Air Act, for example, through its treatment of the pollutants that cause acid deposition, has resulted in lower pH levels in the Nation's waters. In practice it is difficult to fully separate the impacts of various programs; therefore, we assume that the benefits we are measuring are attributable to the CWA.

The benefits of the CWA can be defined (in economic terms) as the increase in human well-being that results from its improvements in water quality. These water quality improvements, in effect, improve the "services" humans receive from surface water resources. To estimate these benefits, it is not enough to examine how water quality has improved since 1972. Rather, it is appropriate to assess current water quality in relation to what it *would have been* today without the CWA initiatives.

This is a complex undertaking since even without the Act other State and local programs may have been expanded or initiated to address the problem of water pollution. Estimating the likelihood and contribution of such efforts is beyond the scope of this study. This study has developed an estimate of what water quality might look like today if current wastewater management practices were similar to 1972's practices, but with today's levels of economic activity. This scenario provides the basis for the without-CWA water quality characterization that is compared to today's water quality levels.

Although the benefit estimates are incomplete, the accomplishments of our study are significant. Only a few prior studies have attempted to value water quality changes, even for a local setting. This study has provided such estimates on a national level, albeit not for all resources. We are continuing the effort to provide the missing elements.

Also included in this report is a case study analysis of the benefits of the water quality improvements in the Willamette River Basin in Oregon. This analysis provides the opportunity to examine the potential benefits of the Act in greater detail and with less abstraction than was possible with the national-level study. The Willamette River Basin was chosen because of the significant improvements in water quality achieved there since the 1960s. The benefits of the water quality improvements for that basin are estimated to be $120 million to $260 million annually.

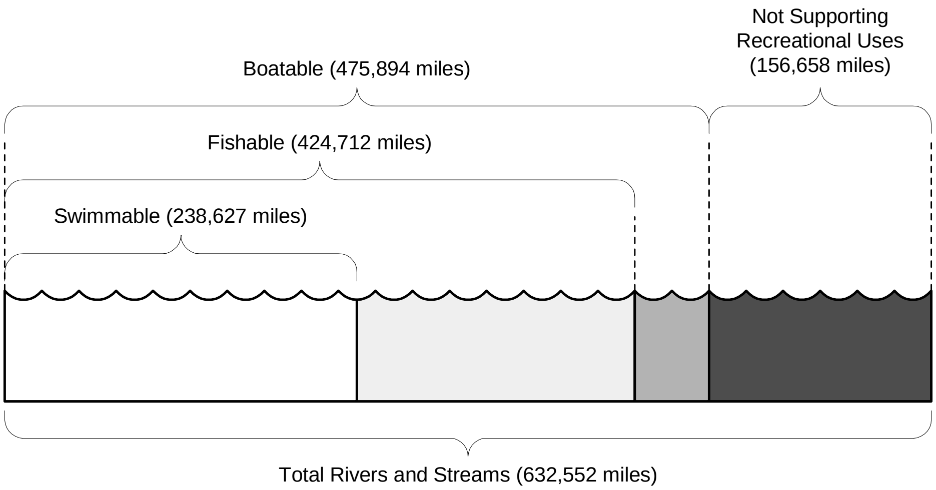
ES.1 WATER QUALITY DIFFERENCES WITH THE CWA

We used the National Water Pollution Control Assessment Model (NWPCAM) developed by EPA and RTI to conduct this assessment of the national benefits of the CWA. The NWPCAM incorporates location-specific estimates of pollutant releases to simulate water quality conditions for 632,552 miles of rivers and streams in the continental United States. Current pollutant PS loadings from industrial and municipal sources and NPS loadings were used in the NWPCAM to characterize today's water quality in terms of oxygen-demanding wastes, sediment, and fecal coliform levels. This characterization was used as the with-CWA water quality reference point.

Without-CWA loadings estimates were also developed, but only for industrial and municipal sources. They were based on estimates of the control efficiency of effluent guidelines and municipal wastewater treatment programs applied to the current industrial base. Because the NPS program is fairly new and data on its effectiveness are not readily available, without-CWA pollutant loadings for these sources were assumed to be the same as current loadings. The without-CWA loadings were used in the NWPCAM to characterize what the current state of water quality would be without the CWA initiatives.

The estimated water quality levels under both with- and without-CWA conditions were mapped into three use support categories—boatable, fishable, or swimmable—based on the minimum levels of water quality needed to support these activities. These three terms, as used here, are essentially shorthand ways to describe water quality based on estimated pollutant levels. The estimated current (with-CWA) national distribution of the river and stream miles across the beneficial use categories is provided in Figure ES-2. Almost 25 percent of the total 632,552 miles of rivers and streams are estimated to be "nonsupport" miles, meaning they

Figure ES-2. Estimated U.S. River and Stream Miles Attaining Recreational Use Criteria With the CWA, Mid-1990s



fail to meet conditions required to support any of the three categories.

The remaining 475,894 miles are estimated to, at least, support boating activities. A majority of these boatable miles are also estimated to be fishable (424,712 miles), and a smaller subset are estimated to be suitable for swimming as well (238,627 miles). For interpreting Figure ES-2 (and the tables on the following pages) it is important to stress that the mile estimates in the three use support categories are **not** mutually exclusive. They are overlapping. In other words, adding miles across the support categories would result in double-counting because some river and stream miles support more than one use (e.g., swimmable miles are, by definition, also boatable).

Table ES-1 shows what the estimated distribution of water quality would be under the without-CWA scenario. Nonsupport miles increase to 178,514. The number of boatable, fishable, and swimmable miles are all estimated to decline relative to with-CWA conditions.

Using the same use support categorization scheme, we also estimated a third scenario to simulate what conditions would be like if all loadings of conventional pollutants from PSs were eliminated. Because this zero PS discharge scenario represents the maximum achievable control of PSs, it serves as a useful point of reference for evaluating the with-CWA (i.e., current control) scenario. It highlights the fact that, even if all point source loadings were reduced to zero, a sizable portion of U.S. rivers and streams would experience little to no improvement (relative to the without-CWA scenario) in their ability to support specific recreational uses. According to the NWPCAM, going from the without-CWA scenario to the zero PS discharge scenario, only a small percentage (10 percent overall) of the 632,552 miles of rivers and streams would achieve higher recreational uses. This is because the remaining miles are either

- upstream of all PSs of conventional pollutants in the model,
- already achieving maximum use support (i.e., swimmable) under the without-CWA scenario, or

- limited by NPS loadings.

Therefore, Table ES-1 also shows the estimated number of river and stream miles in each recreational use support category for the zero PS discharge scenarios. It shows that, going from the without-CWA scenario to the zero PS discharge scenario, the maximum achievable increase in swimmable miles through PS controls is 33,355 miles. For the fishable and boatable categories, the maximum increases are 42,754 and 36,810, miles, respectively.

Table ES-1. Maximum Achievable Increases in Recreational Use Support Through Point Source Controls

	Number of U.S. River and Stream Miles in Each Use Support Category		
Highest Use Supported	Without-CWA Conditions	Zero PS Discharge Conditions	Maximum Achievable Change
Swimmable	222,120	255,475	33,355
Fishable	399,999	442,753	42,754
Boatable	454,038	490,848	36,810
Nonsupport	178,514	141,704	–36,810

Table ES-2a compares the estimated distribution of river and stream miles across use categories with and without the Act. We estimate that CWA pollution controls have increased the number of miles of rivers and streams attaining swimmable standards by 16,507, which is 50 percent of the maximum increase that would have been achieved by eliminating PS discharges. The additional number of river and stream miles nationally achieving fishable and boatable standards today is estimated to be 24,713 and 21,856, respectively. These increases represent almost 60 percent of the maximum that would have been achieved by complete controls on PS discharges.

Because many of the services received from water resources depend on their proximity to people, in Table ES-2b we also provide estimates of the water quality increases specifically for "populated places" (as defined by the Census). These estimates show that about one-third of the 632,552 river and stream miles modeled in the NWPCAM are in these more populated locations. More importantly, over two-thirds of the *improved* river and stream

Table ES-2a. Rivers and Streams (632,552 miles) Supporting Recreational Uses: Comparison of With-CWA and Without-CWA Conditions in the Mid-1990s

Highest Use Supported	Without-CWA Conditions (miles)	With-CWA Conditions (miles)	Increase in Use Support	
			Miles	Percent of Maximum Increase[a]
Swimmable	222,120	238,627	16,507	49.5%
Fishable	399,999	424,712	24,713	57.8%
Boatable	454,038	475,894	21,856	59.4%
Nonsupport	178,514	156,658	–21,856	59.4%

[a] Maximum defined by difference between without-CWA scenario and zero PS discharge scenario.

Table ES-2b. Rivers and Streams *in Populated Places* (222,789 miles): Comparison of With-CWA and Without-CWA Conditions in the Mid-1990s

Highest Use Supported	Without-CWA Conditions (miles)	With-CWA Conditions (miles)	Increase in Use Support (miles)
Swimmable	109,003	121,530	12,527
Fishable	161,861	178,588	16,727
Boatable	175,666	190,319	14,653
Nonsupport	47,123	32,470	–14,653

miles are also located in these areas. For example, 12,527 (76 percent) of the 16,507 miles that are estimated to achieve swimmable status as a result of the CWA are in populated places.

There are other characterizations of current water quality. In particular, the Index of Watershed Indicators (the IWI or Index) organizes and presents aquatic resource information from numerous sources across the country on a watershed basis. The first and foremost of these sources is the information reported under the 305(b) program. Under this program States and jurisdictions designate uses for their water resources and conduct surveys to determine the extent to which each water resource supports each relevant designated use. This is the most comprehensive characterization of the quality of these resources and of the pollutants and pollutant sources that threaten their quality.

A drawback to using the 305(b) information for benefits estimation, however, is that the reported water quality information does not provide an absolute measure of water quality; rather it is an assessment *relative* to the designated use. A further limitation to these data is that they are based on inconsistent sample surveys—the sampling methods vary among the States and, in many cases, are not based on statistical sampling techniques. The resources surveyed are typically those of most importance to the State or under the greatest threat of impairment.

Another drawback to using the 305(b) estimates for benefits estimation is that there is no way to develop alternative (e.g., without-CWA) water quality scenarios within the 305(b) structure. Although data from IWI have supported the development of the NWPCAM, for consistency we used the NWPCAM to estimate water quality conditions both with and without the CWA.

ES.2 WATER QUALITY BENEFITS VALUATION

To assess the value that individuals place on changes in beneficial uses, we relied on estimates (derived in a previous study) of willingness to pay (WTP) for freshwater quality improvements. WTP is usually regarded as the best observable measure of the value that people place on the improvements in the quality of the services provided by the environment. Its use is consistent with most governmental directives for conducting benefits analyses. However, using WTP implies a human-based perspective on the benefits of water quality improvements. For decisionmakers who believe that a more expanded view of the value of ecosystems should be the basis of public policy, WTP would, presumably, represent a lower bound on the value of the water quality improvements under the CWA.

The WTP values used in this study were originally estimated for a 1983 contingent valuation (CV) study conducted for EPA. These CV estimates have been updated, to the extent feasible, to reflect current values. The CV method uses a survey instrument to elicit respondents' valuation of environmental quality improvements. This survey approach provides an effective way to develop some first-order approximations of values that would otherwise be difficult or impossible to obtain.

To estimate values for local water quality improvements, we applied the CV survey results specifically to households living in populated places where rivers and streams improved in quality. To estimate values for more general (i.e., nonlocal) water quality improvements, we applied the CV results to households in the Nation at large. Comparing current conditions with those that would have prevailed in the absence of the CWA, we estimated the *annual* monetary value of the water quality improvements to be $11 billion. Table ES-3 shows the composition of our annual benefits estimate. Most of the estimate is attributable to the estimated improvement in the in-place services of water (especially recreation and aesthetic services) for households that are proximate to the affected resources. In addition, households expressed a value in the CV study for improvements in water quality for resources that they do not expect to use or, at least, that are outside their local area. These existence services are typically assumed to arise from a sense of environmental stewardship. They make up less than 15 percent of the benefits of the Act.

Table ES-3. Estimated Annual Value of Selected In-Place and Existence Benefits of the CWA, Mid-1990s (million 1997$/yr)

Use Attainment	Local/In-Place Benefits	Nonlocal/ Existence Benefits	Total Benefits
Boatable	$4,192	$784	$4,977
Fishable	$3,043	$512	$3,556
Swimmable	$2,356	$216	$2,572
Total	$9,592	$1,513	$11,105

Again, we note that the methodology used to develop our benefits estimate does not address all the sources and loadings, pollutants, water resources, and services affected by the CWA. Thus, the total benefits of the CWA are underestimated by this report. Future Agency efforts are designed to incorporate the omitted sources, pollutants, resources, and services. Once all of these factors are accounted for, the estimated value should increase and provide a more accurate assessment of the total benefits of the CWA.

1 Introduction

The amendment of the 1948 Federal Water Pollution Control Act (FWPCA) in 1972 signaled a major shift in water quality management responsibility from the States to the Federal government. Under the amendments, the U.S. Environmental Protection Agency (EPA) was given the responsibility to, among other things, set technology-driven national effluent limitations for industrial sources, establish water quality standards, and administer a construction grants program for publicly owned treatment works (POTWs) designed to achieve a minimum level of secondary treatment for wastewaters discharged to surface waters by municipal facilities. The industrial standards are administered through the National Pollutant Discharge Elimination System (NPDES). Discharges from POTWs are regulated through national pretreatment standards and local pretreatment programs (Fogarty, 1991). The FWPCA was further amended in 1977 to address the problem of toxic pollutants. Recognition of the impact of pollutants from nonpoint sources (NPSs) on water quality resulted in provisions in the 1987 amendments to address these sources. Today this body of legislation is commonly referred to as the Clean Water Act (CWA).

The overall goal of the CWA is to "... restore and maintain the chemical, physical, and biological integrity of the Nation's waters." One of the more specific provisions of the Act required eliminating "... the discharge of pollutants into navigable waters" by 1985. The

Act is generally credited with reversing the trend in the degradation in water quality that began with the industrialization of the economy in the 1800s and was epitomized by the incident in June 1969 when the Cuyahoga River near Cleveland caught fire. Today, that location is lined with restaurants and pleasure boat slips (Schneider, 1997).

Complementing the CWA are other governmental initiatives at the Federal and subfederal levels that address the problem of water quality. Notably, the Coastal Zone Management Act is directed toward coastal water pollution problems at a national level. Actions taken under this and other legislation have contributed to the improvements in the Nation's water quality. Because the CWA has been in place longest with the greatest coverage, however, programs administered under this Act are primarily responsible for the water quality improvements. For this reason, as well as for the convenience of having a single inclusive term, we attribute the water quality improvements described in this report to the CWA.

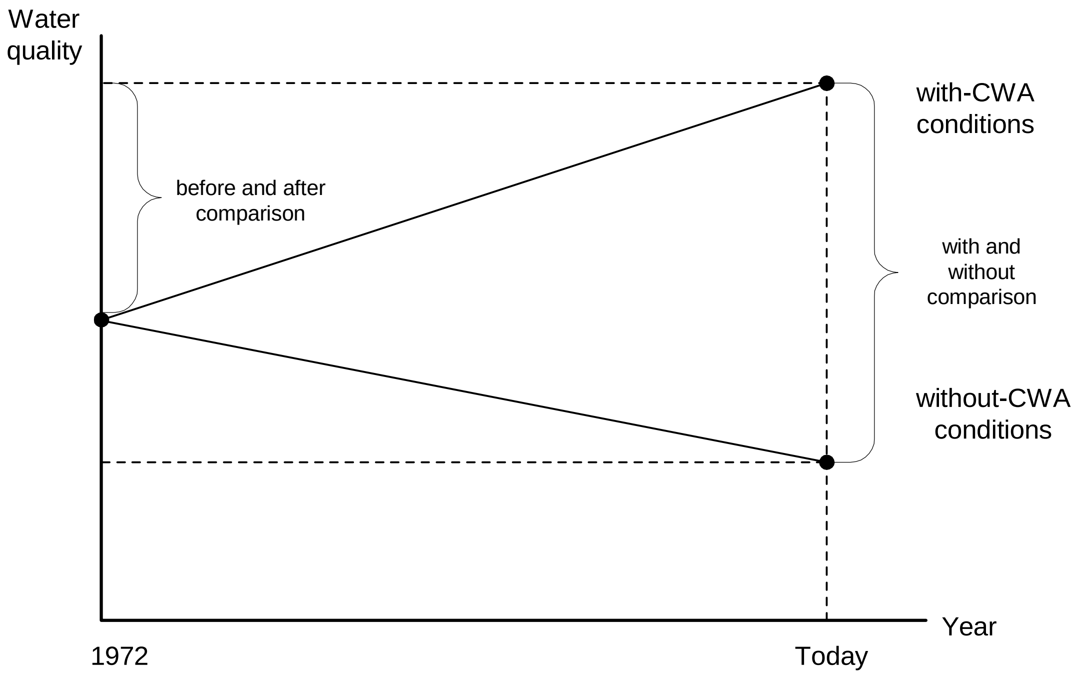
It is natural and appropriate to ask "what have we achieved since 1972?" Such a question is motivated by the desire to know how we are doing in achieving the Act's goals and by the recognition that resources needed to protect and restore the Nation's waters are scarce (costly) while the benefits of water quality improvements are not infinite. Thus, society may seek to learn if the benefits of this public policy, as of others, are worth its costs. Students of public policy counsel that part of effective public policymaking is learning how these polices have performed; and then changing them to improve their performance (e.g., see Stokey and Zeckhauser [1978]). The Government Performance and Results Act (GPRA) codifies these expectations into law; it requires that agencies report on their performance goals and actual achievements. Also, under the provisions of Executive Order (EO) 12893, EPA must evaluate the benefits and costs of municipal infrastructure projects designed to protect water quality. Thus, there are many reasons for evaluating progress under the CWA.

Analysts can address the question of the benefits of the CWA from two perspectives:

1) Before-after perspective: How has the Nation's water quality changed since 1972, and what is the benefit of the change to society?
2) With-without perspective: How does the current quality of the Nation's water resources compare with what it would have been like without the CWA, and what is the benefit to society of the difference?

Figure 1-1 illustrates the differences between these two perspectives. In the figure the actual level of water quality is shown as improving because of pollutant reductions due to the CWA. The first perspective identified above takes a "before and after" view of the contributions of the CWA to water quality improvements—it compares conditions in 1972 to current conditions. However, other things may have changed between 1972 and today that would have affected the quality of the Nation's water resources and the services provided by them.

Figure 1-1. Illustration of Alternative Analytical Perspectives for Evaluating CWA Benefits



The second perspective—"with-without"—considers that without changes in pollutant management practices, economic growth would have resulted in the deterioration of water quality over the period. Providing a plausible characterization of current conditions without the CWA requires developing a without-CWA scenario. This scenario is shown in Figure 1-1 as the declining water quality curve. Although it is more analytically demanding, the "with-without" perspective should be adopted because it is the conceptually correct basis for valuing the benefits. The challenge in such analyses is to develop a consistent, accurate characterization of the without-CWA conditions. That characterization must link estimates of pollutant discharges (i.e., loadings) without the CWA to their impacts on surface water quality, on the services provided by water resources, and on the social value of these services. Those metrics are then compared to the ones developed similarly under with-CWA conditions.

The Nation's water resources, broadly described, include rivers and streams, lakes and reservoirs, estuaries, wetlands, the ocean shoreline, and the Great Lakes. This study focuses only on rivers and streams and, within this category, only the 633,000 miles of larger waterbodies (out of 3.5 million in the Nation) that are catalogued in EPA's Reach File 1 (RF1) database. In terms of their size, the rivers and streams captured in this analysis are the key resources in this category. The Agency has plans to extend the analysis to include additional water resources in the future, especially coastal, estuarine waters, and lakes.

Water pollutants are typically divided into conventional, nonconventional, and toxic pollutants. Source types include points sources (PSs) such as drains, ditches, sewer outfalls; nonpoint sources (NPSs) such as runoff; and atmospheric deposition of air pollutants such as rain or snow contaminated with air pollutants. This analysis includes three pollutants: fecal coliform (FC), an infectious agent; biological oxygen demand (BOD), an oxygen-demanding waste; and total suspended solids (TSS), a sediment. While these pollutants are important contributors to water quality, they are not the only contributors. In particular, many EPA programs are currently aimed at controlling toxic pollutants. The Agency has plans to expand the pollutants covered in future analyses of the benefits of the CWA to include toxic and nonconventional pollutants.

The benefits of water quality improvements achieved under the CWA are evaluated here from an exclusively human-based perspective. From this perspective, the value of a resource is based on individuals' preferences, and the valuation effort focuses on how the services provided by water resources affect individuals' welfare. Water resources provide a variety of services both when withdrawn and when left in place. The focus here is primarily on the effect of water quality on the recreation services of water. This human-based perspective of value is the cornerstone of applied benefit-cost analysis and is codified into governmental and agency practices (e.g., EO 12866, Agency guidelines for performing regulatory impact analyses). However, alternative views do exist on why society should seek to preserve or improve the functioning of ecosystems. Such alternative views may provide a more expansive view of CWA benefits than the human-based approach used in this analysis.

To summarize, our study uses a national water resources network model based on RF1. That model is designed to link PS and NPS loadings, river and stream flows, and the beneficial use goals of the CWA. We used the results of this modeling effort, together with results from existing empirical literature, to estimate the economic significance of current beneficial use attainment relative to the expected state of the Nation's water quality in the absence of the CWA.

This analysis builds on previous work undertaken by Clark et al. (1995) and Research Triangle Institute (1997b) and represents an ongoing effort to develop a comprehensive assessment of the benefits of the CWA as discussed above. Thus, although this study does expand the range of pollutants and sources considered in the analysis over earlier versions of the study, it is important to note that it represents only another increment in an on-going process of evaluating all of the water resources, pollutants, and associated service flows affected by the provisions of the Act. A more comprehensive evaluation will require expanding the water resources and pollutants covered, as well as addressing a number of analytical issues.

A case study of the Willamette river basin in northwest Oregon is also included to complement and contrast with the national evaluation. It provides a more comprehensive analysis of the water quality changes and of the services provided by water resources within a specific region. By working on a smaller geographic scale, the analysis has the benefit of being less abstract than is required when conducting a national analysis. Thus, it provides an informal type of validation test for our national modeling approach.

2 Water Pollution and CWA Regulatory Programs

Water pollution results from the release of residuals that change the physical, biological, or chemical properties of waterbodies. These pollutants originate from both natural and human processes. Historically the uninformed and self-interested behaviors of dischargers have degraded water resources in the United States and throughout the world. The CWA reflects a recognition of the problem and incorporates programs for improving water quality. The Agency's implementation of these programs has resulted in a marked reduction in pollutant releases to the Nation's waters.

2.1 WATER POLLUTANTS

Under the CWA, water pollutants are divided into conventional pollutants, nonconventional pollutants, and toxic pollutants.

Conventional Pollutants

The primary conventional pollutants defined in Title 40 of the Code of Federal Regulations (CFR) are biochemical oxygen-demanding wastes, TSS, bacteria, and FC. Oil, grease, and pH are other conventional pollutants. Biodegradable organic materials contain plant, fish, or animal matter that uses oxygen in the water during decomposition. BOD is the standard measure of these pollutants' potential to remove oxygen from the receiving waters. Oxygen-poor waters will only support trash fish and the most resistant microorganisms and invertebrates. In extreme cases, these waters support bacterial activity to such an extent that noxious gases and foul odors are produced.

Excess sediment can fill lakes, smother aquatic life, cloud water, and block sunlight. Sediment can also carry other pollutants into waterbodies. Erosion and runoff are primary sources of this pollutant.

Waterborne pathogenic organisms cause human illnesses ranging from minor respiratory and skin diseases to typhoid, infectious hepatitis, and polio. In addition to these diseases—often caused by direct contact with contaminated water—biting insects can transmit waterborne pathogens. The primary sources of infectious agents found in water resources are feces. Inadequately treated sewage, storm water drains, and livestock runoff are all sources of these pollutants. An indicator bacterium (e.g., FC) is typically measured to determine whether dangerous organisms are present in a body of water.

Nonconventional Pollutants

Nonconventional pollutants include chemical oxygen demand (COD), total organic carbon (TOC), nitrogen, and phosphorous. Fertilizers, sewage, manure, and detergents containing nitrogen and phosphorous from runoff and municipal discharges contribute to increases in nutrient levels and in the biological productivity of water resources (EPA, 1995). However, excess nutrients overstimulate the growth of aquatic weeds and algae, leading to "blooms," oxygen depletion, and elevated levels of sediment accumulation.

Toxic Pollutants

Toxic pollutants are listed by name in the CFR pursuant to Section 307(a)(1) of the Act. There are 65 such named chemicals. They include both natural and synthetic organic chemicals as well as metals discharged from industrial sources. Natural and synthetic organic chemicals can be highly toxic, even in small concentrations. Synthetic compounds such as polychlorinated biphenyls (PCBs), pesticides, solvents, and dioxins often persist and accumulate in the environment because they do not easily decompose (EPA, 1995). Exposure to many of these compounds has been found to cause cancer and birth defects in humans and animals.

Heavy metals (e.g., mercury, lead, cadmium) released to waterbodies often persist and accumulate in the environment because they do not easily decompose (EPA, 1995). Exposure to many of these compounds has been found to damage ecosystems and to cause cancer and birth defects in humans and animals. Mining, processing, and use of these metals are all potential sources of releases. Nonmetallic salts can be toxic for plants and animals. Irrigation of high-salt-content soils and runoff from highways treated with sodium and calcium chloride are sources of nonmetallic salt pollutants. Acids are toxic to many fish and amphibians. Direct releases from industrial processes, leaching of mineral wastes, and atmospheric deposition all contribute to the presence of these pollutants in water resources.

2.2 SOURCES OF POLLUTANTS

Sources that generate major water pollutants are typically classified into PS and NPS groups. PSs directly discharge pollutants into surface waters from pipes, conduits, or conveyances. These sources include industrial facilities, municipal sewage treatment plants, stormwater discharges from discrete conveyances (i.e., pipes), and combined sewer overflows (CSOs). NPSs deliver pollutants to surface waters through a variety of origins. They include agricultural runoff and urban runoff. NPS pollution tends to be highly episodic, depending on rain, snowmelt, or irrigation that occurs in excess of soils' capacity to collect and assimilate pollutants. Table 2-1 lists major sources of water pollution.

2.3 CWA POLLUTION CONTROL PROGRAMS[1]

Water pollution control policy under the CWA is primarily founded on technology-based effluent standards for PSs and management practices for NPSs. This section describes these programs for direct dischargers and POTWs, indirect dischargers, and NPSs.

---

[1] This section draws heavily on John Fogarty's (1991) review of the CWA legislation.

Table 2-1. Major Sources of Water Pollution

Source	Examples
Industrial	Chemical manufacturers, pulp and paper mills, steel plants and food processing plants.
Municipal	Publicly owned sewage treatment plants that may receive indirect discharges from industrial facilities or businesses.
Combined sewers	Single facilities that treat both storm water and sanitary sewage, which may become overloaded during storm events and discharge untreated wastes into surface waters.
Storm sewers/ urban runoff	Runoff from impervious surfaces, including streets, parking lots, buildings, lawns, and other paved areas.
Agricultural	Crop production, pastures, rangeland, feedlots, other animal holding areas.
Silvicultural	Forest management, tree harvesting, logging road construction.
Construction	Land development, road construction.
Resource extraction	Mining, petroleum drilling, runoff from mine tailing sites.
Land disposal	Leachate or discharge from septic tanks, landfills, and hazardous waste sites.

Source: U.S. Environmental Protection Agency. 1995. *National Water Quality Inventory: 1994 Report to Congress*. EPA 841-R-95-005. Washington, DC: Office of Water.

2.3.1 Direct Industrial Dischargers and POTWs

Most industrial sources and all POTWs discharge their effluent directly to water resources. EPA has developed technology-based effluent limitations for these sources under the effluent guideline program. Industry-specific limits are based on BPT—the "best practicable control technology currently available"; BCT—the "best conventional pollutant control technology";—and BAT—the "best available technology economically achievable." The effluent limits based on these technology standards are independent of the quality of the receiving water resources. They are designed to achieve a common level of control across all similar sources regardless of location.

EPA has prepared over 51 effluent guidelines since the CWA was enacted (*Federal Register*, 1996). Table 2-2 lists the effluent guidelines included in CFR Title 40. These effluent limitations are implemented under the NPDES. Under this program all direct dischargers, including storm water PSs, must be permitted by the Agency or, where authorized, by the States. The permit establishes discharge limits and source monitoring and reporting requirements. More than 200,000 sources are regulated by NPDES permits nationwide.

EPA's technology-based control programs for direct industrial dischargers are supplemented on a case-by-case basis by additional control requirements based on water quality. Under Section 303, States, tribes, and jurisdictions establish standards for high priority waterbodies that define water quality in terms of designated beneficial uses, criteria to protect those uses, and antidegradation provisions (EPA, 1995). Total maximum daily loads (TMDLs) for the various pollutants are calculated for these resources based on the pollutant loadings necessary to meet water quality standards. More stringent controls than the effluent guideline technologies are required if discharges are in excess of the TMDLs. The States allocate the TMDL among the various dischargers incorporating the control requirements in the NPDES permits.

POTWs receive wastewaters from residential and industrial sources (indirect dischargers) and storm water runoff, treat the wastewaters, and discharge the treated effluent to water resources. The residual biosolids (sludges) are also treated. POTWs are required in most areas to provide at least secondary treatment to ensure that 85 percent of conventional pollutants are removed (Council on Environmental Quality, 1995). In addition to the national standards, local pretreatment programs are required for POTWs with a total daily design flow of 5 million gallons or more. These programs address the specific treatment capabilities of the local POTW.

To complement its program of effluent standards, EPA provides financial assistance to municipalities to solve their wastewater treatment problems by supporting the construction of public wastewater treatment projects. The 1987 amendments to the CWA shifted the method of Federal assistance from grants to loans

Table 2-2. Effluent Guidelines Included in CFR Title 40

Part	Description
PART 400	[Reserved]
PART 401	General provisions
PART 402	[Reserved]
PART 403	General pretreatment regulations for existing and new sources of pollution
PART 405	Dairy products processing PS category
PART 406	Grain mills PS category
PART 407	Canned and preserved fruits and vegetables processing PS category
PART 408	Canned and preserved seafood processing PS category
PART 409	Sugar processing PS category
PART 410	Textile mills PS category
PART 411	Cement manufacturing PS category
PART 412	Feedlots PS category
PART 413	Electroplating PS category
PART 414	Organic chemicals, plastics, and synthetic fibers PS category
PART 415	Inorganic chemicals manufacturing PS category
PART 416	[Reserved]
PART 417	Soap and detergent manufacturing PS category
PART 418	Fertilizer manufacturing PS category
PART 419	Petroleum refining PS category
PART 420	Iron and steel manufacturing PS category
PART 421	Nonferrous metals manufacturing PS category
PART 422	Phosphate manufacturing PS category
PART 423	Steam electric power generating PS category
PART 424	Ferroalloy manufacturing PS category
PART 425	Leather tanning and finishing PS category
PART 426	Glass manufacturing PS category
PART 427	Asbestos manufacturing PS category
PART 428	Rubber manufacturing PS category
PART 429	Timber products processing PS category

(continued)

Table 2-2. Effluent Guidelines Included in CFR Title 40 (continued)

Part	Description
PART 430	Pulp, paper, and paperboard PS category
PART 431	The builders' paper and board mills PS category
PART 432	Meat products PS category
PART 433	Metal finishing PS category
PART 434	Coal mining PS category BPT, BAT, BCT limitations and NSPS
PART 435	Oil and gas extraction PS category
PART 436	Mineral mining and processing PS category
PART 439	Pharmaceutical manufacturing PS category
PART 440	Ore mining and dressing PS category
PART 446	Paint formulating PS category
PART 447	Ink formulating PS category
PART 454	Gum and wood chemicals manufacturing PS category
PART 455	Pesticide chemicals
PART 457	Explosives manufacturing PS category
PART 458	Carbon black manufacturing PS category
PART 459	Photographic PS category
PART 460	Hospital PS category
PART 461	Battery manufacturing PS category
PART 463	Plastics molding and forming PS category
PART 464	Metal molding and casting PS category
PART 465	Coil coating PS category
PART 466	Porcelain enameling PS category
PART 467	Aluminum forming PS category
PART 468	Copper forming PS category
PART 469	Electrical and electronic components PS category
PART 471	Nonferrous metals forming and metal powders PS category

Source: U.S. Environmental Protection Agency. 1997. World Wide Web site: <http://www.epa.gov.docs/epacfr40/contents.html>.

provided by state revolving funds (SRF) (Council on Environmental Quality, 1995). Currently all 50 States are operating SRF programs.

2.3.2 Indirect Industrial Dischargers

Indirect industrial dischargers release their effluents to POTWs where they are treated. The treated effluent is then released to water resources. Because POTWs are primarily designed to handle residential wastes, national pretreatment requirements for industrial direct dischargers were established under CWA Section 307(b). Their purpose is to address any problems caused by pollutants that are not susceptible to treatment by most POTWs and thus would otherwise pass through without being treated before discharge or would interfere with the proper operation of the POTW's treatment system. Standards for indirect dischargers are generally analogous to the limitations imposed on direct industrial dischargers (*Federal Register*, 1996).

2.3.3 Nonpoint Sources

NPSs are addressed under the CWA and under the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA). Under these Acts, EPA establishes guidance for the States to use when developing their nonpoint pollution control programs. Under the CWA, the States conduct assessments of their NPS problems, design NPS management programs, and implement the programs. Unlike PSs that can be regulated at the discharge point, NPSs, by their very nature, require implementing management practices. EPA's guidance does not have the force of regulatory authority, although the States' programs must be approved by the Agency. But it does codify a set of best available control practices to address NPS water pollution. The States must develop their specific programs to deal with their NPS problems. EPA has grant programs to assist the States in implementing their EPA-approved programs.

3

Water Quality Conditions and Water Resources and Their Services

The Nation's water resources consist of marine and freshwaters, as well, as estuarine waters where these two systems interact. One of the most comprehensive characterizations of the quality of these resources is provided by the Agency's National Water Quality Inventory (NWQI or 305[b]) reports, which identify the pollutants and primary categories of pollutant sources that threaten their quality. This information is summarized here to complement the water quality estimates we have developed using a simulation approach.

The NWQI provides an overview of current water quality conditions relative to the use support goals that the States and jurisdictions have established for their water resources. It is useful because it offers a broad description of water quality; however, because water quality is defined in relative, rather than absolute terms, it is less useful to our broader goal of describing the change in water quality resulting from the CWA. To do this, we use a simulation approach that establishes distinct levels that can be compared in a with- and without-CWA framework. This is described in more detail in Section 4.

In this section, we present an overview of the water conditions in the mid-1990s as described in the NWQI. We also provide a taxonomy of the full range of services provided by water resources based on the observation that some services are provided when the water is withdrawn; others are in-place services. In either case, the quality of these services may be affected by water quality changes. The information on water quality, resources, and services provided here provides a useful context for interpreting the results of our simulation model, which are described in the next two sections of this report.

3.1 CURRENT WATER QUALITY CONDITIONS

Table 3-1 summarizes the resources comprising the Nation's surface water system. Under the CWA, States and jurisdictions are required to designate "beneficial uses" (see Table 3-2 for a list of these uses) for each of their waterbodies and to report to EPA on the attainment of these uses. The results have been summarized most recently by EPA in *The National Water Quality Inventory: 1994 Report to Congress* (EPA, 1995). This report covers the 1992 to 1993 period and provides a comprehensive characterization of water quality for these resources.

A majority of States and jurisdictions have adopted the beneficial use categorization listed in Table 3-2. They conduct surveys to determine the extent to which each water resource supports each relevant designated use and, under Section 305(b), report on the status of their resources. Table 3-3 describes the various "scores" or levels assigned to each of the relevant beneficial use categories for every water resource.

The 305(b) reports are still a very useful basis for characterizing with-CWA water quality conditions because of their significant scope and because they are based on the reporting entities' goals for their water resources. For the *1994 Report to Congress*, States and jurisdictions surveyed 17 percent (615,806 miles) of the Nation's rivers and streams; 42 percent (17,134,152 acres) of its lakes, ponds, and reservoirs; 78 percent (26,847 square miles) of its estuaries; 9 percent (5,208 miles) of its ocean shoreline waters; and 94 percent (5,224 miles) of the Great Lakes shoreline to determine the quality of the Nation's water resources. These surveys primarily cover conditions in 1992 and 1993 and occasionally early 1994. Table 3-4 presents the percentage of surveyed waters that States and other jurisdictions reported as "good." That is, the water quality of the surveyed resource meets the designated use criteria,

Table 3-1. Surface Water Resources in the U.S.[a]

Water Body Classification	Size	
Rivers and streams	3,548,738	miles[b]
Perennial streams	1,292,439	miles
Nonperennial streams	1,468,031	miles
Canals and ditches	133,898	miles
Lakes and reservoirs	40,826,064	acres
Significant public acres[c]	12,189,916	acres
Estuaries	22,008,307	acres
Ocean shoreline	58,421	miles
Great Lakes shoreline	5,559	miles

[a] The data reported here are taken from 1994 State 305(b) reports, as reported in the *National Water Quality Inventory: 1994 Report to Congress* (EPA, 1995). The majority of river and lake data were taken from EPA's Total Waters database (EPA, 1993). In some cases, however, States prefer to report their own estimates of the size of water resources.

[b] Values for the types of rivers and streams do not add to the total because some States do not provide the breakdown.

[c] These are the subset of the total lakes and reservoirs that the States have chosen to designate as "significant." The basis for the designation includes size, location, and the importance of the resource to the States' citizens. Other lakes and reservoirs that are included in the total may be publically or privately owned or owned by Indian tribes.

Source: U.S. Environmental Protection Agency. 1995. *National Water Quality Inventory: 1994 Report to Congress*. EPA 841-R-95-005. Washington, DC: Office of Water.

even though that use may be threatened. The data show that the quality of most surveyed water resources currently supports the designated use for the resource.

We describe the levels of use support for each type of water resource: rivers and streams, lakes and ponds, ocean shoreline, the Great Lakes shoreline, and estuaries.

- **Rivers and Streams:** Table 3-5 presents the levels of use support for the miles of river that States and other jurisdictions surveyed, representing about 17 percent of the total. Bacteria and siltation remain major sources of water quality impairment. Agriculture was typically identified as the main source of pollution in the Nation's

Table 3-2. Beneficial Uses of Water Bodies

Use Classification	Description
Aquatic life support	Provide suitable habitat for protection and propagation of aquatic organism
Fish consumption	Support fish free from potential health risk
Shellfish harvesting	Support shellfish populations free from potential health risk
Drinking water supply	Supply safe drinking water with conventional treatment
Primary contact recreation	Provide for recreational swimming without adverse health effects
Secondary contact recreation	Provide for "on-water" activities such as boating without adverse human health risks
Agriculture	Provide suitable water for irrigating fields or watering livestock
Ground water recharge	Support adequate surface supply and quality to protect uses of ground water
Wildlife habitat	Support habitat and resources for land-based wildlife
Culture	Support the water body's role in culture

Source: U.S. Environmental Protection Agency. 1995. *National Water Quality Inventory: 1994 Report to Congress.* EPA 841-R-95-005. Washington, DC: Office of Water.

Table 3-3. Levels of Use Support

Use Support Level	Water Quality Condition	Definition
Fully supporting	Good	Water quality meets designated use criteria
Threatened	Good	Water quality supports beneficial uses now but may not in the future unless action is taken
Partially supporting	Fair (impaired)	Water quality fails to meet designated use criteria at times
Non supporting	Poor (impaired)	Water quality frequently fails to meet designated use criteria
Not attainable	Poor	The State or jurisdiction has determined that use support is not attainable due to one of six biological, chemical, physical, or economic/social conditions specified in the Code of Federal Regulations

Source: U.S. Environmental Protection Agency. 1995. *National Water Quality Inventory: 1994 Report to Congress.* EPA 841-R-95-005. Washington, DC: Office of Water.

Table 3-4. Status of U.S. Surface Water Resources, 1992–1993: Proportion of Assessed Waters Reported to Have Good Water Quality (%)

	Rivers and Streams	Lakes and Ponds	Ocean Shoreline	Great Lakes Shoreline	Estuaries
Number of Assessed Waters	615,806 miles	17,134,152 acres	5,209 miles	5,224 miles	26,847 square miles
Use Classification					
Aquatic life	69%	69%	95%	27%	70%
Fish consumption	95%	82%	96%	2%	92%
Swimming	77%	80%	95%	96%	85%
Secondary contact recreation	87%	86%	99%	96%	83%
Drinking water	83%	87%	NA	98%	NA
Agriculture	92%	94%	NA	89%	NA
Shellfishing	NA	NA	95%	NA	74%

NA = Not available.

Source: U.S. Environmental Protection Agency. 1995. *National Water Quality Inventory: 1994 Report to Congress.* EPA 841-R-95-005. Washington, DC: Office of Water.

Table 3-5. Levels of Use Support—Rivers[a], 1992–1993

Use Classification	Fully Supporting	Threatened	Partially Supporting	Poor	Not Attainable
Aquatic life	62%	7%	21%	10%	<1%
Fish consumption	94%	1%	3%	2%	<1%
Swimming	74%	3%	10%	13%	<1%
Secondary contact recreation	85%	2%	7%	6%	<1%
Drinking water	80%	3%	8%	9%	<1%
Agriculture	91%	<1%	4%	4%	<1%
Shellfishing	NA	NA	NA	NA	NA

NA = Not available.

[a] Expressed as a percentage of surveyed river miles.

Source: U.S. Environmental Protection Agency. 1995. *National Water Quality Inventory: 1994 Report to Congress.* EPA 841-R-95-005. Washington, DC: Office of Water.

surveyed rivers. Municipal sewage treatment plants were the second most common source of river pollution.

- **Lakes and Ponds:** Table 3-6 provides the levels of use support for the lake acres that States and other jurisdictions surveyed, representing about 42 percent of the total. Elevated nutrient loadings are a main source of lake pollution along with siltation, organic wastes, and metals. Agriculture was identified as the most prevalent source of lake and pond pollution followed by municipal sewage, urban runoff, and storm sewers.

Table 3-6. Levels of Use Support—Lakes and Ponds[a], 1992-1993

Use Classification	Fully Supporting	Threatened	Partially Supporting	Poor	Not Attainable
Aquatic life	56%	13%	23%	8%	<1%
Fish consumption	76%	6%	14%	4%	<1%
Swimming	69%	12%	15%	4%	<1%
Secondary contact recreation	80%	6%	13%	1%	0%
Drinking water	82%	5%	7%	6%	0%
Agriculture	93%	1%	5%	0%	<1%
Shellfishing	NA	NA	NA	NA	NA

NA = Not available.

[a] Expressed as a percentage of surveyed lake areas.

Source: U.S. Environmental Protection Agency. 1995. *National Water Quality Inventory: 1994 Report to Congress.* EPA 841-R-95-005. Washington, DC: Office of Water.

- **Ocean Shoreline:** Table 3-7 presents the levels of use support for the miles of ocean shoreline that States and other jurisdictions surveyed, representing about 9 percent of the total. Only six of 27 coastal States identified pollutants and sources of pollutants degrading ocean shoreline waters. Such sparse data make drawing any national-level generalizations difficult. However, the six States identified bacteria, metals, nutrients, turbidity, siltation, and pesticides as major pollutants.

Table 3-7. Levels of Use Support—Ocean Shoreline[a], 1992–1993

Use Classification	Fully Supporting	Threatened	Partially Supporting	Poor	Not Attainable
Aquatic life	93%	2%	4%	1%	0%
Fish consumption	96%	0%	4%	0%	0%
Swimming	64%	31%	4%	1%	0%
Secondary contact recreation	98%	1%	<1%	1%	0%
Drinking water	NA	NA	NA	NA	NA
Agriculture	NA	NA	NA	NA	NA
Shellfishing	95%	<1%	4%	1%	0%

NA = Not available.

[a] Expressed as a percentage of surveyed ocean shoreline.

Source: U.S. Environmental Protection Agency. 1995. *National Water Quality Inventory: 1994 Report to Congress.* EPA 841-R-95-005. Washington, DC: Office of Water.

Urban runoff and storm sewers, industrial discharges, land disposal of wastes, septic systems, agriculture, and CSOs were identified as sources.

- **Great Lakes Shoreline:** Table 3-8 provides the levels of overall use support for the 5,224 surveyed miles of Great Lakes shorelines, representing 94 percent of the total. At the time of the survey, most of the Great Lakes shorelines were polluted by toxic organic chemicals. Other causes of use support impairment were pesticides, nonpriority organic chemicals, nutrients, and metals. Leading sources were atmospheric deposition, urban runoff and storm sewers, CSOs, industrial and municipal discharges, agriculture, and land disposal of wastes.

- **Estuaries:** Table 3-9 presents the levels of overall use support for the 26,847 square miles of surveyed estuaries, representing 78 percent of the total. Nutrients and bacteria were the main pollutants of estuarine waters. Organic wastes and oil and grease also polluted estuaries. Urban runoff and storm sewers, municipal sewage treatment plants, agriculture, and industrial discharges were the most widespread sources of pollution in the Nation's surveyed estuarine waters.

Table 3-8. Levels of Use Support—Great Lakes Shoreline[a], 1992–1993

Use Classification	Fully Supporting	Threatened	Partially Supporting	Poor	Not Attainable
Aquatic life	11%	17%	10%	63%	0%
Fish consumption	2%	0%	34%	64%	0%
Swimming	96%	1%	3%	<1%	0%
Secondary contact recreation	96%	<1%	4%	0%	0%
Drinking water	98%	<1%	<1%	2%	0%
Agriculture	89%	0%	11%	0%	0%
Shellfishing	NA	NA	NA	NA	NA

NA = Not available.

[a] Expressed as a percentage of surveyed Great Lakes acres.

Source: U.S. Environmental Protection Agency. 1995. *National Water Quality Inventory: 1994 Report to Congress.* EPA 841-R-95-005. Washington, DC: Office of Water.

Table 3-9. Levels of Use Support—Estuaries[a], 1992–1993

Use Classification	Fully Supporting	Threatened	Partially Supporting	Poor	Not Attainable
Aquatic life	61%	9%	27%	3%	0%
Fish consumption	90%	2%	6%	2%	0%
Swimming	83%	2%	13%	2%	<1%
Secondary contact recreation	83%	0%	17%	<1%	0%
Drinking water	NA	NA	NA	NA	NA
Agriculture	NA	NA	NA	NA	NA
Shellfishing	73%	1%	12%	13%	1%

NA = Not available.

[a] Expressed as a percentage of surveyed estuarine areas.

Source: U.S. Environmental Protection Agency. 1995. *National Water Quality Inventory: 1994 Report to Congress.* EPA 841-R-95-005. Washington, DC: Office of Water.

Although the 305(b) data provide useful insights into national water quality conditions, as mentioned earlier, they also have important limitations. One drawback to using this information for characterizing water quality throughout the Nation is that it does not provide an absolute measure of water quality; rather it provides an assessment of water quality *relative* to the designated use. A further limitation to these data is that they are based on inconsistent sample surveys—the sampling methods vary among the States and, in many cases, are not based on statistical sampling techniques. The resources surveyed are typically those of most importance to the State or under the greatest threat of impairment.

To address these limitations and to provide a more appropriate framework for assessing changes attributable to CWA controls, we use a simulation approach that is described in Section 4.

3.2 WATER RESOURCES SERVICES

Individuals perceive the benefits of the CWA through the improvements in water-based services they experience. Bergstrom et al. (1996) have developed a taxonomy of groundwater services that is a useful starting point for identifying how surface water quality improvements may directly and indirectly benefit people. The services provided by water resources are divided into withdrawal, in-place, and existence services. The first two involve direct contact or use of the resource; the latter is related to individuals' altruism toward others whose welfare is affected by changes in water quality, or to a sense of stewardship regarding water resources.

Although the following is a comprehensive list of water resource services, note again that the valuation component of this study only focused on in-place and existence services.

3.2.1 Withdrawal Services

Each day, U.S. inhabitants withdraw about 327 billion gallons of water from surface water sources for life support and other productive purposes. The availability and quality of the water affect the performance of these life and economic systems.

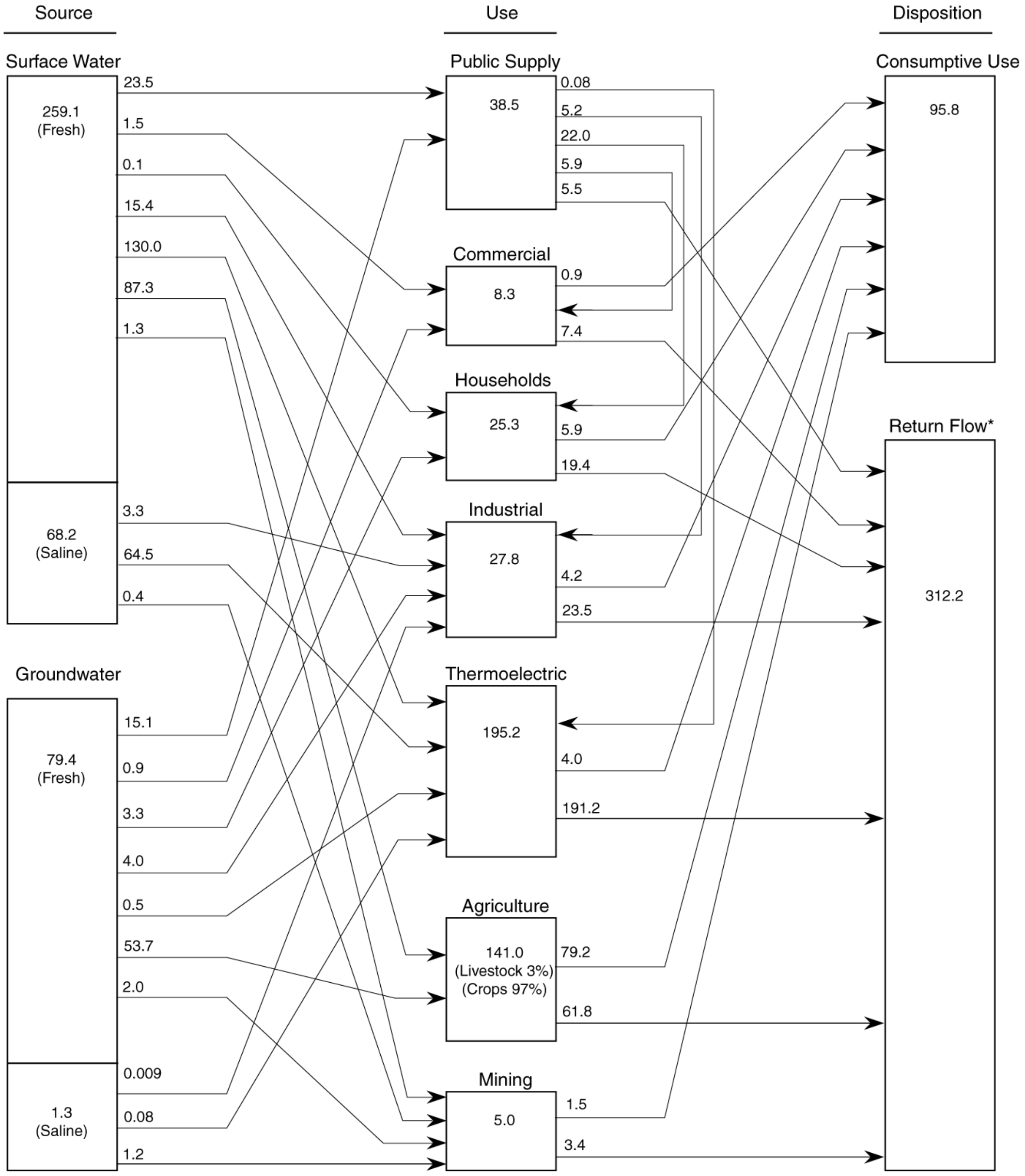
Figure 3-1 provides an overview of the water sources, users, and ultimate disposition of withdrawn water. Most withdrawals are from fresh surface water resources. Seven broad economic use sectors are identified in the figure, covering the entire range of productive activity in an economy. Once used, the water may be returned to one of the water resources as part of return flow or it may be effectively consumed through a number of pathways (e.g., evaporation of irrigation water). About one-quarter of water resources are lost this way. Table 3-10 identifies the major withdrawal services of surface water and the key interfaces between these services and the sectors that use them. We describe the withdrawal services that depend on water quality.

- **Life Support for Humans, Animals, and Plants:** Water resources are needed to support the various life functions, most importantly as sources of *drinking water*. Without the proper quantity and quality of water, the health of living things may be impaired, and death may result in situations of extreme water deficiencies. High concentrations of nitrates, metals, organic and inorganic contaminants, sediment, salt, radionuclides, pathogens, and other toxins all have the potential to cause serious harm.

- **Cooking:** Water is used for cooking in kitchens of all sizes, from small households to large commercial users. In this capacity, water serves two purposes—as a heat transfer medium and as an integral part of the food product.

- **Watering and Irrigation:** Agriculture, primarily through watering and irrigation, accounts for the great majority of water withdrawals. Water is used on farms for crop and livestock production and in households for watering lawns, shrubs, and pets. In this capacity, water also provides important life support services.

Figure 3-1. Source, Use, and Disposition of Withdrawn Water—1990



Note: All values in BGD.

*Includes public supply and conveyance losses.

Source: United States Geological Survey (USGS). 1992. *Estimated Use of Water in the United States in 1990.* Tables available from http://www.h20.sgs.gov/public/watuse.

Table 3-10. Water Resources: Withdrawal Services and Major Uses

	Life Support Services			Other Services					
Users	Humans	Animals	Plants	Cooking	Watering and Irrigation	Sanitary Services	Production/ Processing	Cooling and Air Conditioning	Boiler Feed
Public Supply Systems	X								
Commercial/Government				X		X			
Households	X	X	X	X	X	X			
Manufacturing/Industrial							X	X	X
Thermoelectric Power Generation								X	X
Agriculture									
Crop Production			X		X				
Livestock Production		X			X				
Forestry									
Fishing, Hunting, Trapping									
Mining							X		
Hydroelectric Generation									
Transportation									

- **Sanitary Services:** Water is used for a variety of sanitary services: dishwashing, toilet flushing, bathing, laundering, washing, and garbage disposal. All economic sectors use water for some type of sanitary service. Commercial use varies greatly depending on the type of industry. Water quality can be a concern when water is used for sanitary services. Water with high salt content may corrode metal pipes. The presence of iron, manganese, and hydrogen sulfide gas can cause objectionable odors and stain fixtures and appliances.

- **Production/Processing:** Water is commonly used for many industrial purposes, whether it is incorporated into the finished product or used for some other purpose (e.g., dilution, cooling, washing). Some manufacturing groups, such as paper and food processing, demand high-quality water before use. These groups may have guidelines for acidity and alkalinity (pH), color, turbidity, metals, dissolved and suspended solids, and other water quality parameters.

- **Cooling, Air Conditioning, and Boiler Feed Applications:** The high specific heat of water makes it useful for transferring heat from one place to another. Water is used in two ways for cooling. Cooling water may be used once and released to a surface water body. The quality requirements for this use are slight. However, recirculation of cooling water before release by industrial users is becoming common because of stricter government regulations on the amount of heat industrial users are allowed to release into streams. In this case, treating recirculated water addresses quality concerns related to corrosiveness and iron deposits.

  Water is also used for steam production in heating, electricity generation, and other industrial purposes. Chemical salt content is the biggest quality parameter of concern for boiler feed water. Chemical salt forms a film of mineral deposits on heating surfaces in boilers. However, nearly all water sources have naturally occurring and prohibitively high salt content; thus, practically all water is treated before boiler feed use.

3.2.2 In-Place Services

The Nation's surface water resources provide a number of important services in-place; that is, the water is not withdrawn or used outside its natural setting. Table 3-11 identifies water's major in-place services and the key interfaces between these services and the sectors that use them. We describe the in-place services that depend on water quality.

- **Life Support for Animals and Plants:** In-place water supplies support various life functions of living systems. Undomesticated animals have access to natural water sources. Aquatic plants uptake water through their root systems to perform photosynthesis. As described above, without the proper quantity and quality of water, the health of these systems may be impaired and death may even result in extreme situations. Support for animals and plants also results in auxiliary services such as clean air, clean water, climate regulation, and ecosystem activities.

- **Residuals Removal/Dilution/Storage/Treatment:** Water is commonly used as a means of removing wastes from their point of discharge and treating those wastes in natural systems through the physical and chemical action of water resource systems. Virtually all sectors have directly used this service. Indeed, the waste loads have become so large that they have degraded the quality of the receiving waters, impairing the quality of the withdrawal and in-place services of water.

- **Commercial Fishing:** The success of commercial fishing activities is directly related to the health of the stock of commercially exploitable fish species. Because clean water provides life support for these species, poor water quality can result in increased harvest costs and prices for fish.

Table 3-11. Water Resources: In-Place Services and Major Uses

	Life Support Services		Other Services					
Users	**Animals**	**Plants**	**Residuals Removal/ Dilution/Storage/ Treatment**	**Navigation/ Transportation**	**Flood and Storm Protection**	**Energy Production**	**Recreation**	**Aesthetic and Spiritual Services**
Public Supply Systems					X			
Commercial/Government			X		X		X	X
Households			X		X		X	X
Manufacturing/Industrial			X		X			
Thermoelectric Power Generation			X		X			
Agriculture					X			
Crop Production		X	X					
Livestock Production	X		X					
Forestry		X						
Fishing, Hunting	X	X						
Mining			X		X			
Hydroelectric Generation						X		

- **Navigation/Transport:** The abundance and smooth surface of water provide an economical means of moving people and goods. This service is primarily affected by water quantity rather than water quality because excessively low or high stream flow can impair these services.

- **Flood and Storm Protection:** Wetlands, in particular, may provide flood and storm protection services. Flood and storm water may collect in wetlands that serve as a kind of buffer, lowering flood heights and preventing erosion of shorelines. By supporting healthy wetland ecosystems, water quality can therefore be an important ingredient for the provision of this service.

- **Energy Production:** The kinetic energy in moving water is used to generate power. Today, the largest use of water for the production of energy is hydroelectric generation. At hydroelectric facilities, falling water is used directly to turn turbines, which generates electricity. Water quantity is the primary determinant of the quality of this service.

- **Recreation:** Water is the focal point of many recreational activities such as swimming, boating, fishing, hunting, trapping, and plant gathering. In this capacity, water serves as a medium for transportation, an essential ecosystem component, and a source of aesthetic beauty.

  Recreational water quality concerns stem from the multitude of pollutant constituents that may affect an ecosystem. Declining ecosystem health may in turn generate changes in the quantity or quality of recreational activities or a change in human health or health risks. A common source of impaired recreational water use is pathogen infestations that impede swimming and other forms of contact recreation.

- **Aesthetic Services:** Throughout history, water has been cherished for its aesthetic value. For many people, the onsite observation of water resources and associated living and physical systems is a source of inspiration. Often, aesthetic services are referred to as passive uses.

  Both water quantity and quality may affect the quality of aesthetic amenities. Any degradation of water, whether it be excessive flow that erodes stream banks or chemicals that harm aquatic organisms, may reduce the enjoyment humans receive from viewing water resources.

3.2.3 Existence Services

John Krutilla (1967) first introduced the notion that individuals could derive satisfaction (utility) from natural resources even though they neither currently use them nor plan to do so in the future. Economists have suggested various motivations to support this nonuse concept over the past 30 years. The literature identifies altruism and stewardship as the most prominent.

Altruism involves the generalized concern for the welfare of others. In this context, altruism would be registered through the effect of water quality and its services on the welfare of others. Individuals may also have a concern for nonhuman organisms. In that case, the service is the life support for natural systems.

4 Impact of the Clean Water Act on Use Support of Water Resources

Estimating the benefits of the CWA requires, in part, characterizing the water quality conditions expected in the absence of the CWA. These without-CWA water quality estimates, combined with estimates of the with-CWA (i.e., current) conditions, provide the basis for estimating the changes in the quality of the services provided by water resources. To have a valid comparison, estimates of both the without-CWA and the with-CWA conditions must be for the same time period.

The National Water Pollution Control Assessment Model (NWPCAM) was used to develop estimates of without-CWA water quality conditions. This model builds on the Clean Water Act Effects Model (CWAEM), which was used in an earlier study by Clark et al. (1995). The NWPCAM is a significant improvement over the CWAEM because both the pollutants and pollutant sources included in the model have been expanded. To provide a consistent basis for comparing with- and without-CWA conditions, the NWPCAM was also used to develop the with-CWA conditions estimates. The Section 305(b) water quality assessment information cannot be used as the with-CWA conditions, in part because there is no way to create without-CWA assessments within the 305(b) structure based on alternative pollutant loadings. Further, the 305(b) evaluation of the support status of each water resource is relative to an administratively determined use. Finally, not all resources are systematically and consistently evaluated. Thus, we have used pollutant loadings estimates under the with-CWA and without-CWA conditions to derive the NWPCAM results.

The NWPCAM is a national-level water quality simulation model that includes the pollutants BOD, TSS, and FC. Tens of thousands of major and minor sources and area sources are included in the model. However, nonconventional and toxic pollutants are not currently included. The NWPCAM characterizes water quality for rivers and streams; it does not currently include most estuaries or lakes, the ocean shorelines, or the Great Lakes. Because the model does not include these waters, the economic valuation of benefits is limited to the impact of the CWA on only a subset of the pollutants and a subset of the Nation's water resources.

4.1 BRIEF OVERVIEW OF THE NWPCAM[1]

A key component in developing water quality estimates is a model that can simulate the water quality changes associated with the place-specific pollutant loadings changes that have occurred under the CWA. The NWPCAM is a national-level water quality simulation model. It is a fairly simple hydrodynamic and water quality model that is applied on a very large and detailed spatial scale. The large, detailed spatial scale makes the NWPCAM capable of developing place-specific water quality estimates.

The NWPCAM has five key features. It

- estimates water quality for a river network that can characterize a meaningful "universe" of waters. In particular, the river and stream network used in the model is the EPA RF1 database.
- accounts for pollutant loadings from both PSs and NPSs.
- uses stream flow and stream velocity data in modeling pollutant fate to simulate dilution and self-purification effects.

---

[1] This section is largely drawn from *A Comparative Analysis of Beneficial Use Attainment in Major U.S. Rivers and Streams Under Alternative Water Pollution Control Scenarios* (Research Triangle Institute, 1997b).

- estimates both water quality and beneficial use attainment—categories include boating, fishing, and swimming.
- is capable of characterizing PS loadings under different states of the world to do either retrospective analyses of existing programs or prospective analyses of new programs under Agency consideration.

The NWPCAM incorporates the approximately 633,000 miles of rivers and streams in RF1 grouped into 68,000 stream segments, known as "reaches," of which approximately 61,000 are river and stream reaches with an average length of about 10 miles. These are transport reaches—water flows down them. The remaining 7,000 reaches are nontransport reaches (e.g., lake shorelines). The transport reaches are subdivided into subreaches for computational purposes by breaking them at each "milepost" and at any place where there is a known PS discharge. EPA, other agencies, and the States are currently developing a more comprehensive reach database, RF3. It will include virtually all of the 3 million miles of rivers and streams because it will incorporate data on smaller, even intermittent, streams.

Estimates of mean and low stream flows and velocities were incorporated in the NWPCAM for each transport reach in RF1 to trace pollutant transport and to simulate dilution and self-purification. Hydrological relationships were used with the loadings and water flow data to estimate mean water quality for each mile in RF1.

While the NWPCAM is very extensive in terms of water resources and pollutants, it is not complete. Estuaries, coastal waters, and lakes, including the Great Lakes, are not included in the model. Nonconventional and toxic pollutants are not included either.

4.2 POLLUTANT LOADINGS

Place-specific estimates of the discharge of three conventional pollutants drive the water quality estimates developed by the NWPCAM. The pollutant loadings were estimated under both with-CWA and without-CWA conditions. While the great majority of the pollutant loadings differences may be attributed to initiatives taken under the CWA, some of the changes in pollutant releases characterized below as "with CWA" are undoubtedly due to other nonfederal programs or would have happened without the Act. Prior to the passage of the 1972 amendments, some States and other authorities had begun to more vigorously address the problem of water pollution in their area. Even without the Act, loadings would have been affected by such actions. However, because there is no way to project the impact of the nonfederal programs if there had been no CWA, and because the CWA is generally believed to be the major impetus behind the loadings changes (and subsequent water quality improvements), we attribute all estimated differences in pollutant loadings and water quality to the CWA.

When developing the loadings estimates, it is not always possible to have conformity in the current loadings estimates because data sources for the different dischargers are not always released for the same years. Data for the latest year available, generally mid-1990s, were used as our with-CWA conditions.

4.2.1 Loadings Under the With-CWA Conditions

PS loadings of BOD and TSS by place were derived from the 1988 Needs Survey database, the Industrial Facilities Discharge database (IFD), and the Permit Compliance System (PCS), which contains data from the NPDES Discharge Monitoring Reports. In total, the model incorporates place-specific discharge data from 37,510 sources, including 9,890 municipal dischargers, 2,261 major industrial dischargers, and 505 CSOs. A significant advance of the NWPCAM over the CWAEM is the inclusion for the first time of 24,854 minor industrial dischargers.

Estimates of current (circa mid-1990s) national-level loadings of BOD and TSS from industrial and municipal point sources are provided in Table 4-1. The table includes estimated loadings from all dischargers in the continental United States as well as discharges from the subset of facilities on the rivers and streams modeled in the NWPCAM.

NPS loadings are based on county-level loadings estimates developed by Lovejoy (1989) and Lovejoy and Dunkelberg (1990). Rural and urban loadings are reported separately. For rural areas, the annual NPS loadings were allocated to each mile of the rivers and streams in RF1 in proportion to the total stream length in the county. For instance, if a county has a total of 100 miles of RF1 rivers and streams, then we allocated 1 percent of the county's NPS

Table 4-1. Total Loadings of BOD and TSS for Industrial and Municipal Point Sources With the CWA, Mid-1990s

	Industrial Dischargers		Municipal Dischargers		Totals	
Water Resources	**BOD (thousand tons/yr)**	**TSS (thousand tons/yr)**	**BOD (thousand tons/yr)**	**TSS (thousand tons/yr)**	**BOD (thousand tons/yr)**	**TSS (thousand tons/yr)**
Inland rivers and streams[a]	1,050	4,496	524	577	1,575	5,073
Coastal	239	958	233	219	472	1,177
Great Lakes	4	629	16	18	20	647
Unknown[b]	558	1,255	101	116	659	1,372
Total	1,852	7,339	874	929	2,726	8,268

[a] The water quality effects are only estimated for these RF1 resources.
[b] The water resource to which the loadings are released is unknown.

loadings to each mile. For stream segments overlapping more than one county, we assumed an equal proportion of the reach segment is in each county. For urban NPS loads, the allocation was proportional to both stream length and the population associated with each reach segment. Only a portion of NPS loads will actually get into the stream depending on the local sediment delivery ratio (SDR), which can vary greatly by watershed area. Separate SDRs were used for BOD and TSS for each of the 18 hydrologic regions in the United States.

Loadings of BOD, TSS, and FC from CSOs serving approximately 43 million people were obtained from Tetra Tech (1993). These loadings were updated to 1995. Table 4-2 provides the NPS and CSO current loadings estimates for BOD and TSS.

Table 4-2. Total Loadings of BOD and TSS for Nonpoint Sources and CSOs with the CWA, Mid-1990s

Source[a]	**BOD (thousand tons/year)**	**TSS (thousand tons/year)**
NPS	1,847	64,363
CSO	1,309	4,806

[a] Only sources included in the NWPCAM.

4.2.2 Loadings Under the Without-CWA Conditions

Since the passage of the CWA, pollutant loadings have changed because of changes in both the pollutant intensity of economic activity and in the level and distribution of that activity. The pollutant intensity of economic activity—that is, the ratio of pollutant loadings per unit of activity—has generally decreased due to the promulgation of effluent guidelines and the construction of municipal wastewater treatment facilities. However, the aggregate level of economic activity has increased 87 percent over the 1972 to 1996 period (U.S. Department of Commerce, 1997), implying that, without the change in pollutant intensity, loadings would have risen by a similar percentage (assuming that this growth was proportionally experienced across the economy's sectors).

In constructing the without-CWA loadings estimates, we first estimated early 1970s' loadings/sales ratios by industry. We then applied these estimates to (i.e., multiplied by) estimates of mid-1990s' sales by industry. These estimates of economic activity were developed accounting for the fact that the CWA has imposed costs on these industries and that this has altered somewhat the growth and distribution of economic activity across the Nation.

Estimates of pollutant loadings without the CWA are provided in Table 4-3. As discussed above, we attribute all these changes to initiatives under the CWA. This approach undoubtedly overstates, by an unknown amount, the impact of the Act.

Table 4-3. Total Loadings of BOD and TSS for Industrial and Municipal Point Sources Without the CWA, Mid-1990s

	Industrial Dischargers		Municipal Dischargers		Totals	
Water Resources	**BOD (thousand tons/yr)**	**TSS (thousand tons/yr)**	**BOD (thousand tons/yr)**	**TSS (thousand tons/yr)**	**BOD (thousand tons/yr)**	**TSS (thousand tons/yr)**
Inland rivers and streams[a]	1,619	8,306	1,106	1,217	2,725	9,523
Coastal	306	1,709	492	462	798	2,171
Great Lakes	6	1,140	34	38	40	1,178
Unknown[b]	1,154	2,441	222	244	1,376	2,685
Total	3,084	13,596	1,855	1,962	4,939	15,558

[a] The water quality effects are only estimated for these RF1 resources.
[b] The water resource to which the loadings are released is unknown.

Municipal Sources

For municipal sources, we computed without-CWA effluent loadings as a percentage of influent loadings—loadings to municipal wastewater treatment facilities prior to treatment. The current treatment level for municipal wastewater is a well-operating secondary treatment system with 82 percent removal for both BOD and TSS, a standard that has been largely achieved under the Construction Grants Program (EPA, 1992a). Given the mid-1990s' effluent PS loads, and assuming 82 percent removal of these pollutants, computing the influent loadings is straightforward. We assumed that mid-1990s' influent loadings would be the same both with and without the CWA. However, we also assumed that, in the absence of the CWA, BOD and TSS removal would remain at 1972 levels of 62 percent. Therefore, current influent loadings, treated at a 62 percent removal rate, were used to represent effluent loadings from these sources under the without-CWA scenario.

We have not explicitly addressed the impact of the pretreatment program on water quality. The main focus of the pretreatment program is on nonconventional and toxic pollutants that may simply pass through POTWs. These pollutants are not addressed in this study. To the extent that the pretreatment program also affects conventional pollutants, our without-CWA loadings estimates are underestimates of these loadings.

Industrial Sources

For industrial facilities, we assumed that 1972 loadings per unit of output would have remained constant over the 1972 to mid-1990s period without the CWA. Constant-dollar industry sales were used as the output surrogate. The 1972 values are based on estimates developed in the early 1970s (EPA, 1976). Unfortunately, these estimates, while the best available, are not complete and in some cases may not be completely reliable. In cases where the values were questionable or incomplete, to develop the 1972 ratio for an industry, we scaled up its current pollutant-to-output ratio by a factor equal to the average change (from 1972 to 1995) in pollutant-to-output ratios from other industries. Current estimates of industrial output were combined with the estimates of discharges per dollar of output in 1972 to determine an initial measure of industry-specific effluent loadings for the without-CWA conditions for those industries.

Because the CWA is presumed to have led to increased production costs and reduced output and growth in the industrial sectors of the economy (EPA, 1992b), changes in industrial output attributable to the Act were estimated using a dynamic "general equilibrium" model of the entire U.S. economy (FEMA, 1987). We then assumed that a percentage change in economic growth due to the CWA leads to an equal (and opposite) percentage change in pollutant loadings. For example, if it is determined that CWA requirements resulted in a 5 percent decrease in the annual economic output for a particular sector relative to what the output would have been otherwise, then PS loads for each industry in that sector were increased by 5 percent when modeling the without-CWA scenario. It is important to note, however, that changes in economic growth estimated using the general equilibrium model are quite small and have virtually no effect on the NWPCAM results.

Combined Sewer Overflows and Nonpoint Sources

Changes in loadings from CSOs are excluded from the without-CWA scenario because EPA programs designed to control pollutant loadings from these sources are currently being implemented. For a prospective analysis of the expected benefits of EPA's Urban Wet Weather Management Program, see Research Triangle Institute (1997a).

NPS loadings are also assumed to remain at mid-1990s levels under the without-CWA scenario because we lack data on the effectiveness of NPS controls.

4.3 WATER QUALITY

Water quality levels for BOD TSS, DO, and FC were estimated for all stream segments in RF1 using the NWPCAM and pollutant loadings estimates for the with-CWA and without-CWA conditions. These water pollutant levels were then related to beneficial use for recreation activities (boating, fishing, swimming) using an approach developed by Vaughn for Resources for the Future (Mitchell and Carson, 1986). His approach involves choosing a maximum pollutant level for BOD, TSS, DO, and FC that corresponds to boatable, fishable, and swimmable waters. Vaughn's water quality ladder includes BOD, turbidity, DO, pH, and FC. TSS is used in this study as a surrogate for turbidity. The omission in our model of pH, nutrients, and other water quality variables suggests that our model overestimates the number of river and stream miles in a beneficial use category to the extent that these excluded parameters would further degrade attainment status.

The water quality ladder values for each beneficial use is provided in Table 4-4. Each stream segment in the NWPCAM is assigned to a beneficial use category based on the requirement that the segment must have water quality that meets all four of the corresponding water quality criteria. A water resource that fails to meet the boating criteria is classified as a "nonsupport" resource.

Table 4-4. RFF Water Quality Ladder Values

Beneficial Use	BOD (mg/L)	Total Suspended Solids (mg/L)	Dissolved Oxygen (% saturated)	Fecal Coliforms (MPN/100 mL)
Swimming	1.5	10	0.83	200
Fishing	2.4	50	0.64	1,000
Boating	4.0	100	0.45	2,000

4.3.1 Water Quality Conditions Under Alternative Point Source Control Scenarios

The estimated national distribution of the 632,552 river and stream miles in RF1 across the beneficial use categories in the mid-1990s is shown in Tables 4-5 and 4-6 for three separate PS control scenarios:

1. a with-CWA scenario,
2. a without-CWA scenario, and
3. a zero PS discharge scenario.

It is important to note that, in each case, the miles in the swimmable category are a subset of the fishable and boatable miles, because a portion of the miles that are suitable for fishing are also suitable for swimming. Similarly, the fishable miles are a subset of the boatable miles. In other words, these three

Table 4-5. Maximum Achievable Increases in Recreational Use Support Through Point Source Controls

	Number of U.S. River and Stream Miles in Each Use Support Category		
Highest Use Supported	**Without-CWA Conditions**	**Zero PS Discharge Conditions**	**Maximum Achievable Change**
Swimmable	222,120	255,475	33,355
Fishable	399,999	442,753	42,754
Boatable	454,038	490,848	36,810
Nonsupport	178,514	141,704	–36,810

Table 4-6. Rivers and Streams (632,552 miles) Supporting Recreational Uses: Comparison of With-CWA and Without-CWA Conditions in the Mid-1990s

			Increase in Use Support	
Highest Use Supported	**Without-CWA Conditions (miles)**	**With-CWA Conditions (miles)**	**Miles**	**Percent of Maximum Increase[a]**
Swimmable	222,120	238,627	16,507	49.5%
Fishable	399,999	424,712	24,713	57.8%
Boatable	454,038	475,894	21,856	59.4%
Nonsupport	178,514	156,658	–21,856	59.4%

[a] Maximum defined by difference between without-CWA scenario and zero PS discharge scenario.

categories—boatable, fishable, and swimmable—are not mutually exclusive. Therefore, adding miles across the three support categories is not appropriate and would result in double-counting because some river and stream miles support more than one use.

Estimates for the with-CWA and without-CWA scenarios were based on the loadings data described in Sections 3.2.1 and 3.2.2. The third scenario was estimated based on the assumption that all loadings of conventional pollutants from PSs were equal to zero. Because this zero PS discharge scenario represents the maximum achievable control of PSs, it serves as a useful point of reference for evaluating the with-CWA (i.e., current control) scenario. It highlights the fact that, even if all PS loadings were reduced to zero, a sizable portion of U.S. rivers and streams would experience little to no improvement (relative to the without-CWA scenario) in their ability to support specific recreational uses.

According to the NWPCAM, going from the without-CWA scenario to the zero PS discharge scenario, only a small percentage (roughly 10 percent) of the 632,552 miles of rivers and streams would achieve higher recreational uses. This occurs for the following reasons. First, only 288,034 of the 632,552 miles are downstream of PSs and, thus, potentially affected by PS controls. Second, of these remaining miles, 91,353 would achieve swimmable status, even without the CWA controls. This leaves 196,681 potentially improvable miles. Third, because the remaining miles are affected to differing degrees by NPSs, a large portion of them would not support higher recreational uses even if upstream PSs were eliminated. Their recreational uses are, in effect, limited by upstream NPSs. Deducting these miles leaves at most 62,815 miles that could achieve higher recreational uses through PS controls.

For both the without-CWA and zero PS discharge scenarios, Table 4-5 shows the estimated number of river and stream miles in each recreational use support category. For each use support category, it also shows the maximum achievable increase in support miles through PS controls. For the swimmable, fishable, and boatable categories, the maximum increases are 33,355, 42,754, and 36,810 miles, respectively.

Table 4-6 displays the estimated number of river and stream miles in each recreational use support category for the with-CWA and the without-CWA scenarios. Estimated improvements in recreational use support include 16,507 more miles supporting swimming, 24,713 more miles supporting fishing, and 21,865 more miles supporting boating. Although these changes represent relatively small percentages of the nationwide number of river and stream miles, they do represent sizable increases relative to the maximum improvements achievable through PS controls (as shown in Table 4-5). An estimated 50 percent of all the miles that could potentially improve to swimmable status through PS controls do so as a result of CWA controls. The numbers achieving fishable and boatable status as a result of CWA controls are closer to 60 percent of their respective maxima.

We note again that, even without the CWA, water quality may have improved because of the existence or establishment of water quality programs at the State or local level. Thus, the water quality estimates for the without-CWA scenario may understate the number of miles in each recreational use support category. This would imply that the estimated increases in use-support that are attributed to the CWA (Table 4-6) and to complete PS controls (Table 4-5) are overstated.

Because many of the services received from water resources depend on their proximity to people, Table 4-6 also reports estimates of water quality changes specifically for inland rivers and streams that pass through "populated places" (as defined by the Census Bureau [U.S. Department of Commerce, 1991]). NWPCAM includes 14,490 such places, accounting for almost two-thirds of the U.S. population and over 35 percent of all RF1 rivers and stream miles. As shown in Table 4-7, these areas also account for over two-thirds of the river and stream miles that achieve higher recreational use categories as a result of the CWA. For example, 12,527 (76 percent) of the 16,507 miles that are estimated to achieve swimmable status as a result of the CWA are in populated places. This indicates that controls initiated under the Act have, on a proportional basis, had more of an impact on water quality in populated places than in the nation as a whole. PSs tend to be located near more populated places; therefore, PSs have a particularly large effect on water quality in these areas.

Table 4-7. Rivers and Streams *in Populated Places* (222,789 miles): Comparison of With-CWA and Without-CWA Conditions in the Mid-1990s

Highest Use Supported	Without-CWA Conditions (miles)	With-CWA Conditions (miles)	Increase in Use Support (miles)
Swimmable	109,003	121,530	12,527
Fishable	161,861	178,588	16,727
Boatable	175,666	190,319	14,653
Nonsupport	47,123	32,470	–14,653

It is important to emphasize that these estimates of water quality improvements are not directly comparable to those in the States' 305(b) reports. These estimates cover only a subset of the Nation's water resources (rivers and streams in RF1), whereas the 305(b) reports cover all resources. Further, under Section 305(b) the authorities designate a use for the water resource, then evaluate its ability to support that use. Thus, under 305(b) the use support assessment is *relative* to the designated use, and the examination is selective (i.e., not all resources are evaluated and the selected resources are purposefully, rather than randomly, sampled to determine their use support). In contrast, our evaluation is an *absolute* measure of water quality, and the coverage of RF1 resources using the NWPCAM is complete. For these reasons, this analysis and the 305(b) reports should not be directly compared.

5 Valuation of Selected In-Place and Existence Benefits

In 1983 Robert Mitchell and Richard Carson conducted a study for EPA of the national benefits of freshwater pollution control using the contingent valuation method (CVM) (Mitchell and Carson, 1986; Carson and Mitchell, 1993). Their results are applied here with the NWPCAM water quality simulations to estimate the value of the nationwide improvements in selected water resource services as a result of the CWA. The methodology employed generally follows that of Clark et al. (1995).

Although the benefits estimates provided in this report are the most comprehensive yet developed, they are incomplete. In particular, toxic and nonconventional pollutants are not covered by this analysis. Further, the water resources incorporated in the NWPCAM do not include most estuaries, the ocean shoreline, the Great Lakes, and other lakes. Only rivers and streams are represented and not all of them, but the most important ones are included. Finally, the services captured by the Mitchell and Carson study cover only some of the in-place services of freshwater resources. Existence services are also included, but no withdrawal services are addressed.

Most studies in the economics literature that have examined the value of water resources have evaluated the value of water, per se (e.g., the value of a residence with a water view), the value of access to water resources for recreation, especially fishing, or the value of site attributes other than water quality (e.g., fish abundance). Relatively few studies have attempted to estimate the value of water quality changes, even for a local setting. What is unique here is that our methodology is designed to capture (some of) the benefits of water quality changes at a national level.

The measure of value employed in this study is households' maximum willingness to pay (WTP) for the estimated improvements in water quality under the CWA. WTP is usually regarded as the best observable measure of the value that people place on the benefits of environmental quality improvements, and its use is consistent with governmental directives for conducting benefits analyses. Use of WTP implies a human-oriented perspective on the benefits of water quality improvements. For decisionmakers who believe that a more expanded view of the value of ecosystems should be the basis of public policy, WTP would, presumably, represent a lower bound on the value of the water quality improvements under the CWA.

5.1 OVERVIEW OF THE MITCHELL AND CARSON STUDY

The CVM uses survey questions to uncover individuals' preferences for a commodity of interest. It is part of a family of preference elicitation methods that include voting and conjoint analysis, the latter of which is widely used in market research to gauge the market for new commodities. With the CVM, a survey instrument is designed that asks respondents to provide their value for a good, usually a public good, of interest. The instrument typically includes a detailed characterization of the good, a description of the payment vehicle, WTP questions, and questions on the respondent's socioeconomic status. The collected data are econometrically analyzed to estimate the value of the good for the population of inference.

Mitchell and Carson conducted a series of in-person interviews at 61 sampling points across the United States in 1983 using a national probability sample based on the 1980 Census. The purpose of the interviews was to learn about the importance households place on clean water. The measure of importance is the sacrifice they would be willing to make in dollars to achieve specified levels of water quality, that is, their WTP.

The interviews elicited responses on a number of topics related to environmental protection, water pollution, and water-based recreational activities. The basic outline of the survey instrument covered the following topics:

- Water Resources: The water resources covered by the survey were confined to freshwater lakes, rivers, and streams throughout the Nation. Subsequent discussions with one of the authors indicate that the Great Lakes are not part of the water resources that respondents included in their values (Carson, 1997).

- Water Resources Services: Withdrawal services, including drinking water, were not part of the services respondents were asked to value. Only in-place and existence services were included.

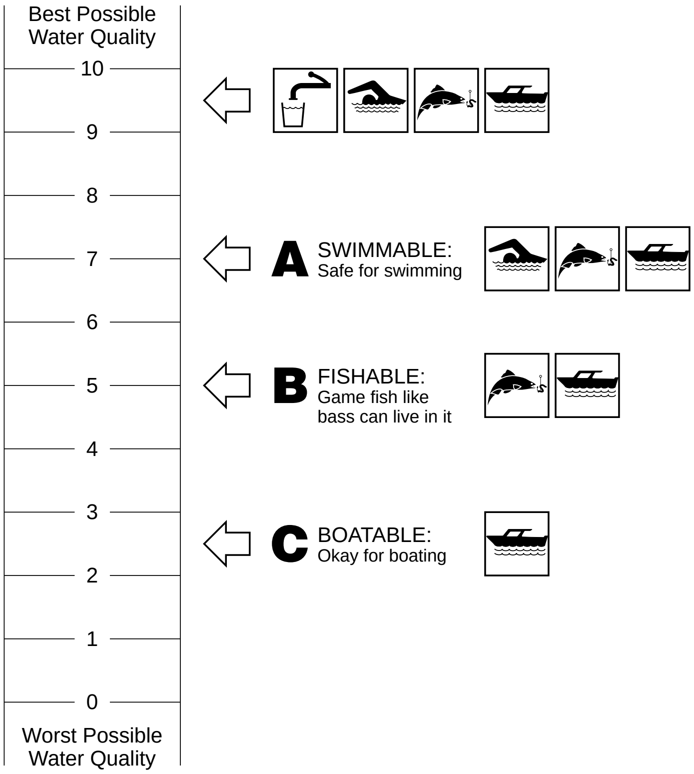
- Valuation Component: Respondents were presented with a water quality ladder[1] (Figure 5-1) depicting levels of water quality ranging from below "boatable" to "drinkable" and asked to state how much they would be willing to pay to maintain or achieve various levels of minimum water quality throughout the country.[2] Thus, there is a close correspondence between the Mitchell and Carson economic value study and our assessment of realized water quality improvements.

---

[1] This water quality ladder was originally developed by W.J. Vaughan for Resources for the Future for a pilot study conducted by Mitchell and Carson in 1980. The pilot study was a precursor to the study outlined in this section.

[2] Nonboatable water was further described as having "oil, raw sewage, and other things like trash in it; it has no plant or animal life, smells bad, and contact with it is dangerous to human health." Boatable water was described as "[not harming] you if you happened to fall into it for a short time while boating or sailing."

Figure 5-1. Resources for the Future Water Quality Ladder



- Elicitation Procedure: A payment card was used on which respondents were shown amounts average households were then currently paying in taxes and higher prices for selected publicly provided goods (e.g., national defense) and were asked to state their WTP for the water quality change.

- Payment Vehicle: Respondents were told that the water quality changes would be paid for in higher product prices and higher taxes.

The estimated WTP values from the Mitchell and Carson study after adjusting for nonresponse effects are provided in Table 5-1. These values represent their “best estimates” of the mean annual household values in 1983 for achieving the incremental water quality goals. Analysis of the WTP bids by Mitchell and Carson indicated that WTP increased proportionately with respondents’

Table 5-1. Individual Household WTP Values for Water Quality Improvements

	Mean Annual Household Values, 1983[a]		Mean Modified Household Values, 1996[b]	
	Total	Incremental	Total	Incremental
Swimmable: WTP to raise all subswimmable water quality to swimmable	$241	$78	$491	$159
Fishable: WTP to raise all subfishable water quality to fishable	$163	$70	$332	$143
Boatable: WTP to maintain boatable water quality	$93	$93	$189	$189

[a] Mitchell, R.C., and R.T. Carson. 1986. *The Use of Contingent Valuation Data for Benefit/Cost Analysis in Water Pollution Control*. CR-810224-02. Prepared for U.S. Environmental Protection Agency, Office of Policy Planning and Evaluation. Washington, DC.

[b] Scaled Mitchell and Carson values based on real income growth and price changes over 1983 to 1996 period.

household income—a 1 percent increase in household income increased its expected WTP by approximately 1 percent. Based on data indicating that per capita disposable income increased by 26.5 percent from 1983 to 1997, and that consumer prices increased by 61 percent over the same period, Mitchell and Carson's best estimates of WTP have been adjusted in Table 5-1 to 1997 values.

5.2 APPLICATION OF THE MITCHELL AND CARSON ESTIMATES

The pollution control initiatives taken under the CWA have changed the distribution of water quality throughout the Nation's water resources from what it would have been without the Act. As set out in the previous chapter, current water quality modeling limitations have forced us to focus only on the 633,000 miles of rivers and streams that make up RF1 and on selected conventional pollutants and pollutant sources. Applying the Mitchell and Carson estimates to value the estimated water quality improvements requires consideration of how households' WTP is likely to vary (1) with the characteristics of the affected water resources and (2) with the extent of the water quality changes.

Following Smith (1996), we would expect that arguably different water resources should be valued differently by people. For example, individuals are likely to place more value on water resources that are nearer to them. This is simply because they provide lower cost recreation opportunities, more encounters where the aesthetic services of the resource can be enjoyed, and so forth. Other characteristics of the resources that affect the quality of their withdrawal and in-place services may also be expected to influence households' WTP for water quality changes.

One would also expect that the scope (or amount) of the water quality changes due to the Act would be directly associated with people's WTP for those changes. For example, if ten miles of a river changed from boatable to fishable water quality, that change should be more highly valued than if the change only affected one mile. The Mitchell and Carson results provide only minimal support for the hypothesis that scope matters. They report that many respondents to their survey indicated that their WTP for partial improvements was not much lower than for complete attainment of the stated water quality goals.

In their survey, Mitchell and Carson asked respondents to apportion each of their expressed WTP values between achieving the water quality goals in their own State and achieving those goals in the Nation as a whole. On average, respondents allocated 67 percent of their values to achieving in-state water quality goals and the remainder to the Nation as a whole. Mitchell and Carson argue that for valuing *local* water quality changes, 67 percent of the total reported value is a reasonable upper bound for the local share of WTP. Their findings support the view that proximity does matter as do, almost by definition, the results of travel cost studies of recreation behavior. Based on the Mitchell and Carson results, we treat local and nonlocal water resources as different commodities.

5.2.1 Local/In-Place Benefits

We confined our application of local values to "populated places" with an RF1 resource. Populated places are specified in the 1990 Census Bureau database (U.S. Department of Commerce, 1991).

They account for 75 percent of the U.S. population; however, not all such places have an RF1 water resource within them.[3] This is a more restrictive definition of "local" than using State boundaries, which seem too large to meet this requirement. The method we use does result in some underestimation of the local benefits of the Act. Even if this definition of local is reasonable, there are undoubtedly water quality changes for resources with proximate populations that are not included in the definition of populated places.

To capture the scope effects of a policy, Mitchell and Carson (1986) propose the use of a simple multiplier (i.e., scaling factor) to account for how WTP would vary with the *proportion* of waters that experience improvement. As an upper-bound approximation, we set this multiplier equal to one for the local benefits and applied it to any water quality change in a populated place. For example, if *any* portion of *any* stream segment in a populated place moves from, say, boatable to fishable, we applied the household WTP value of $143 to all local households regardless of the stream length affected. We did this because we believe that the water resources most likely to be significantly impacted by the CWA are those that matter most to people, since PSs are likely to be located along larger rivers. An alternative would be to scale the WTP value by, for instance, the share of impacted stream miles in the area. However, this approach is likely to underestimate the importance of the water quality changes for the more important local water resources due to the many miles of unaffected small rivers and streams in RF1. As shown in Table 5-2, the estimate of local annual benefits from the CWA, based on this approach, is almost $9.5 million per year in the mid-1990s (i.e., 1997).

The two assumptions made to operationalize the use of the Mitchell and Carson values push the estimated local benefits value in different directions. Defining "local" as a populated place rather than a State tends to produce lower benefit estimates. However,

---

[3] The number of individuals in populated places was multiplied by 1.08 to account for the increase in urban population between 1990 and 1997. Furthermore, the number of *individuals* in the population was converted to the number of *households* by dividing the population by 2.64, which was the average number of individuals per household in the United States in 1997 (U.S. Department of Commerce, 1999).

applying the full WTP value to the entire population when there is any water quality change in a place rather than using a fractional estimate is likely to overestimate the population's WTP for partial water quality changes.

5.2.2 Nonlocal/Existence Benefits

In contrast to local benefits, which we treat as being derived primarily from the in-place services of proximate water resources, nonlocal benefits are derived primarily from existence services. This is because the geographical area of nonlocal is, essentially, the rest of the Nation. Furthermore, we do assume there is a scope effect for nonlocal water quality changes. To distinguish nonlocal benefits, for each category of beneficial use, we deducted the fraction of WTP that is assumed to be for local water quality changes only (67 percent). This leaves 33 percent (of total WTP to attain each use target) for nonlocal water quality changes. This value was multiplied by the *fraction* of previously impaired national waters (in each use category) that attain the beneficial use as a result of the CWA. To measure aggregate national WTP for nonlocal water quality improvements, we then multiplied this value by the total number of households in the United States.

This approach probably results in an underestimate of the existence benefits of the CWA since each river is only represented by its length in the calculation. If water quality in some rivers matters more than in others, the estimate is likely to undervalue existence benefits because the larger rivers are most affected by the CWA.

5.2.3 Total Estimated Benefits

Combining the local and nonlocal values, the annual benefits of water quality improvements attributable to the CWA are about $11 billion annually, an average of about $109 per household. As shown in Table 5-2, local benefits make up the largest component of the benefits. Respondents to the Mitchell and Carson survey did provide a higher WTP for local than nonlocal water quality changes, two to one. Also, we have used a unitary multiplier for local water quality changes and a fractional multiplier for the nonlocal changes to account for scope effects. As shown in Table 5-2, the estimate of annual existence benefits from the CWA based on this approach is $1.5 billion per year in the mid-1990s.

Table 5-2. Estimated Annual Value of Selected In-Place and Existence Benefits of the CWA, Mid-1990s (million 1997$/yr)

Use Attainment	Local/ In-Place Benefits	Nonlocal/ Existence Benefits	Total Benefits
Boatable	$4,192	$784	$4,977
Fishable	$3,043	$512	$3,556
Swimmable	$2,356	$216	$2,572
Total	$9,592	$1,513	$11,105

It is important to emphasize again that our estimate of the benefit of the CWA is an underestimate because the coverage of this analysis is not comprehensive. The estimated benefits cover only the recreation, aesthetic, and existence benefits of surface water quality changes. While these water resource services are most likely to be enhanced by the CWA, other in-place and withdrawal services may also be enhanced. Further, these values only cover rivers and streams. The quality of estuarine and marine water, lakes, and the Great Lakes has also improved as a result of the CWA. These waters are not included in this analysis because of current modeling limitations. Finally, only a subset of water pollutants regulated under the CWA is included in this analysis. Future Agency efforts are designed to incorporate the omitted sources, pollutants, resources, and services. Once all of these factors are accounted for, the estimated value should increase and provide a more accurate assessment of the total benefits of the CWA.

6 Case Study: The Willamette River Basin[1]

This case study of the Willamette River Basin provides an opportunity to examine the benefits of the CWA at a regional level. This perspective provides greater detail than is possible with a national study. Following the taxonomy developed by the General Accounting Office (GAO, 1990), this is an illustrative case study. It is designed to describe what happened to water quality in Oregon's Willamette River with the CWA controls. The Willamette River was selected for analysis because its water quality has improved significantly since the 1960s. Thus, this site was selected because of the special interest this river provides. This selection approach precludes any generalizations of the findings from this site that would be possible with, for example, a probability sample of case study sites. However, the Willamette River case study does provide a broader characterization of the benefits of water quality than is possible at the national level and an illustration of the gains in social welfare that are possible with pollution controls.

The approach to this benefits analysis uses an activity day methodology. With this approach, an estimate of the difference in the level of recreational activities with and without the water

---

[1] This section, except Section 6.6, is an RTI abridgement of larger studies by Tetra Tech, Inc. (1997), and Industrial Economics, Inc.

quality improvements is first developed. Then the value of the activity differences is estimated by multiplying the unit value for each activity by the number of units. The unit values are drawn from the literature. Activity rates were developed for the latest year for which data are available. This is the early 1990s for some activities, late 1980s for others. Thus, these results should be considered reflective of about 1990 conditions. As is the case for the national-level estimates of CWA benefits, these case study estimates are also incomplete. They only focus on the recreation benefits of the Act, although other water resources services are qualitatively evaluated.

To compare the methodology used to develop the national estimates with the activity day approach, we also applied the NWPCAM to the Willamette River.

6.1 PROFILE OF THE WILLAMETTE RIVER BASIN

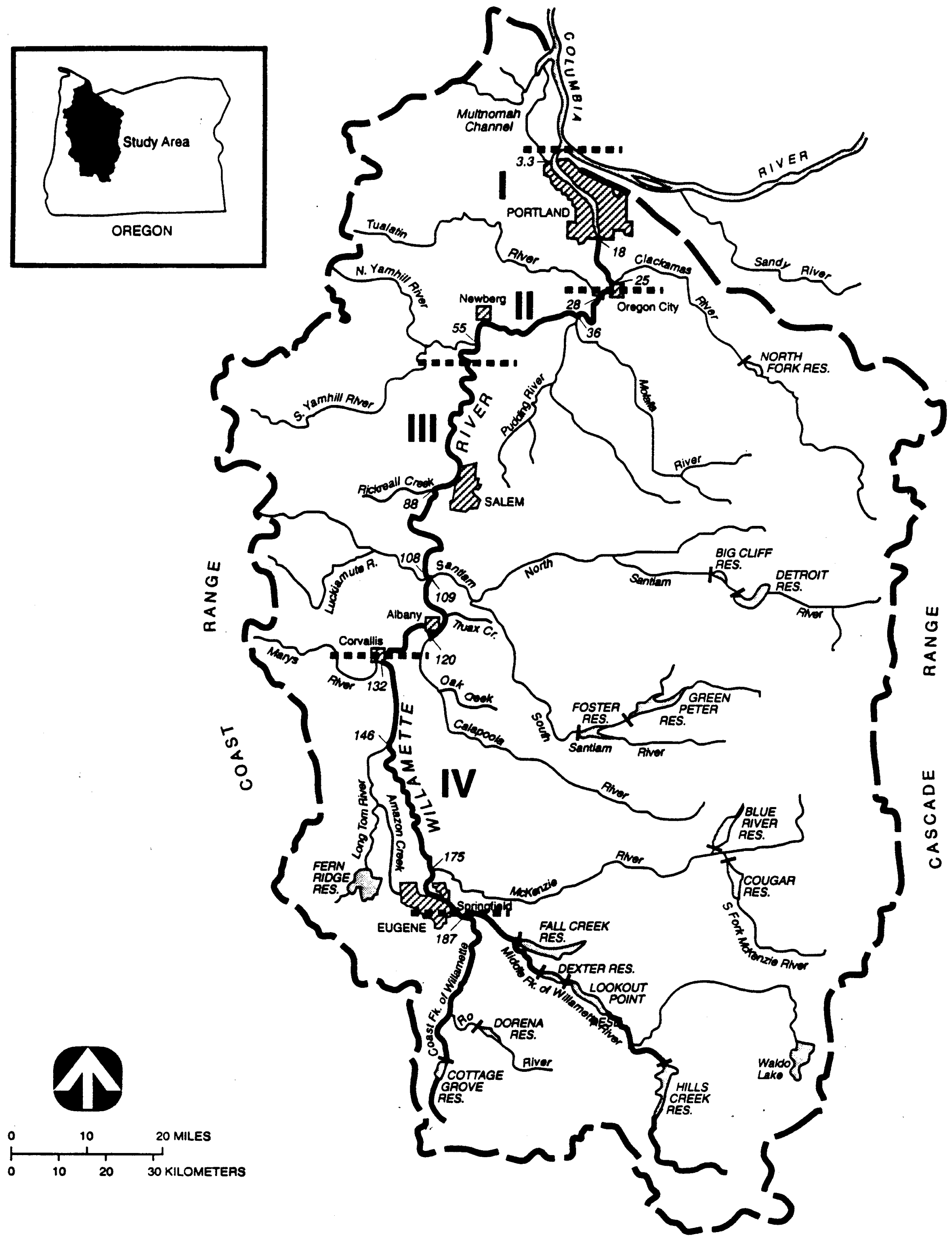
The Willamette River's drainage basin spans approximately 11,500 mi^2 in northwest Oregon between the coast (west) and Cascade (east) mountain ranges (Figure 6-1).[2] The main stem of the river meanders approximately 187 miles north through an alluvial valley to the Columbia River. Elevations range from less than 10 ft. at the mouth near the Columbia River to 450 ft. in the valley near Eugene to greater than 10,000 ft. in the headwaters of the Cascade range. The Willamette is the tenth largest river in the continental U.S. in terms of total discharge; the discharge per unit area is the highest of large U.S. rivers (Sedell and Frogatt, 1984).

The population of the Willamette River basin has steadily increased since World War II, and Oregon's three largest cities—Salem, Portland, and Eugene—with a total population of 1.8 million (nearly 70 percent of the State's population) are located within the basin. The wood products and agricultural economy of the Willamette basin accounts for about 70 percent of the total industrial production for Oregon. Industrial production, like the population of the basin, has steadily increased over the past several decades.

---

[2] The study region encompasses Columbia, Multanomah, Yamhill, Clackamas, Polk, Marion, Benton, Linn, Lane, and Washington counties in Oregon.

Figure 6-1. Willamette River Basin Water Quality Study Area and the Four River Regions



Source: STORET.

The river has played a key historical role in the agricultural and industrial development of the valley. The Willamette River, a major source for the basin's municipal (20 cities) and industrial (600 facilities) water supply, also provides irrigation water for the rich fruit and vegetable farms of the valley. The river and its tributaries have long been recognized as important spawning grounds for anadromous fish and have contributed markedly to the commercial and recreational fishery of the Columbia River, as well as offshore catch. Other major uses of the Willamette River include commercial navigation; hydroelectric power production; and water-based recreational activities, including aesthetic enjoyment of the Greenway Trail, which runs along the length of the river. As the region has grown, the river has also been used for municipal and industrial waste disposal.

6.2 POLLUTANT LOADINGS AND WATER QUALITY

The primary source of pollution load to the Willamette River has always been the wastewater discharge from the pulp and paper industry. Beginning with the first mills in the late 1800s, untreated wastewater was discharged directly to the river. In 1948, the four sulphite mills located on the main stem discharged in excess of 2,500,000 population equivalents.[3] The subsequent construction of additional mills increased this amount to 4,490,000 population equivalents (Gleeson, 1972). By 1965, however, the practice of ponding, barging, or process changes reduced pulp and paper mill wastewater discharge to the river by 76 percent for the low water period. By 1969, all mills had installed primary treatment, and by 1972, all mills were required to have installed secondary treatment and chemical recovery facilities. According to the Oregon Department of Environmental Quality (ODEQ), the additional changes required by 1972 were expected to result in an overall reduction in BOD of over 92 percent (ODEQ, 1970; Gleeson, 1972).

Water quality studies conducted on the Willamette River in the early 1920s indicated that the untreated wastewaters discharged by

---

[3] Population equivalents are the calculated population that would normally contribute the same amount of BOD per day. A common base is one-sixth of a pound of BOD per person per day (ODEQ, 1970).

municipal and industrial facilities had created a condition of severe and extensive pollution (Gleeson, 1972). In 1927, the Portland City Club described the river as “ugly and filthy” and conditions of the river were “intolerable” to the point that construction workers refused to work on riverside projects (Gleeson, 1972; CEQ, 1973). A 1934 water quality survey indicated that the Willamette River through the Portland Harbor was in very poor condition and devoid of all DO in a stretch of several miles (Gleeson, 1972). Study results published from 1936 through 1938 concluded that there existed “undisputed evidence that portions of the Willamette River had become so polluted with municipal sewage and industrial wastes that these waters were a menace to health, destructive to fish life, and unfit for certain other beneficial uses” (Westgarth and Northcraft, 1964).

6.2.1 Oxygen Depletion

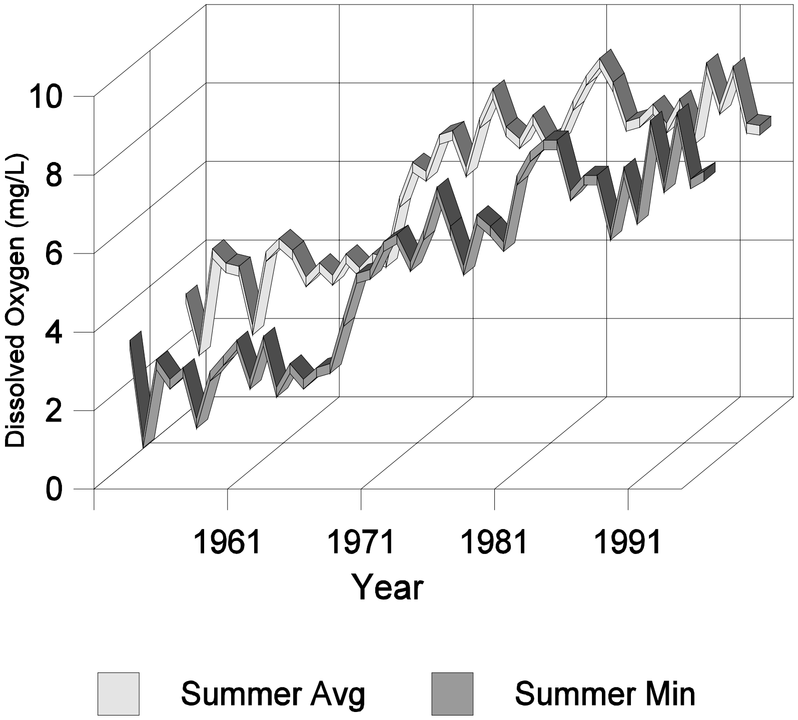
Severe summer oxygen depletion has been the key historical water quality problem in the Willamette River. Over the past 20 years, however, summer oxygen levels have increased significantly as a result of the implementation of basinwide secondary treatment for municipal and industrial PSs and low flow augmentation from reservoir releases. A comparison of results from the earliest water quality survey conducted in 1929 to those conducted during the early 1990s for the Willamette River Basin Water Quality Study (WRBWQS) illustrates the dramatic improvement (ODEQ, 1995). The summer oxygen levels in the river are clearly shown in the distribution of oxygen from Salem to Portland Harbor and the long-term historical trend for oxygen in the lower Willamette River at the SP&S Bridge near Portland Harbor (Figure 6-2).

A 1964 report on water quality documented the impact pulp and paper mill effluents had on water quality. The report projected that by 1966 pulp and paper mills would contribute nearly 83 percent of the pollution load to the river (Oregon State Sanitary Authority, 1964).

6.2.2 Nutrients

In addition to the demands placed on the river’s oxygen supply, the discharge of spent sulphite liquor from pulp mills provided an excess of nutrients, resulting in the formation of bacterial slimes.

Figure 6-2. Long-Term Trends of Summer DO in the Willamette River at the SP&S Bridge, Portland Harbor: 1950-1995



Source: Data from STORET.

These slimes either formed on stationary attachment surfaces and periodically sloughed off and floated downstream to eventually settle and decay, or they formed flocs around suspended organic particles and settled to form sludge deposits in areas where river velocities were low.

Raw wood fiber, ground wood debris, chips, and waste wood fibers associated with bacterial slime had long been the cause of considerable public complaints. These items would collect and decay in the bottom sediments, and in late summer, their associated gases buoyed large, unsightly, foul-smelling sludge rafts to the surface (Oregon State Sanitary Authority, 1964). Intense areas of gasification were evident in the river long before and after the sludge rafts rose and fell. The 1964 report also reported that coliform bacterial contamination of the river was five to 100 times the limit that was considered safe for water-based recreation, such as swimming and water skiing (Oregon State Sanitary Authority, 1964).

Results from recent water quality monitoring indicate that the current status of the river is visibly much improved. Coliform levels have decreased to levels that are safe for swimming and other primary contact recreational activities. With only two exceedances of the State standard for DO (90 percent saturation) and no exceedances of the State action level of 15 μg/L for chlorophyll a, salmon are once again able to migrate up the Willamette River to their spawning sites (ODEQ, 1995).

6.2.3 Pollutants from Nonpoint Sources

NPSs of pollution represent one potential threat to the health of the Willamette River. The flow of storm water runoff over lands used for agricultural, silvicultural, and industrial purposes can transport suspended solids, nutrients, animal wastes, irrigation water, and toxic contaminants to the river. The WRBWQS evaluated applicable land use loading coefficients for the basin based on available water quality data, tabulated summaries of NPS yields, and modeling efforts in smaller watersheds. The results of this analysis indicated that the greatest threats to water quality resulting from NPS runoff are the potentially high levels of suspended particles and agricultural nutrients coming from croplands.

Current estimates of NPS pollution loads for the subbasins of the Willamette River indicate that the sediment and nutrient loads are produced primarily in agricultural areas located in the middle portions of the basin (ODEQ, 1995). However, the lack of historical data for NPS loadings to the river precludes the evaluation of loadings trends over time.

6.2.4 Toxins

Much less information is known about the status and trends of toxic contaminants in the river. Until the 1970s, water quality conditions were primarily evaluated by measuring temperature, pH, TSS, DO, BOD, and bacterial concentrations. Almost no historical data are available on the status and trends of toxic contaminants in the Willamette River. In 1977, the USGS conducted a synoptic survey of trace metals in bottom sediments of the Willamette River. The report of the survey results concludes that the river was a clean environment with the exception of a moderate enrichment of zinc and slight enrichment of copper and lead (Rickert et al., 1977). The zinc enrichment was thought to be from using zinc hydrosulfite as a brightening agent in three ground-wood pulp and paper mills. Upon learning of the results, ODEQ ordered the mills to cease using zinc hydrosulfite by July 1977. Lead enrichment appeared to be directly related to urban runoff (possibly from automobile exhaust) and no source of copper could be identified. The study concluded that no metals were accumulated in the Willamette River sediments at concentrations that might represent an immediate ecological threat; however, further investigations would be required to determine how much lead is annually reaching the river (Rickert et al., 1977).

More recent investigations indicate, however, that toxic contamination of the Willamette River does exist. Oregon's 1990 water quality status assessment report classified the river as "water quality limited" as a result of seven contaminants exceeding either EPA draft sediment guidelines (arsenic, chromium, lead, zinc, and DDT); State water quality standards (arsenic); or both (2,3,7,8-TCDD) (ODEQ, 1990). Other recent surveys have found levels of toxic chemicals in water, sediments, and fish tissue at various locations in the river basin (ODEQ, 1995). Surveys conducted by ODEQ in 1994 indicated that levels of metals (arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc); pesticides (chlordane and DDT); other organic chemicals (carbon tetrachloride, creosote, dichloroethylene, dioxin, polynuclear aromatic hydrocarbons, PCBs, phenol, pentachlorophenol, phenanthrene, phthalates, trichloroethane, trichloroethylene, and trichlorophenol); and bacteria exceed regulatory or guidance criteria for the protection of aquatic life and human health in at least one location of the river.

In the early 1990s, given the public concern over the continued discharge of dioxin by pulp and paper mills, and in anticipation of the revision of the industry's effluent guidelines, the majority of mills began converting from conventional process technologies that employed elemental chlorine bleaching (known to produce dioxins) to process technologies that eliminated the use of elemental chlorine (e.g., substituting chlorine dioxide for elemental chlorine or oxygen delignification), in turn eliminating the discharge of detectable levels of dioxins. In 1995, effluent samples from mills employing the upgraded process technologies indicated that dioxin concentrations in the effluents are now below detectable concentrations (EPA, 1996).

6.3 LEGISLATIVE AND REGULATORY HISTORY OF WATER POLLUTION CONTROL

After over a decade of public concern about the polluted conditions of the Willamette River, the citizens of Oregon passed a referendum in 1938 setting water quality standards and establishing the Oregon State Sanitary Authority. With the establishment of the Sanitary Authority, the stated public policy of Oregon was to restore and maintain the natural purity of all public waters. As a result of regulatory actions by the Sanitary Authority, all municipalities discharging into the Willamette implemented primary treatment during the period 1949 to 1957, with all costs borne by the municipalities. Beginning in 1952, industrial waste discharges from the pulp and paper mills were controlled by required lagoon diversions during summer months. In 1953, the new Army Corps of Engineers dams began operation, resulting in augmentation of the natural summer flow. Although not originally planned for water quality management, summer reservoir releases have become a significant factor in maintaining water quality and enabling salmon migration during the fall.

Although tremendous accomplishments had been made in controlling water pollution in the Willamette basin, large increases in industrial production and in the population served by municipal wastewater plants exceeded the assimilative capacity of the river. By 1960, the Sanitary Authority required that all municipalities discharging to the Willamette River achieve a minimum of secondary treatment (85 percent removal of carbonaceous BOD). In 1964, the pulp and paper mills were directed to implement primary treatment, with secondary treatment during the summer months. In 1967, industrial secondary treatment was required on a year-round basis. The Sanitary Authority had thus established a minimum policy of secondary treatment for all municipal and industrial waste dischargers with the option of requiring tertiary treatment if needed to maintain water quality. The State initiated the issuance of discharge permits for wastewater plants in 1968, 4 years before the CWA of 1972 established the NPDES. The policy adopted in 1967 remains the current water pollution control policy of the State of Oregon for the Willamette River (ODEQ, 1970).

In response to the 1965 Federal Water Quality Act, Oregon established intrastate and interstate water quality standards in 1967 that were among the first new State water quality standards to be approved by the Federal government. The CWA of 1972 provided even further authority for Oregon to issue discharge permits limiting the pollutant loading of municipal and industrial facilities.

EPA established a policy of revising effluent guidelines as scientific advances improved methodologies for analyzing water quality data and for treating industrial wastewaters. From 1989 through 1993, EPA began a nationwide effort to sample the effluents and receiving waters of pulp and paper mills. The initial results of this sampling indicate that pulp and paper mill effluents contain toxic chemical compounds, as well as conventional pollutants such as BOD and TSS. In response to this information, EPA began evaluating the environmental benefits of technology and water quality-based controls applicable to the pulp and paper mill discharges. Based in part on the results of this benefits analysis, in 1998 EPA promulgated revised effluent guidelines and standards for the pulp and paper industry.

6.4 BIOLOGICAL AND HABITAT INDICATORS OF WATER QUALITY

The first comprehensive study of the Willamette River biota was conducted by Dimick and Merryfield (1945) in the summer of 1944. Their study was specifically intended to assess the impact of pollution on benthic invertebrates and fish in the river. Benthic organisms and fish provide particularly good indicators of long-term trends in water quality. Because they are generally sedentary and have long life spans, benthic organisms can provide local indicators of water quality. This study was repeated in 1983 to assess the changes that had occurred in the river since its cleanup began. In 1987, Hughes and Gammon sampled the same sites that Dimick and Merryfield had sampled in 1944. ODEQ conducted an ecological assessment that evaluated benthic communities, fish assemblages, skeletal deformities of juvenile fish, and the physical habitat.

Dimick and Merryfield (1945) found very different biological conditions in different stretches of the river. Upstream of Salem, where pollutant sources to the river were few, they found an abundance of healthy fish and intolerant caddisfly, mayfly, and stonefly nymphs. Below Salem to Portland, where pollutant loadings to the river were greatest, they found few to no fish, dead fish on the banks of or in the river, and a total absence of stoneflies and mayflies. They further noted that the biomass of insect larvae downstream of Salem was less than upstream, and that largemouth bass collected below Salem were generally smaller than normal and in poor physical condition. Both of these situations are indicative of poor water quality.

A comparison of recent data to that collected by Dimick and Merryfield indicates a vast improvement in the diversity and integrity of the benthic communities found in the Willamette River basin. In 1945, Dimick and Merryfield found a total absence of intolerant benthic species between Salem and Portland, whereas benthic data collected in 1994 indicated that 34 percent of the total taxa of benthic species collected consisted of intolerant species of caddisfly, mayfly, and stonefly (ODEQ, 1995). Although it is evident that there is still some impairment of the benthic communities at certain locations along the river (ODEQ, 1995), the conditions below Salem have recovered significantly as a result of implementing water quality controls.

Dimick and Merryfield conducted similar studies in 1983, and in 1987, Hughes and Gammon replicated the 1944 study. While the 1983 study showed some signs of a pollution-stressed river below Salem, the differences between the findings of the studies demonstrated a marked improvement in water quality. Where Dimick and Merryfield had found only tolerant species associated with sluggish, warm water and muddy or sandy substrates, Hughes and Gammon found many intolerant species suited to fast moving, cold water, and rubble and gravel bottoms—an obvious indication that the conditions of the river had undergone a vast improvement.

The improvements in the fish communities of the Willamette River between 1944 and 1983 were not solely due to water quality improvements. Historically, the river provided important spawning and nursery grounds for salmon and steelhead, but dams built along the river prevented these fish from reaching their spawning grounds. Corrections to this situation accompanied water quality improvements. Fish ladders were built at dams and four large fish hatcheries were put into operation, producing 3.8 million salmon per year (Bennett, 1995). The dams also provide flow augmentation during autumn low-flow periods, which provides faster moving, oxygenated water to running fall chinook (Starbird and Georgia, 1972).

The improvement in the quality of the Willamette River has played an important role in the survival and return of both wild and hatchery-reared salmon. In 1965, only 79 chinook salmon were counted in the fall run. That number increased to 5,000 in 1971 (Starbird and Georgia, 1972). A record high of 106,300 spring chinook salmon were counted in the 1990 run, up 30 percent from the 1985 to 1989 average of 81,900. The 1990 catch of chinook salmon of 27,700 was 39 percent greater than the 1980 to 1989 average of 20,000 (Bennett, 1995). With the recent and continuing population growth in the Portland area (where most of the salmon are caught) and the improvements in water quality, interest in angling in the river has increased dramatically. The Willamette River is once again able to support important commercial and recreational fisheries.

6.5 VALUATION OF SELECTED WITHDRAWAL AND IN-PLACE BENEFITS

Improvements in the quality of the Willamette River since the 1960s have contributed to improvements in the quality of the services provided by this resource and, hence, to social welfare. Below, we discuss the way that water quality improvements in the river may have improved the value that the resource provides. WTP estimates were developed for improvements in recreation services.

6.5.1 Withdrawal Benefits

Numerous private and public enterprises rely on the waters of the Willamette Basin. Below, we discuss water use by agriculture and manufacturing industries and public water suppliers and consider the potential economic benefit associated with enhanced pretreatment or wastewater.

Agricultural and Industrial Water Use

The Willamette Valley is a major agricultural production center, and many of the crops produced require irrigation. As shown in Table 6-1, farms withdraw approximately 80 billion gallons of water each year from the rivers of the Willamette Basin.[4] About 24 percent of the total acreage in production requires irrigation. Most of this irrigated land is used to produce vegetables (beans, corn, broccoli, cabbage, garlic, onions, and squash); mint; berries; and hops.

Table 6-1. Surface Water Used in Irrigation and Manufacturing in Willamette Basin

Irrigation	Water use (millions gal/year)	80,300
	Total irrigated acres	290,000
Manufacturing	Water use (millions gal/year)	54,750
	Number of facilities	4,212

Source: U.S. Geological Survey. 1996. *Estimated Water Use and General Hydrologic Conditions for Oregon: 1985 and 1990*. Water Resources Investigations Report 96-4080.

Water Resources Department officials recalled no time in the past when pollution impeded the withdrawal of irrigation water (Szeramek, 1997) probably because irrigation water is not highly water quality dependent. In addition, much of the water used for irrigation is withdrawn from the tributaries of the Willamette, which tend to be less polluted than the main stem of the river. Nonetheless, officials could not rule out the possibility of situations where water quality may have influenced cropping choices or otherwise discouraged irrigation.

In addition to agriculture, a number of manufacturing industries use surface water in the Willamette Basin. Table 6-1 summarizes total

---

[4] Note that available USGS data on water withdrawals in the Willamette region include withdrawals from the Columbia River. Therefore, we likely overstate total withdrawals by agriculture, industry, and public suppliers.

water withdrawn for industrial purposes. As shown, industrial users withdraw approximately 55 billion gallons each year, over half of which is taken from the main stem of the Willamette. A total of about 4,200 facilities take water from rivers in the Basin. The pulp and paper industry accounts for approximately 80 percent of the withdrawals; food processors and chemical manufacturers are other major users.

Water quality has had little influence on industry's treatment practices and the overall ability to use water withdrawn from the Willamette Basin. Pulp and paper plants use water to cool steam-generating equipment and in the pulping process itself. The plants typically treat water prior to use to remove suspended solids and algae; other water quality parameters are of limited importance (Whittaker, 1997). Likewise, food processing plants use withdrawn water for noncontact applications that have lower purity requirements. Frozen foods producers and others requiring high-quality water use municipal supplies or groundwater (Szeramek, 1997; Leland, 1997).

Public Water Supplies

Municipal and regional water supply utilities are another major user of the waters of the Willamette Basin. Table 6-2 summarizes withdrawals for public drinking water supplies and other smaller domestic supplies (e.g., individual household withdrawals). As shown in 1990, drinking water suppliers took a total of 95 billion gallons of water from the Willamette and its tributaries. In 1990, an estimated 1.45 million individuals in the Willamette region received their water primarily from surface water supplies; this represents over 80 percent of the people living in the region.

Table 6-2. Public and Domestic Use of Surface Water in Willamette Basin

	1990
Water withdrawals (millions gal/year)	94,900
Total population served	1,450,000

Source: U.S. Geological Survey. 1996. *Estimated Water Use and General Hydrologic Conditions for Oregon: 1985 and 1990*. Water Resources Investigations Report 96-4080.

Water quality in the Willamette Basin has influenced how municipalities supply water. State officials noted that many of the region's larger municipalities hold water rights on the main stem of the Willamette River but have not exercised these rights because of historically poor water quality (Starr, 1997). Instead, these municipalities have established supplies in tributaries and reservoirs in higher elevations. For example, Portland receives 60 percent of its water from the Bull Run River; similarly, Salem and Albany take water from the North and South Santiam, respectively.[5] Given this pattern of water use, cleanup of the Willamette has had little influence on the actual treatment practices applied and the intensity of this treatment. However, cleanup of the main stem of the Willamette ultimately may influence the choice of whether to use the Willamette as a water source. For example, Portland recently looked more closely at the possibility of using the Willamette as a supply source (Yon, 1997). The cost associated with delivering water from the Willamette may be less than the cost of delivering water from more remote sources. In effect, the cost of "producing" water would be reduced and the savings realized either in the form of producer surplus (if water rates remained unchanged) or consumer surplus (if water rates were reduced). Such savings would represent a real economic benefit.

6.5.2 In-Place Benefits

Commercial Fishing

Little commercial fishing takes place on the Willamette and its tributaries. Today, a few licenses are issued each year for commercial harvesting of shad (allowed only in the Multnomah Channel), crawfish, lamprey eel, and freshwater mussels (King, undated). The total value of the catch is small, about $47,000 in 1993 (Oregon Department of Wildlife and Fisheries, 1996). Most of this total is accounted for by the crawfish catch in Multnomah and Yamhill Counties. While it is likely that improvements in water quality have led to improvements in social welfare through lower prices for these species, the value is likely of a very small magnitude.

---

[5] Corvallis is the only major municipality using the Willamette as a drinking water supply.

Recreation

In the 1960s, the Willamette was one of the "filthiest rivers in the Northwest and one of the most polluted in the country." Recent water quality improvements, however, have helped the study area become "one of the most heavily used recreation rivers in the United States" (ODEQ, undated). In addition to water quality improvements, the increased availability of recreation sites in the Willamette Basin has positively affected participation in many water-dependent recreation activities. For instance, the State Parks and Recreation Department coordinated the "Greenways" program to develop parks and access sites for hiking, fishing, camping, and launching boats.

Recreation benefits are valued here as the product of the estimated difference in recreation activity between the with-CWA and without-CWA levels and the unit value of each activity evaluated. To develop without-CWA activity levels, we considered the degree of water contact associated with each activity. We assumed that poor water quality conditions have the greatest effect on individuals' willingness to engage in direct contact activities, such as swimming. For these recreational categories, we assumed a without-CWA activity level of zero (i.e., the Willamette Basin could not support these activities today had steps to improve and maintain water quality not been undertaken). Since water resources that could provide similar recreational opportunities are relatively remote and thus poor substitutes, we treated all current activity levels as a net gain and based our estimate of the benefits of improved water quality on these activity levels. For activities that include indirect water contact (e.g., fishing) or no water contact (e.g., wildlife viewing), we attributed smaller portions of current activity to water quality improvements, on the assumption that some activity would currently exist even in the absence of efforts to improve water quality.

We monetized the estimated changes in uses of the Basin by applying a benefits transfer approach. This approach applies unit values for recreation activities drawn from the literature on recreation demand to the case study setting.

Table 6-3 summarizes our findings. As shown, estimated annual benefits range from $121.1 million to $259.4 million, and recreational fishing is the largest component. We describe these results in detail in the sections below.

Table 6-3. Summary of Annual Recreation Benefits for Willamette Resources (1997 $)

Activity	Lower Bound (millions $/yr)	Upper Bound (millions $/yr)
Recreational fishing	$63.7	$88.0
Swimming	$20.0	$31.7
Beach use	$9.1	$9.7
Windsurfing	$5.4	
Water skiing	$9.0	$10.5
Jet skiing	$1.2	$2.3
Cruising (boating)	$3.4	$9.8
Sailing	$0.4	$1.4
Wildlife viewing	$9.1	$46.5
Total benefits	$121.1	$259.4

Recreational Fishing. The return of a diverse fish population to the Willamette Basin during the 1970s resulted in a surge of recreational fishing activity. Anglers now enjoy catching a variety of highly valued species of sportfish. We used the results of the 1991 Oregon Angler Survey and Economic Study (The Research Group, 1991), conducted for the Oregon Department of Fish and Wildlife, to obtain an estimate of the number of current fishing trips and days for different fish species in the Willamette Basin (The Research Group, 1991). This study provides activity estimates for salmon, steelhead, trout, warmwater, sturgeon, and “other” fishing days and trips by sampling fishing license holders in Oregon. Even though the fish population may have dropped significantly in the 1960s, anglers may have continued to fish in the Willamette Basin despite low catch rates. Continued fishing is also likely given that the Willamette Basin covers such an extensive geographic area (i.e., tributaries in higher elevations may have supported fishing, even in the 1960s).

For these reasons we assumed that without-CWA water quality conditions would preclude most, but not all, of the angling activity in the Basin. Specifically, we assumed without-CWA levels to be 10 percent of current activity. Table 6-4 indicates current activity levels for each species and without-CWA levels assuming a 90 percent activity increase due to improved water quality conditions.

Table 6-4. Summary of Recreational Fishing Activity in the Willamette Basin

Fish Type	With-CWA Conditions Activity Levels	Without-CWA Conditions Activity Levels	Differences in Activity Levels
Salmon	213,019 trips	21,302 trips	191,717 trips
Steelhead	207,659 trips	20,766 trips	186,893 trips
Trout	1,002,182 days	100,218 days	901,964 days
Warmwater	242,069 days	24,207 days	217,862 days
Sturgeon	14,905 trips 22,142 days	1,491 trips 2,214 days	13,414 trips 19,928 days
Other	29,921 trips 51,698 days	2,992 trips 5,170 days	26,929 trips 46,528 days

We drew estimates of the value of fishing days/trip from the economic literature, focusing on studies that provide estimates in the general vicinity of the Willamette region (e.g., studies analyzing Oregon fisheries) (see Table 6-5). Where necessary, we expanded our base of information to include studies of more distant regions that provide values for species found in the study area. To reflect the uncertainty in the value estimates, we provide a range in Table 6-4 of fishing activity values for most species. Multiplying the upper- and lower-bound values by the total increase in fishing trips or days for each species yields annual benefits that range from $63.7 million to $88.0 million. Table 6-6 presents these results. As shown, fishing for salmon, trout, and steelhead accounts for the vast majority of fishing benefits.

Table 6-5. Summary of Recreational Fishing Values

Species	Author (date)	Study Location	Habitat/Fishing Type	Value (1997 $)
Salmon	Olsen, Richards, and Scott (1991)	Columbia River Basin, Oregon/ Washington	Marine, river and estuary salmon fishing	$140.79 per trip
	Rowe et al. (1985)	Oregon	All fishing habitats, including other species	$91.08 per trip
Steelhead	Olsen, Richards, and Scott (1991)	Columbia River Basin, Oregon/ Washington	Marine, river and estuary steelhead fishing	$113.79 per trip
Trout	McCollum et al. (1990)	Oregon, Washington	All coldwater fishing	$33.49 per day
	Brown and Hay (1987)	Oregon	45 stream and tributary trout fishing	$22.51 per day
Warmwater	Walsh, Johnson, McKean (1992)	U.S.	All warmwater fishing	$32.08 per day
	Bergstrom and Cordell (1991)	U.S.	All warmwater fishing	$17.08 per day
Sturgeon	Roach (1996)	Sacramento, CA area	Sturgeon river fishing	$24.48 per trip
	Walsh, Johnson, McKean (1992)	U.S.	All coldwater fishing	$41.75 per day
Other	Roach (1996)	Sacramento, CA area	Shad river fishing	$35.35 per trip
	McCollum et al. (1990)	Oregon, Washington area	All coldwater fishing	$33.48 per day

Direct Water Contact Recreation. As a result of water quality improvements, direct water contact recreation is now permitted in the waters of the Willamette. The waters meander to provide several sand bars and areas of low flow suitable for swimming and boat moorage. Other categories of contact recreation include windsurfing, water skiing, and jet skiing. In contrast with the 1960s, when "the appearance of the river and threat of disease put a stop to safe swimming," the improved water quality conditions of the Willamette promote participation in such direct contact activities (ODEQ, undated).

Table 6-6. Annual Recreational Fishing Benefits in the Willamette Basin

Fish Type	Estimated Differences in Activity Levels	Value per Day or Trip[a]		Benefits (millions 1997$/yr)	
		Low Estimate	High Estimate	Lower Bound	Upper Bound
Salmon	191,717 trips	$92 per trip	$141 per trip	$17.6	$27.1
Steelhead	186,893 trips	$114 per trip	$114 per trip	$21.3	$21.3
Trout	901,964 days	$22 per day	$34 per day	$19.9	$30.4
Warmwater	217,862 days	$17 per day	$32 per day	$3.7	$6.8
Sturgeon	13,414 trips 19,928 days	$24 per trip	$42 per day	$0.3	$0.8
Other	26,929 trips 46,528 days	$36 per trip	$34 per day	$0.9	$1.6
Total				$63.7	$88.0

[a] Based on estimates summarized in Table 6-5.

The Oregon State Comprehensive Outdoor Recreation Plan, Recreational Needs Bulletin (SCORP) provides 1987 regional estimates of activity days for direct contact recreation, including beach swimming, beach use, and windsurfing (Oregon State Parks and Recreation Department, 1991). To develop benefit estimates for our analysis, we relied on the SCORP's activity data for Regions 7 and 8, which include the counties of the Willamette Basin: Benton, Clackamas, Columbia, most of Lane, Linn, Marion, Multnomah, Polk, Washington, and Yamhill. Since the SCORP data may include some Columbia River participation, these activity levels are likely to overstate 1987 participation rates for the Willamette Basin; conversely, the estimates are somewhat dated and may understate current activity, because they ignore likely increases in participation due to recent population growth.

In contrast to the recreational uses discussed above, data on water skiing and jet skiing activity are relatively current. The 1996 Oregon Recreational Boating Survey provides 1995 county and water body-specific estimates of water skiing and jet skiing activities (Oregon State Marine Board, 1996). Based on these data, we estimate that 244,200 water skiing days and 54,700 jet skiing days currently occur in Willamette waters annually (see Table 6-7). We estimated water skiing and jet skiing activity levels for the Willamette Basin using county and water body participation estimates relevant to the study area.

Table 6-7. Selected Recreation Benefits

Category	Annual Activity Days	Value per Day		Benefits (millions 1997$/yr)	
		Lower	Upper	Lower	Upper
Swimming	1,001,859	$20	$32	$20	$31.7
Beach Use	1,710,293	$5	$35	$9.1	$59.4
Windsurfing	146,282	$37	$66	$5.4	$9.7
Water skiing	244,197	$37	$43	$9.0	$10.5
Jet skiing	54,703	$22	$43	$1.2	$2.3

Although data describing 1960s activity levels for direct contact recreation are unavailable, the swimming bans in the Basin prior to 1972 precluded direct water contact activities (Oregon State Marine Board and Oregon State Parks, 1995). Since these bans were not lifted until 1972, we assumed that no direct contact recreation would be permitted under without-CWA water quality conditions.

Assuming a without-CWA level of zero for these activities, we estimated annual benefits for each water contact recreation category as follows:

Boat Cruising and Sailing. Improvements in water quality increase opportunities for and enhance the enjoyment of recreational boating. The Oregon State Marine Board's survey of registered Oregon boaters indicates that the growth of Oregon registered boats has exceeded statewide population growth. The data indicate a growth from 30 registered boats per 1,000 population in 1965 to 60.5 registered boats per 1,000 population in 1992 (Oregon State Marine Board, 1997). In addition, the availability of boat launch sites has grown. According to the Oregon State Marine Board, parks and moorages have increased over the years due in large part to the improved water quality of the Willamette Basin (Broggi, 1997).

To estimate current annual boat cruising and sailing days in the Willamette Basin, we relied on the 1996 Marine Board survey. This survey sampled owners of motorized boats and sailboats greater than 12 feet in length registered in the State. The survey asked users how many days they used the boat in Oregon waters during the year, and where they took boat trips. The results of the survey indicate that 231,134 boat cruising days and 42,888 sailing days occurred in the waters of the Willamette Basin. These activity days represent the participation for a boat crew, not an individual. Because the economic literature reports per-day or per-trip boat values for an individual, we converted the Marine Board activity days per crew to activity days per individual. We estimated individual activity days by applying a lower bound of two people per boat and an upper bound of three people per boat to the Marine Board estimate of 231,000 boat cruising days. We also converted the estimated 43,000 sailing days by assuming a lower bound of one person per boat and an upper bound of two people per boat. Table 6-8 summarizes the resulting participation estimates.

Table 6-8. Boating and Sailing Benefits

	With-CWA Conditions Annual Activity Days		Without-CWA Annual Activity Days		Differences in Activity Days		Value per Day		Benefits (million 1997$/yr)	
Category	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**	**Lower**	**Upper**
Boat cruising	462,268	693,402	310,247	465,370	152,021	228,032	$22	$43	$3.4	$9.8
Sailing	42,888	85,776	32,739	65,478	10,149	20,298	$37	$66	$0.4	$1.4

To estimate without-CWA cruising and sailing levels in the Willamette Basin, we relied on historical Marine Board Survey data (Oregon State Marine Board, 1972). The 1972 survey offers the earliest data on cruising and sailing activity, providing information disaggregated by county. A comparison of the 1972 data to 1996 figures indicates a 92 percent increase in cruising and a 74 percent increase in sailing in the Willamette region. Some of this increased participation is due to overall population growth; Oregon's population grew 43 percent from 1972 to 1995 (i.e., from

2,195,000 to 3,132,000) (U.S. Department of Commerce, 1994; Center for Population Research and Census, 1995). Assuming that water quality improvements are responsible for increases in boating activity net of population growth, we calculated that water quality improvements increase cruising activity from 462,000 days to 693,000 days per year, and sailing activity from 43,000 days to 86,000 days per year. Table 6-8 reports these activity estimates.

To value boat cruising, we used estimates of motorized boating from Bergstrom and Cordell (1991) and Walsh, Johnson, and McKean (1992). These nationwide estimates range from $22 to $43 per day. For sailing, we applied the Bergstrom and Cordell value for "rowing/other boating" to represent the lower-bound value. We applied the Walsh, Johnson, and McKean value for nonmotorized boating to represent the upper-bound sailing value. These nationwide estimates range from $37 to $66 per day. For each activity, we multiplied the upper- and lower-bound values by the upper- and lower-bound activity change estimates, respectively, to obtain total benefits. This procedure yields an estimate of annual boat cruising benefits that ranges from $3.4 million to $9.8 million, and an estimate of annual sailing benefits that ranges from $0.4 million to $1.4 million. Results are presented in Table 6-8.

Wildlife Viewing. Improvements in water quality restore wildlife habitat and enhance the wildlife viewing experience by eliminating odors and improving visual aesthetics. In addition, newly procured Greenways parcels in the Willamette Valley have increased parklands and public access along the waters, enabling visitors to enjoy the scenery and thriving bird populations more readily.

These elements have contributed to an increase in shoreline-viewing activities. Using Oregon SCORP data on nature and wildlife observation (for Regions 7 and 8), we estimated current participation in wildlife viewing along the Willamette or its tributaries. To obtain this estimate, we scaled the 2.4 million days reported in the SCORP to reflect viewing in wildlife areas that directly border the water. As our scaling factor, we employed the ratio of refuge land area in close proximity to the Willamette or its tributaries to total refuge land area in the ten counties of the Basin.[6]

The level of wildlife viewing activity near the Willamette in 1965 is unclear; the SCORP data do not provide such estimates. It is likely, however, that the river's poor condition had an adverse effect on participation rates. A short documentary film on the Willamette supports this assumption, noting that "at times people completely avoided the river because of the stench" (ODEQ, undated). To reflect our uncertainty concerning the without-CWA conditions, we estimated a range of without-CWA activity levels that reflect between 25 and 75 percent of current activity levels. Table 6-9 presents these estimates and the resulting upper- and lower-bound estimates of changes in wildlife viewing activity due to improved water quality.

Table 6-9. Annual Wildlife Viewing Benefits

Estimate	With-CWA Conditions Activity Days	Without-CWA Activity Days	Difference in Activity Days	Value per Day	Benefits (millions 1997$/yr)
Lower Bound	2,032,436	1,524,327	508,109	$18	$9.1
Upper Bound	2,032,436	508,109	1,524,327	$31	$46.5

To value the estimated change in wildlife viewing activity, we employed use-day values from Bergstrom and Cordell (1991) and Walsh, Johnson, and McKean (1992). We used Bergstrom and Cordell's wildlife observation estimate of $18 per day as the lower-

---

[6] We calculated the total land area of the following refuges and wildlife viewing areas: Fern Ridge Wildlife Area, William L. Finley National Wildlife Refuge, Ankeny and Baskett Slough National Wildlife Refuges, Molalla River State Park, Oxbow Park, Metro Washington Park Zoo, Audubon Society of Portland, Tryon Creek State Park, Jackson Bottom Wetlands Preserve, Sauvie Island Wildlife Management Area, Tualitin River National Wildlife Refuge, Burlington Bottom, and Oaks Bottom. The refuges we determined to be on the river or one of its tributaries include Fern Ridge, Molalla River State Park, Tryon Creek, Jackson Bottom, Sauvie Island, and Tualitin. To obtain the 2,032,436 upper-bound estimate of wildlife viewing days along the Willamette and its tributaries, we scaled the original estimate of 2,422,761 wildlife viewing days within SCORP Regions 7 and 8 by 0.84 (36,996 acres/44,101 acres).

bound value and the Walsh, Johnson, and McKean wildlife viewing estimate of $31 per day as the upper-bound value. Multiplying these values by the estimated change in activity levels due to improved water quality yields annual wildlife viewing benefits that range from $9.1 million to $46.5 million. Table 6-9 presents these results.

We may understate benefits if our analysis excludes categories of recreation affected by water quality. For example, we have excluded the following categories:

- Camping: Camping along the Willamette has become more accessible over the years with the procurement of publicly owned Greenway parcels. While improved water quality may have made camping experiences more pleasing for some participants, it is difficult to judge the overall impact of water quality improvements on this activity. Since we are unable to measure these potential benefits and exclude this category from our analysis, our benefit estimates may underestimate the benefits of water quality improvements.

- Hunting: We exclude this activity from our analysis because the physical effects of pollution on waterfowl are not well established in the Willamette region.

- Hiking: We exclude this benefit category from the analysis because available data do not allow us to calculate the number of river-associated hiking days.

The net effect of these uncertainties is not clear; our approach may under- or overstate the true recreational benefits of water quality improvements in the Willamette Valley.

Aesthetic Services

A number of studies have attempted to disentangle the values people have for a resource. For example, Desvousges , Smith, and Fisher (1987) evaluated annual WTP per household for improved water quality in the Monongahela River (Pennsylvania). In the survey, households were asked to estimate their total WTP for water quality improvements and then to indicate what portion of this value was due to their actual use of the river. Based on this study, Desvousges, Smith, and Fisher estimated an option price for passive uses (i.e., nonrecreators) of the water resource for improving water quality from nonboatable to swimmable conditions. However, in the context of the taxonomy set up in Section 2 these terms come closer to our characterization of the aesthetic (or passive use) services enjoyed by people proximate to the resource than to "nonusers," a term we reserve for true nonusers.

To estimate per-household values of the aesthetic services of water resources, we reviewed the literature for studies that measure communities' WTP for water quality improvements for resources analogous to the Willamette, (i.e., freshwater rivers of regional importance). Table 6-10 identifies the most relevant studies and provides their estimates.

Table 6-10. Summary of Passive Use Values for Clean Water

Authors (Date)	Study Location	Description of Good Valued in Study	Passive Value per Household ($1997)
Sutherland and Walsh (1985)	Montana	Value of protecting water quality at Flathead River and Lake	$80.15 (existence + bequest)
Desvousges, Smith, Fisher (1987)	Western Pennsylvania	Option price for water quality changes from nonboatable to swimmable in Monongahela River	$56.16 – $142.36 (for "nonusers" of the river)
Sanders, Walsh, Loomis (1990)	Colorado	Value for preservation of three most valuable rivers in the State	$49.35

To estimate the number of households that maintain aesthetic values for the Willamette, we considered households living in close proximity to the case study area. Specifically, we based our lower-bound estimate on the number of households in the ten Oregon counties roughly corresponding to the boundaries of the Willamette Valley (see earlier discussion). There are approximately 774,000 households in these ten counties (U.S. Department of Commerce, 1994). For our upper bound, we extended the analysis to include households in the four counties in southwestern Washington nearest to the Willamette. (This includes Clark, Cowlitz, Skamania, and Whakiakum counties.) This area adds approximately 125,000 households, for an upper-bound total of 899,000 households.

Since passive use value estimates vary according to research method, study location, and proximity to the affected resource, we provide a low and high estimate of passive values for the Willamette. Specifically, we applied WTP estimates ranging from $42 to $84 per household per year. Combining these estimates with the corresponding lower- and upper-bound estimates of households yields an estimate of passive use value of between $33 million and $76 million per year. These results are presented in Table 6-11.

Table 6-11. Annual Benefits Attributable to Aesthetic Values for the Willamette Basin

Estimate	Number of Households	Value per Household	Total Passive Use Value (million 1997$/yr)
Lower Bound	774,000	$42	$32.6
Upper Bound	899,000	$84	$75.7

Table 6-12 summarizes the benefit estimates for the case study of the Willamette River Basin. Recreation benefits total between $121 million and $259 million, and aesthetic benefits range from $33 million to $76 million. In total, therefore, the estimated benefits range from $275 million to $594 million per year.

Table 6-12. Summary of Case Study Estimates of Annual Clean Water Benefits for the Willamette River Basin

	Benefits (million 1997$/yr)	
Benefit Category	Lower Bound	Upper Bound
Recreation		
Fishing	63.70	88.00
Swimming	20.00	31.70
Beach use	9.10	59.40
Windsurfing	5.40	9.70
Water skiing	9.00	10.50
Jet skiing	1.20	2.30
Boat cruising	3.40	9.80
Sailing	0.40	1.40
Wildlife viewing	9.10	46.50
Total recreation	121.30	259.30
Aesthetic	32.60	75.70
Total Estimated Benefits	275.20	594.30

6.6 APPLYING THE NWPCAM TO THE WILLAMETTE RIVER BASIN

An alternative to the benefits transfer approach used above is to apply the NWPCAM and Mitchell and Carson values to the ten counties surrounding the Willamette River Basin. This provides both an alternative estimate and basis for comparison of the two methodologies. The results are in general agreement. The river and stream miles attaining recreational use support under the with-CWA scenario are presented in Table 6-13. These reflect the estimated conditions in the mid-1990s. In Table 6-14 we present the corresponding miles of beneficial use attainment for the without-CWA (i.e., without the CWA) scenario. Finally, we present local recreation and aesthetic benefits estimates for these cases in Table 6-15.

Table 6-13. Estimated River and Stream Miles Attaining Beneficial Uses for Recreation in the Willamette River Basin With the CWA, Mid-1990s

Highest Use Supported	Miles	Proportion (%)
Swimmable	3,650	84%
Fishable	4,208	97%
Boatable	4,269	98%
Nonsupport	75	2%
Total	4,344	

Table 6-14. Estimated Impact of the CWA on River and Stream Miles Attaining Beneficial Uses for Recreation in the Willamette River Basin, Mid-1990s

Highest Use Support	Without-CWA Conditions	Changes with CWA	Changes with CWA (%)
Swimmable	3,493	157	4.5%
Fishable	4,106	102	2.5%
Boatable	4,174	95	2.3%
Nonsupport	170	-95	-55.9%

Table 6-15. Estimated Annual Value of Selected In-Place Benefits of the CWA in the Willamette River Basin, Mid-1990s

Use Attainment	In-Place Benefits[a] (million 1997$/yr)
Boatable	$34
Fishable	$25
Swimmable	$44
Total	$103

[a] Local recreation and aesthetic services.

The case study found recreation benefits of $121 million to $259 million annually at late 1980s to early 1990s rates (see Table 6-3). The application of the national methodology, which incorporates a somewhat more expansive set of services, finds a value of $103 million, close to the lower-bound estimate of the case study.

It is important to keep in mind, however, that there are fundamental differences between the NWPCAM as applied to the Willamette River Basin and the case study presented in this section. Among other differences, the NWPCAM, as applied in this context, can only loosely approximate the magnitude of benefits of local water quality changes. The Mitchell-Carson benefits estimates used with the NWPCAM were derived using a national probability sample of households to determine a representative, or average, WTP measure. To the extent that household and site-specific characteristics in the Willamette River Basin differ from the national average, the results derived using the NWPCAM will differ from those of the case study.

7 Directions for Future Research

This analysis represents part of an ongoing effort by the Agency to develop a comprehensive assessment of the benefits of the CWA using modern valuation methods. Because this is a work-in-progress, it is especially important to identify areas where further research would be useful in improving the analysis. These areas generally address extending the scope of the analysis and improving the methodologies employed.

7.1 RESOURCE COVERAGE

This study examines only a subset of the surface waters affected by the CWA. In particular, the site database used in this analysis, RF1, includes major river and stream reaches but does not include most lakes (including the Great Lakes), estuaries, or the marine coast. A key area for improvement in terms of resource coverage is to extend the analysis to include coastal and estuarine waters. These resources are critical because a substantial share of the United States population resides near the Nation's coastal and estuarine waters and uses these water resources for recreational activities. They are also a critical source of habitat, ecological diversity, and biological production. Including a broader coverage of lakes and smaller streams will also be an important enhancement to the NWPCAM and will support a more complete assessment of benefits.

7.2 POLLUTANT COVERAGE

In this study we were able to characterize with- and without-CWA pollutant loadings for oxygen-demanding wastes, an infectious agent, and sediment. These are critical pollutants, affecting water quality and the services of water resources; however, they are not comprehensive. Pollutants including toxic chemicals and nutrients also have large impacts on water quality and, hence, the services provided by surface waters. Including these pollutants is an important priority in expanding the capabilities of the NWPCAM.

7.3 SOURCE COVERAGE

Expanding the NWPCAM's coverage of point and nonpoint sources will be an important complement to expanding its coverage of pollutants and water resources. In addition, the loadings for CSOs and NPSs in this study are assumed to be the same under the with- and without-CWA conditions. Data on the implementation and effectiveness of NPS controls and controls on CSOs would further improve the comprehensiveness of the analysis.

7.4 SERVICES COVERAGE

A subset of the in-place services affected by water quality is valued in this study, and no withdrawal services are included. The next step would be to develop a methodology for incorporating all services of surface water into a national water quality benefits model. Many of the benefits of the omitted services, especially the withdrawal services, will be transmitted through markets in the form of commodity price or income changes. Others may be directly experienced by households. Characterizing all the linkages between water quality and individual welfare will be important in developing an approach for including all of those services in the benefits valuation.

Some of the impacts of water quality changes are registered in the performance of ecosystems. Like water resources, per se, these systems provide services of value to humans. Consideration should be given to developing a taxonomy of these services and incorporating estimates of the change in their service flows due to changes in water quality.

7.5 WTP ESTIMATES

The WTP estimates developed by Mitchell and Carson (Mitchell and Carson, 1986; Carson and Mitchell, 1993) used in this study are rather dated, and their resource and service coverage is incomplete. They estimate the freshwater in-place water quality benefits accruing to households, expressly excluding commercial in-place and withdrawal benefits. Although updating the estimates to account for the relationship between income growth and WTP has been possible, it is not clear how other factors have affected WTP over the last 14 years.

References

Bennett, Donald E. September 1995. *1994 Willamette River Spring Chinook Salmon Run, Fisheries, and Passage at Willamette Falls.* Oregon Department of Fish and Wildlife, Fish Division, Columbia River Management.

Bergstrom, John C., Kevin J. Boyle, Charles A. Job, and Mary Jo Kealy. 1996. "Assessing the Economic Benefits of Ground Water for Environmental Policy Decisions." *Water Resources Bulletin* 32(2):279-291.

Bergstrom, J., and H. Cordell. 1991. "An Analysis of the Demand for and Value of Outdoor Recreation in the United States." *Journal of Leisure Research* 23(1):67-86.

Broggi, Jill, Oregon State Marine Boards. Personal conversation. March 4, 1997.

Brown, Gardner Jr. and Michael J. Hay. March 1987. "Net Economic Recreation Values for Deer and Waterfowl Hunting and Trout Fishing, 1980." Division of Policy and Directives Management, U.S. Fish and Wildlife Service, Working Paper No. 23.

Carson, Richard T. Personal communication with Tayler Bingham. April 11, 1997.

Carson, Richard, and Robert Mitchell. 1993. "The Value of Clean Water: The Public's Willingness to Pay for Boatable, Fishable, Swimmable Water Quality." *Water Resources Research* 29(7):2445-2454.

Center for Population Research and Census, School of Public Affairs. 1995. "Population Estimates for Oregon: July 1, 1995." Portland State University.

Clark, Matthew, Mary Jo Kealy, Virginia Kibler, and Raffael Stein. 1995. "Impacts of Municipal Wastewater Treatment: A Retrospective Analysis." Washington, DC: U.S. Environmental Protection Agency, Office of Water.

Council on Environmental Quality. 1973. *Fourth Annual Report on Environmental Quality*. Washington, DC: Council on Environmental Quality.

Council on Environmental Quality. 1995. *The Twenty-Fifth Anniversary Report of the Council on Environmental Quality*.

Desvousges, William H., V. Kerry Smith, and Ann Fisher. 1987. "Option Price Estimates for Water Quality Improvements: A Contingent Valuation Study for the Monongahela River." *Journal of Environmental Economics and Management* 14:248-267.

Dimick, R.E., and F. Merryfield. June 1945. *The Fishes of the Willamette River System in Relation to Pollution*. Oregon State College Engineering Experiment Station Bulletin Series No. 20. p. 7-55.

Federal Emergency Management Agency (FEMA). 1987. *36 DGEM: The 36 Sector Dynamic General Equilibrium Model*. Final Report. Washington, DC: FEMA.

Federal Register. July 3, 1996. "Part VI: Environmental Protection Agency: Effluent Guideline Plan; Notice." 61(129):35041-35054.

Fogarty, John P.C. 1991. "Short History of Federal Water Pollution Control Act." In *Clean Water Deskbook: The Environmental Law Reporter*. Washington, DC: Environmental Law Institute.

General Accounting Office. *Case Study Evaluations*. November 1990. Washington, DC: Program Evaluation and Methodology Division.

Gleeson, G.W. 1972. *The Return of a River, the Willamette River, Oregon*. Corvallis, OR: Oregon State University.

King, Steve, Oregon Department of Fish and Wildlife. Personal communication.

Krutilla, J. 1967. "Conservation Reconsidered." *American Economic Review* 57:777-786.

Leland, Dave. Oregon Health Division. Personal communication. February 28, 1997.

Lovejoy, Stephen B. 1989. *Changes in Cropland Loadings to Surface Waters*: Interim Report No. 1 for the Development of the CSC National Water Quality Model. West Lafayette, IN: Purdue University.

Lovejoy, Stephen B., and Barbara Dunkelberg. 1990. *Water Quality and Agricultural Policies in the 1990s: Interim Report No. 3 for Development of the SCS National Water Quality Model*. West Lafayette, IN: Purdue University.

McCollum, Daniel W., George L. Peterson, J. Ross Arnold, Donald C. Markstrom, and Daniel M. Hellerstein. 1990. *The Net Economic Value of Recreation in the National Forests: Twelve Types of Primary Activity Trips Across Nine Forest Service Regions*. U.S. Department of Agriculture, Forest Service, Research Paper, RM-289.

Mitchell, R.C., and R.T. Carson. 1986. *The Use of Contingent Valuation Data for Benefit/Cost Analysis in Water Pollution Control*. CR-810224-02. Prepared for U.S. Environmental Protection Agency, Office of Policy Planning and Evaluation. Washington, DC.

Olsen, Darryll, Jack Richards, and R. Douglas Scott. January 1991. "Existence and Sport Values for Doubling the Size of Columbia River Basin Salmon and Steelhead Runs." *Rivers* 2(1):44-56.

Oregon Department of Environmental Quality. Undated. "A River Restored: Oregon's Willamette." Video produced by ImageSound.

Oregon Department of Environmental Quality. December 1970. Water Quality Control in Oregon. Portland, OR: Oregon Department of Environmental Quality.

Oregon Department of Environmental Quality. 1990. Oregon 1990 Water Quality Status Assessment Report - 305(b) Report. Portland, OR: Oregon Department of Environmental Quality. 135 pp.

Oregon Department of Environmental Quality. 1995. *Willamette River Basin Water Quality Study: Summary and Synthesis of Study Findings*. Portland, OR: Oregon Department of Environmental Quality.

Oregon Department of Wildlife and Fisheries. March 1996. *1993 Pounds and Value of Commercially Caught Fish and Shellfish Landed in Oregon*.

Oregon State Marine Board. 1972. *Pleasure Boating in Oregon*.

Oregon State Marine Board. *Oregon Recreational Boating Survey, 1996.*

Oregon State Marine Board. February 1997. *Boating Recreation in Oregon: Economic Importance, Trends, and Implications for the Future*. Prepared by Robert Neely, Bruce DeYoung, and Rebecca Johnson.

Oregon State Marine Board and Oregon State Parks. May 1, 1995. *Willamette River Recreation Guide*.

Oregon State Parks and Recreation Department. 1991. *Recreational Needs Bulletin: Oregon State Comprehensive Outdoor Recreation Plan*.

Oregon State Sanitary Authority. May 1964. *Report on Water Quality and Waste Treatment Needs for the Willamette River*. Portland, OR: Division of the State Board of Health.

The Research Group. June 1991. *Oregon Angler Survey and Economic Study*. Prepared for Oregon Department of Fish and Wildlife.

Research Triangle Institute. 1997a. *The Benefits of the Urban Wet Weather Management Program*. Prepared for the U.S. Environmental Protection Agency. Research Triangle Park, NC: Research Triangle Institute.

Research Triangle Institute. 1997b. “A Comparative Analysis of Beneficial Use Attainment in Major U.S. Rivers and Streams under Alternative Water Pollution Control Scenarios.” Research Triangle Park, NC: Research Triangle Institute.

Rickert, D.A., V.C. Kennedy, S.W. McKenzie, and W.G. Hines. 1977. *A Synoptic Survey of Trace Metals in Bottom Sediments of the Willamette River, Oregon*. U.S. Geological Survey Circular 715-F. Arlington, VA: U.S. Department of the Interior.

Roach, Brian. March 1996. "Angler Benefits Along Four California Rivers: An Application of Tobit Analysis," Davis, CA: University of California, Division of Environmental Studies.

Rowe, Robert W., et al. June 1985. *Valuing Marine Recreational Fishing on the Pacific Coast*. National Marine Fisheries Service, Southwest Fisheries Center, LJ-85-18C.

Sanders, L.D., R.G. Walsh, and J.B. Loomis. 1990. "Toward Empirical Estimation of the Total Value of Protecting Rivers." *Water Resources Research* 26(7):1345-1357.

Schneider, Paul. 1997. "Clear Progress: 25 Years of the Clean Water Act." *Audubon* 99(5):36-47, 106-107.

Sedell, J.R., and J.L. Frogatt. 1984. "Importance of Streamside Forests to Large Rivers: The Isolation of the Willamette River, Oregon, U.S.A. from its Floodplain by Snagging and Streamside Forest Removal." *Verh. Internat. Limnol.* 22:1828-1834.

Smith, V. Kerry. 1996. "Contingent Valuation and Different Public Goods." *Land Economics* 73(2):139-151.

Starbird, E.A., and L.J. Georgia. 1972. "A River Restored: Oregon's Willamette." *National Geographic* 141(6):816-835.

Starr, Ken, Oregon Water Resources Department. February 20, 1997. Personal communication.

Stokey, Edith, and Richard Zeckhauser. 1978. *A Primer for Policy Analysis*. New York: W.W. Norton & Company, Inc.

Sutherland, Ronald J., and Richard G. Walsh. 1985. "Effect of Distance on the Preservation Value of Water Quality." *Land Economics* 61(3):281-291.

Szeramek, Jake, Oregon Water Resources Department. February 21, 1997. Personal communication.

Tetra Tech. 1993. *Support to the 1992 Needs Survey CSO Cost Assessment, CSO Water Quality Modeling*. EPA Contract No. 68-C9-0013. Prepared for the U.S. Environmental Protection Agency, Washington, DC.

Tetra Tech. 1997. Willamette River Basin: *A Review of Water Quality Improvements and Issues*. Prepared for the U.S. Environmental Protection Agency. Fairfax, VA: Tetra Tech.

U.S. Department of Commerce, Bureau of the Census. 1991. *Populated Places*. Washington, DC.

U.S. Department of Commerce, Bureau of the Census. 1994. *County and City Data Book*. Washington, DC.

U.S. Department of Commerce, Bureau of the Census. 1999. *Statistical Abstract of the United States*. 119th ed. Washington, DC.

U.S. Department of Commerce. August 1997. *Survey of Current Business.* Washington, DC.

U.S. Environmental Protection Agency. 1976. *The National Commission on Water Quality. The National Residuals Discharge Inventory*. NTIS #NCWQ 75/104. Springfield, VA.

U.S. Environmental Protection Agency. 1992a. *National Environmental Benefits of Secondary Treatment: A Retrospective Look at Progress Made Under the 1992 Clean Water Act*. Washington, DC.

U.S. Environmental Protection Agency. 1992b. *Output Effects of Costly Water Pollution Controls*. Washington, DC: Office of Policy Planning and Evaluation, Economic Analysis and Research Branch.

U.S. Environmental Protection Agency. 1993. Total Waters Database. Washington, DC: Office of Water.

U.S. Environmental Protection Agency. 1995. *National Water Quality Inventory: 1994 Report to Congress*. EPA 841-R-95-005. Washington, DC: Office of Water.

U.S. Environmental Protection Agency. June 1996. *Ecological Benefits Assessment Model: Documentation Manual.* Prepared for the U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics. Cambridge, MA: Industrial Economics, Incorporated.

U.S. Environmental Protection Agency. 1997. World Wide Web site: <http://www.epa.gov.docs/epacfr40/contents.html>.

U.S. Geological Survey. 1992. *Estimated Use of Water in the United States in 1990*. Tables available from <http://www.h2o.usgs.gov/public/watuse>.

U.S. Geological Survey. 1996. *Estimated Water Use and General Hydrologic Conditions for Oregon: 1985 and 1990*, Water Resources Investigations Report 96-4080.

Walsh, Richard G., Donn M. Johnson, and John R. McKean. 1992. "Benefit Transfer of Outdoor Recreation Demand Studies, 1968-1988," *Water Resources Research* Vol. 28(3):707-713.

Westgarth, W.C., and M. Northcraft. 1964. *Water Quality and Waste Treatment Needs for the Willamette River*. Report Oregon State Sanitary Authority.

Wittaker, Carol, James River Corporation. Personal communication. February 24, 1997.

Yon, Don, Oregon Department of Environmental Quality. Personal communication. February 26, 1997.