Benefits of Abating

Sanitary Sewer Overflows (SSOs)

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EXECUTIVE SUMMARY

Effective wastewater collection and treatment systems are among the most important factors responsible for the general level of good health enjoyed in the United States. When a collection system does not function properly, sanitary sewer overflows (SSO) occur, posing risks to public health and the environment, and adversely impacting the overall quality of life. There is currently significant variation in collection system performance across the country. Consequently, some communities experience a significant number of SSOs. National estimates of the costs for sanitary sewer collection systems (SSCS) to come into compliance with existing Clean Water Act (CWA) requirements regarding SSOs have been developed in a separate report (the "SSO Needs Report"). This report is intended to provide estimates of the national benefits that will accrue from abating SSOs consistent with current CWA requirements.

Benefits associated with SSO abatement are divided into three principal categories: water quality-related benefits (for both freshwater and marine water), non-water quality benefits (e.g. reduction in basement backups, avoided costs of responding to SSOs), and system benefits (cost savings for SSCS associated with measures to reduce SSOs) . To the extent possible, we quantify and monetize benefit estimates for these categories. Where quantification is not possible, we provide a qualitative discussion of benefits. Each of these benefits categories is introduced below, along with a summary of the monetized benefit estimates developed in this report.

Water quality-related benefits

SSOs can make waters less suitable for productive use, can harm the health of individuals using the waters, and can degrade the ecological communities dependent on the waters.

SSO abatement would yield several types of freshwater benefits that can be quantified and monetized. If SSOs were eliminated, thereby improving water quality where SSOs currently contribute to freshwater impairment, more areas would be available for such direct uses as swimming, fishing and boating. In areas where people currently use freshwater resources that are impacted by SSOs, their swimming, fishing or boating experience would be enhanced. Indirect uses near the water, such as picnicking, jogging, walking, sunbathing, and photography, would also be enhanced. In addition, SSO-related water quality improvements would provide non-use, or intrinsic benefits: people derive satisfaction from knowing that other people can use fresh water resources, and knowing that the nation's water is cleaner. To estimate the freshwater benefits of SSO abatement, we use the results of a well-established, relatively comprehensive contingent valuation (CV) study in which survey respondents indicated their willingness to pay (WTP) for a national set of water quality improvements for rivers, lakes and streams. Respondents' WTP amounts reflect values derived from direct uses, indirect uses near water, and non-use factors.

In addition to those freshwater benefits that can be estimated using the CV study, we estimate the substantial benefits that will accrue as improved fresh water quality reduces the number of swimming-related illnesses. Freshwater benefit categories that could not be monetized include enhanced freshwater commercial fishing and withdrawal benefits, health benefits associated with avoiding SSO-related exposure to pathogens through contaminated drinking water, and the value of improved water quality where improvement occurs but not sufficiently to allow a new use.

The elimination of SSO-related impairment of marine waters would also produce important benefits. Enhanced marine water quality would increase the fishable area available to the commercial finfishing and shellfishing industries, and would enhance the productivity of fisheries, leading to larger catches. It would also increase the fishable area available to people who enjoy marine recreational fishing. Beach closures resulting from SSOs would be avoided, as would illnesses among people who swim in marine waters and who eat shellfish. Water quality improvements would also lead to increased wildlife viewing along the coast. In addition to use-related benefits, there are intrinsic, or non-use benefits associated with the satisfaction people derive from knowing that marine waters are clean and that others can use them. Marine water quality benefits that could not be monetized include enhanced recreational shellfishing and aesthetic benefits for people who live near the beach, and for tourists who visit the beach.

Non-water quality benefits

Non-water quality benefits of SSO abatement include a reduction in the number of basement backups that occur. Every time a sewer backs up into a basement, the homeowner or the community incurs clean-up costs -- costs that would be avoided if measures to abate SSOs are undertaken. Another set of costs that would be avoided is the costs incurred by wastewater utilities to respond to SSOs. When SSOs occur, utility staff and equipment are often dispatched to clean up the spill, monitor water quality, and perform other tasks. Other damages that SSOs cause cannot be quantified or monetized, but are potentially significant. SSOs result in damages to property, and impose costs on homeowners that are difficult to quantify in a comprehensive way. Even for people who do not suffer SSO-related property damage, the unpleasant aesthetic impact of SSOs can be dramatic. People's sensibilities are offended when raw sewage gushes out of manholes and onto the street, and when traces are left behind.

System benefits

System benefits refer to the savings in the costs of managing wastewater collection and treatment systems that arise from measures taken to reduce SSOs. The SSO Needs report costs out four types of measures to abate SSOs: additional system storage capacity, additional wet weather treatment capacity, reduction in infiltration and inflow (I/I) into the collection system, and enhanced operations and maintenance (O&M) programs. In addition to abating SSOs, enhanced O&M will lead to long-term savings for collection systems that we have quantified and monetized. Enhanced O&M slows the deterioration of the collection system over time, reduces the number of trouble spots in the system, and extends the life of the system. As a result, expenditures on long-term rehabilitation and replacement, spot repairs, and emergency repairs can be expected to decline, thereby reducing total operating costs to the system.

Summary of estimated benefits

Table ES-1 provides an overview of the benefits, both monetized and non-monetized, of abating all SSOs. Total monetized benefits across all categories range from $ 1.1 billion to $ 6.1 billion annually. Lower and upper estimates were developed for most benefit categories to reflect uncertainties.

All benefit estimates presented in this report assume complete elimination of SSOs. However, as discussed in the SSO Needs Report, there are several factors that make it very difficult for a collection system to be completely free from overflows. The Needs Report estimates the costs of reducing collection system infrastructure deficiencies to very low levels in accordance with existing control objectives of minimizing SSOs. To the extent that all SSOs are not abated by the control measures projected in the Needs Report, the resulting benefits will be somewhat less than is estimated in this report.

Summary of non-monetized benefits

As indicated by the summary benefits table, several categories of benefits have not been monetized. In some cases, existing data is insufficient to estimate monetized benefits. For other categories, methodologies have not yet been developed to estimate benefits. Where monetized benefits have not been calculated, it should not be assumed that important benefits do not exist. In fact, it is reasonable to expect that, when sufficient data and/or methodologies become available, the monetized benefits associated with some currently non-monetized benefits categories will add significantly to the existing total of monetized benefits. A review of the non-monetized benefits categories suggests that the actual value of benefits associated with SSO abatement may substantially exceed the monetized benefits estimates presented in this report.

One potentially significant category of non-monetized benefits is avoided illnesses from contaminated drinking water. Although SSO events that impact drinking water supplies are not uncommon, the role of SSOs in contaminating drinking water supplies and spreading illnesses may often go unidentified, unrecognized or unreported. The toll associated with waterborne disease outbreaks -- in lost work days, medical costs, and even lives -- can be large. Section 5 of this report presents a case study of a sewage spill in Brushy Creek, Texas, which contaminated drinking water supplies and resulted in approximately 1,400 people becoming sick. The estimated cost of lost work days associated with the spill ranged from $224,000 to $480,000. Other SSO-related outbreaks have resulted in numerous hospitalizations and even deaths. Given the local health and economic impacts of these SSO-related outbreaks, the monetized benefits of avoiding illnesses from SSO-contaminated drinking water could be significant.

Another potentially significant category of benefits for which benefits could not be monetized is avoided aesthetic impacts on marine beaches and coastal recreation areas. If SSOs were eliminated, the aesthetic quality of marine water and oceanfront land would be enhanced. It is likely that people who live near marine beaches and enjoy them on a regular basis (beachcombers, joggers, bicyclists, photographers, and people who simply enjoy waterfront views) would value such enhancements. Tourists who visit beaches on weekends and during their vacations would also probably assign some value to an improvement in marine water quality. We are unaware of any study that attempts to estimate these values. Nevertheless, in light of the importance of coastal tourism, as well as the proportion of the U.S. population that lives near or visits the coast, it is reasonable to expect that monetized benefits for this category would be significant.

A third non-monetized benefits category is the benefit of avoiding the unpleasant aesthetic impacts of SSOs on the land over which they flow. No study has attempted to estimate the amount that people would be willing to pay to avoid these aesthetic impacts. However, given that SSOs typically elicit reactions of disgust, it is likely that people would attach some value to avoiding their negative aesthetic impacts on streets, residential areas, and green spaces.

The final potentially significant category of benefits that has not been monetized is the value of freshwater quality improvements in waters where eliminating SSOs improves water quality but not sufficiently to allow for a new use (e.g., boating, fishing, swimming) that was previously impaired. Technical and data limitations have prevented monetization of infra-category water quality improvements (e.g., when a fishable water becomes even more fishable, but does not improve sufficiently to become swimmable).

Other benefits categories that could not be monetized include enhanced freshwater commercial fishing; freshwater withdrawal benefits; enhanced marine water recreational shellfishing; and reduced property damage.

Table ES-1: Summary of monetized benefits from eliminating SSOs (in 1999 $/yr)

	Lower Estimate (millions)	Upper Estimate (millions)
Water Quality-Related Benefits		
Improved Freshwater Quality		
Direct Use Benefits - Boating, Fishing, Swimming, etc.		
Indirect Use Benefits - Waterside Hiking, Picnicking, etc.		
Non-Use (Intrinsic) Benefits		
Total of Direct Use, Indirect Use, and Non-Use Benefits[1]	$45.9	$387.8
Reduced Swimming Illnesses (Fresh Water)	$154.2	$1,103.5
Enhanced Commercial Fishing	NM[2]	NM
Withdrawal Benefits	NM	NM
Reduced Health Risks (via Surface Drinking Water)	NM	NM
Improved Water Quality (Short of New Uses)	NM	NM
Improved Marine Water Quality:		
Commercial Fishing Benefits - Finfishing	$0.2	$1.5
Commercial Fishing Benefits - Shellfishing	$1.7	$15.1
Recreational Fishing Benefits	$0.7	$32.4
Avoided Beach Closures	$36.0	$137.8
Increased Wildlife Viewing Along Coast	$0.9	$18.0
Increased Intrinsic Benefits	$18.8	$94.1
Reduced Swimming Illnesses (Marine Water)	$436.7	$3015.1
Reduced Illnesses from Shellfish Consumption	$2.5	$22.0
Improved Aesthetic Quality	NM	NM
Enhanced Recreational Shellfishing	NM	NM
Non-Water Quality-Related Benefits		
Reduced Basement Backups	$247.2	$529.7
Reduced SSO Response Costs	$10.9	$113.5
Reduced Property Damage	NM	NM
Avoided Aesthetic Impacts	NM	NM
Avoided Illnesses from Contaminated Drinking Water	NM	NM
System Benefits		
From Enhanced O&M	$119.7	$638.2
TOTAL	$1,075.2	$6,108.8

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[1] Each of these subcategories of benefits is reflected in the total benefit figure, which was estimated using the results of a contingent valuation survey. Because the survey did not ask respondents to indicate their willingness to pay for each type of benefit separately, we cannot disaggregate the total.

[2] NM= Benefit could not be monetized.

SECTION 1 INTRODUCTION

A properly functioning wastewater collection and treatment system is a key element in the infrastructure of any municipality. Effective wastewater systems are among the most important factors responsible for the general level of good health enjoyed in the United States.

Sanitary sewer collection systems (SSCSs) are intended to remove wastewater from homes and other buildings and convey it for proper treatment and disposal. If functioning properly, they remove concern for adverse effects from sewage from daily life. However, when a system is not functioning properly, it can pose risks to public health and the environment, and adversely impact the overall quality of life. Sanitary sewer overflows (SSOs) are by far the most common cause of the release of partially treated or untreated sewage.

Historically, efforts to address sanitary sewer overflows under the National Pollutant Discharge Elimination System (NPDES) program and other State and local initiatives have varied from State to State. Differences in program emphasis and approach, along with other factors, have contributed to significant variation in collection system performance. In response to the need for greater national clarity and consistency, EPA has conducted an extensive analysis of SSCSs, SSOs and associated NPDES program implementation issues. EPA is now preparing a regulation that will clarify how existing Clean Water Act (CWA) requirements apply to SSCSs, and that will add several new elements to improve SSCS performance.

1.1 REPORT OBJECTIVES

This report is intended to provide estimates of the national benefits of abating SSOs consistent with existing Clean Water Act (CWA) requirements. This benefits report is intended to be read in conjunction with a parallel report known generally as the “SSO Needs Report” (U.S. EPA, 2000b) that estimates the costs of improving SSCS performance from current levels to virtually no SSOs, or essentially to compliance with the CWA prohibition on SSOs. The Needs Report provides extensive background on SSCS performance and on the number, causes and abatement measures for SSOs, as well as national estimates of the costs for SSCSs to reduce SSOs and thereby meet existing CWA requirements. Cost estimates in the Needs Report address both the capital costs needed to correct existing problems and the costs needed to improve operation, maintenance and management of SSCSs. Because the extensive background information in the Needs Report is not repeated in this document, we recommend that anyone interested in the costs and benefits of improved SSCS performance read the Needs Report first and this document second.

The Needs Report and this Benefits Report estimate the costs and benefits of improving SSCS performance from current levels to compliance with current requirements. The Needs Report and this report do not attempt to estimate the costs and benefits that may result from any incremental changes to the existing NPDES framework as it applies to SSCSs and/or SSOs that may result from the regulations and national SSO policy statement that EPA is developing. The incremental costs and benefits of any changes to current legal requirements are estimated in a separate Economic Analysis supporting EPA's proposed regulations (U.S. EPA, 2000c).

1.2 OVERVIEW OF BENEFITS FROM ABATING SSOs

The Needs Report estimates the measures that SSCSs will need to undertake to meet current CWA requirements, and the likely nationwide costs of these measures. The measures fall in four categories:

1) <u>Reduction of excessive infiltration and inflow (I/I) through system rehabilitation</u>. During wet weather, flows in a collection system with high levels of I/I may exceed the capacity of sewers, pump stations and/or the treatment plant, causing SSOs at any of a wide variety of locations. One answer may be to reduce I/I so that wet weather flows are less likely to exceed the capacity of some portion of the system.

2) <u>Increase capacity of sewers, pump stations and/or the treatment plant</u>. Another answer may be to locate a particular component or part of the system where insufficient capacity is leading to SSOs, and to increase the capacity and/or reliability of that component.

3) <u>Construct wet weather storage and treatment facilities</u>. High wet weather flows may temporarily overwhelm the capacity of some system component and cause overflows. If, however, collection system storage can be increased, the peak wet weather flows can be

reduced, and flows further down the system and to the treatment plant can be equalized over time, avoiding the peak flows that cause overflows.

4) <u>Enhanced sewer system operation, maintenance and rehabilitation</u>. When sewer pipes break or are blocked by obstructions (e.g., tree roots) or when pumps fail SSOs may occur. This can happen in dry or wet weather. The rate at which these events occur can be reduced (though such events probably cannot be completely eliminated) through improved programs to maintain collection system infrastructure and find and fix problems.

These measures, which are projected and costed out in the Needs Report, will yield a variety of benefits that we analyze in this report. We categorize benefits in three principal categories: water quality-related benefits, non-water quality-related benefits, and system benefits. Each of these benefits categories is described below.

<u>Water quality-related benefits</u>

Freshwater

First, and most obviously, SSO abatement will improve the quality of waters that may be affected by SSOs. If SSOs were eliminated, more freshwater areas would be available for such direct uses as swimming, fishing and boating. In areas where people currently use freshwater resources that are impacted by SSOs, their swimming, fishing or boating experience would be enhanced. Indirect uses near the water, such as picnicking, jogging, walking, sunbathing, and photography, would also be enhanced. In addition, SSO-related water quality improvements would provide non-use, or intrinsic benefits: people derive satisfaction from knowing that other people use fresh water resources, and knowing that the nation's water is cleaner.

Fewer SSOs and improved water quality will also result in fewer illnesses among people who swim at beaches and recreational areas located on rivers, lakes and streams. Notwithstanding Federal and State standards and beach water quality monitoring programs, the levels of indicator bacteria often found at freshwater beaches are sufficiently high to pose a likelihood of illness for swimmers. If SSOs were reduced, average pathogen levels at freshwater beaches would be expected to decline and fewer illnesses would ensue.

Improved fresh water quality can be expected to produce benefits for freshwater commercial fishers in the form of a larger, higher-quality, catch. It also can reduce the amount of treatment needed by drinking water, thereby yielding cost savings. Finally, there are health benefits associated with avoiding SSO-related exposure to pathogens through contaminated drinking water. SSOs can pose increased risks to drinking water sources, and lead to other restrictions on the beneficial use of surface waters. The health, environmental and economic risks attributed to SSOs depend on multiple factors, including location and season (which determine the potential for public exposure), frequency, volume, the amount and type of pollutants present in the discharge, and the uses, conditions, and characteristics of the receiving waters.

Marine water

Eliminating SSO-related impairment of marine waters would also produce many benefits. When SSOs impact marine waters, restrictions or prohibitions on fishing and shellfish harvesting may be imposed, resulting in economic losses to the commercial fin-fishing and shellfishing industries. Enhanced marine water quality would increase the fishable area available to the commercial finfishing and shellfishing industries, and would enhance the productivity of fisheries, leading to larger, higher-quality catches. It would also increase the fishable area available to people who enjoy marine recreational fishing. Beach closures resulting from SSOs would be avoided, as would illnesses among people who swim in marine waters and who eat shellfish. Water quality improvements would also lead to increased wildlife viewing along the coast. People who live near the coast and tourists who enjoy beach and oceanfront views and uses would benefit from the positive aesthetic impact of improved water quality. Recreational shellfishing would also be enhanced. In addition to these use-related benefits, there are intrinsic, or non-use benefits associated with the satisfaction people derive from knowing that marine waters are clean and that others can use them.

Non-water quality-related benefits

SSOs can also result in health risks or economic damages even when they do not reach surface waters. Backups into basements cause substantial property damage and cleanup expense, not to mention aggravation to homeowners and the potential for health risks. SSOs in streets or on land are unsightly and cause offensive odors. In addition to harming property, sensibilities and potentially health, SSOs are also expensive for governments and private parties to respond to and to clean up.

System benefits

One of the measures costed out in the Needs Report -- enhanced operations and maintenance -- will generate benefits beyond those associated with a reduction in SSOs. These benefits will accrue to sanitary sewer collection systems (SSCS) in the form of cost savings. Spending now on improved collection system operation, maintenance and remediation improves system reliability and longevity. This reduces the frequency at which pipes and pumps will fail in the future, reducing future costs for repair and rehabilitation, and deferring to some degree future needs for replacement of these components. Enhanced O&M will prolong the useful life of collection system components.

We use the term "system benefits" to refer to these sorts of future costs savings to a wastewater collection and treatment utility (and its customers) that result from investing in enhanced O & M. It does not matter whether the investment in enhanced O & M is prompted by a desire to reduce SSOs or by some other objective; the result in any case is some reduction in the future costs for the utility to provide service. (Note that we do not believe that these system benefits alone are necessarily large enough to justify these sorts of investments. In fact, in an instance where the system benefits alone would be sufficient to justify an investment, economic theory suggests that the system would elect to pursue the investment independent of any concern over SSOs. Instead we believe only that some of the sorts of investments that the Needs Report projects will be undertaken in abating SSOs will yield system benefits that should be considered in addition to the benefits stemming from the reduction in SSOs.)

Limitations

We estimate separately the three major categories of benefits from SSO abatement measures: 1) water quality-related benefits; 2) non-water quality-related benefits, and 3) system benefits. In all cases we estimate the benefits that would result from the eliminating <u>all</u> SSOs. However, as discussed in the SSO

Needs Report, there are several factors that preclude a collection system from being completely free from overflows.[3] The Needs Report estimates financial needs for reducing collection system infrastructure deficiencies to very low levels in accordance with existing control objectives of minimizing SSOs. To the extent that all SSOs are not abated by the control measures in the Needs Report, the benefits estimated in this Benefits Report would be proportionally less.

1.3 ORGANIZATION OF THIS REPORT

This report is organized to match the three broad categories of benefits from the measures that will be implemented to reduce SSOs: water quality-related benefits, non-water quality-related benefits, and system benefits. In addition, we present a case study that further illustrates the benefits associated with abating SSOs. The report is organized as follows:

Section 2:	Estimates benefits stemming from improved receiving water quality when SSOs are abated.
Section 3:	Estimates the remaining benefits -- those not involving improved water quality -- that result when the number of SSOs is reduced.
Section 4:	Estimates cost savings to systems implementing measures to abate SSOs.
Section 5:	Presents a case study of the water quality-related benefits that have resulted from measures to abate SSOs.

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[3] Rare storm events may cause I/I that exceeds a collection system's I/I design capacity allowance, thereby producing an overflow. If pipes are oversized to address this problem, other problems would occur, such as "washout" at the treatment plant and blockages from inadequate flow during non-wet weather periods. Natural disasters such as hurricanes can overwhelm collection systems, which cannot feasibly be designed to address all potential circumstances. Lastly, opportunities for blockages from tree roots and other causes in extensive sewer systems are ubiquitous and can lead to SSOs, even when all reasonable measures have been taken to eliminate them (U.S. EPA, 2000b).

Section 6: Summarizes all the benefits estimates and provides an overall perspective.

SECTION 2 WATER QUALITY-RELATED BENEFITS OF SSO ABATEMENT

SSOs contribute substantial quantities of pathogens and oxygen demanding substances to surface waters. In addition, SSOs may contain nutrients, metals, synthetic chemicals, pesticides, and oils. All of these pollutants can make waters less suitable for productive use, can harm the health of individuals using the waters, and can degrade the ecological communities dependent on the waters. Some of the damages that occur when SSOs contaminate waters can be quantified and some can be monetized, while others can only be described qualitatively. In this section, we estimate the damages that SSOs cause by impairing water quality or, conversely, the benefits that will result from improved water quality when SSOs are abated.

We begin by estimating the water quality-related damages that are caused by all the SSOs that occur, or the water quality-related benefits that would accrue if all SSOs were eliminated. We estimate benefits separately for fresh water (Section 2.1) and for marine water (Section 2.2). This separation is due to the existence of a relatively comprehensive study on the benefits of clean fresh water rivers and lakes that we can use as a starting point for our fresh water benefit estimates. For marine water, though, no such comprehensive study exists on the benefits of clean water, and we develop separate estimates of marine benefits for each of several different potential uses of marine waters.

2.1 FRESHWATER BENEFITS FROM ELIMINATING ALL SSOS

2.1.1 Summary of Approach

In a seminal study, Carson and Mitchell (1993) conducted a contingent valuation survey to estimate the monetary value that American households place on improved freshwater quality. The study estimates the amount that households would be willing to pay for progressive increments of improved freshwater quality nationwide: from non-boatable to boatable, from boatable to fishable, and from fishable to swimmable. In this analysis, we estimate the proportion of all the nation's fresh waters that would improve by these increments if all SSOs were to be eliminated, and then multiply this fraction by the dollar values estimated by Carson and Mitchell. If, for example, the average American household was willing to pay $178 annually to improve all fresh waters from fishable to swimmable and eliminating all SSOs would improve 1 % of the nation's fresh waters from fishable to swimmable, we would estimate this improvement to be worth $1.78 per year to the average household.

Carson and Mitchell's estimates for the value of freshwater quality improvements cover most of the improvements and most of the freshwater values that we might be interested in. However, eliminating SSOs will, for some water bodies, further improve the quality of water that is already swimmable. While such a water quality improvement will not provide for an additional use of the water, reduced bacteria concentrations will reduce the rate of illness among those swimming in these waters. We estimate separately this benefit of improving water quality beyond swimmable. Also, Carson and Mitchell do not estimate values for enhanced commercial in-stream uses (such as commercial fishing or navigation) or enhanced withdrawal uses (drinking water, agriculture, industry) from improved water quality. Although we could not identify a means of quantifying the value of enhanced commercial in-stream uses or withdrawal uses, we discuss separately the qualitative, non-monetary benefits in these use categories that may accrue from eliminating SSOs.

2.1.2 Benefits Captured by the Carson and Mitchell Approach

Our approach to estimating the benefits of improved freshwater quality using Carson and Mitchell involves five steps. This subsection of the report first provides some background on the leading sources of water quality impairment, then an overview of the Carson and Mitchell study, and then a step-by-step discussion of how we apply the Carson and Mitchell results. In the final step, we calculate national willingness to pay (WTP) for eliminating SSO use-impairment of rivers and lakes.

<u>Leading sources of water quality impairment</u>

Section 305(b) of the Clean Water Act requires States to prepare water quality assessment reports. EPA compiles and analyzes the State data and publishes them in a biannual summary report to Congress. The most recent report was published in 1998, summarizing the States' analysis of 1996 water quality data (U.S. EPA, 1998a) For this analysis, we used a data base -- the 1996 National Inventory -- into which the 1996 data submitted by the States has been compiled.

Table 2-1 lists the categories of sources that may impair water quality as used in the National Inventory. SSOs are not listed as a separate source category. This analysis focuses on the two source categories in which SSOs play an important contributing role: municipal discharges and urban runoff/storm sewers. The municipal discharge category includes discharges from publicly owned treatment works (POTWs) and their collection systems, thus including SSOs (U.S. EPA, 1994). The urban runoff/storm sewer category includes runoff from impervious surfaces including streets, parking lots, buildings, lawns and other built-up areas. Although the urban runoff/storm sewer source category is not addressed by SSO regulations, SSOs may contribute to the impairment caused by urban runoff and storm sewers in several ways. First, when an overflow causes street flooding, the overflow may drain into a storm sewer. Second, there may be unknown, unintentional, or illegal cross connections between sanitary sewer systems and storm drains, such that household sewage enters and discharges through storm sewers. Third, leaky systems may result in infiltration and exfiltration between storm and sanitary sewers. EPA staff thus believe that some portion of the impairment caused by urban runoff/storm sewers is actually attributable to SSOs.

Table 2-1: Source categories used in the 1996 National Water Quality Inventory

Category	Examples
Industrial	Pulp and paper mills, chemical manufacturers, steel plants, metal process and product manufacturers, textile manufacturers, food processing plants
Municipal	Discharges from publicly owned sewage treatment plants and collection systems, including any impacts from industrial facilities or businesses connected to these systems
Combined Sewer Overflows (CSOs)	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, and other paved areas.
Agricultural	Crop production, pastures, rangeland, feedlots, animal operations
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
Hydrologic Modification	Channelization, dredging, dam construction, flow regulation
Habitat Modification	Removal of riparian vegetation, streambank modification, drainage/filling of wetlands

Table 2-2 lists the five leading sources of water quality impairment for rivers, lakes and estuaries. Municipal discharges represent the second leading cause of water quality impairment for rivers, the fifth leading cause for lakes, and the third leading cause for estuaries. Urban runoff/storm sewers was the fourth leading cause for lakes and the second leading cause for estuaries.

Table 2-2: Leading sources of water quality impairment

Rank	Rivers	Lakes	Estuaries
1	Agriculture	Agriculture	Industrial Discharges
2	Municipal Discharges	Unspecified Nonpoint Sources	Urban Runoff/Storm Sewers
3	Hydrologic Modification	Atmospheric Deposition	Municipal Discharges
4	Habitat Modification	Urban Runoff/Storm Sewers	Upstream Sources
5	Resource Extraction	Municipal Discharges	Agriculture

Overview of the Carson and Mitchell study

SSOs and these other sources can limit or eliminate the ability to use water for a wide variety of purposes. Carson and Mitchell (1993) performed an important study in which they estimated how much people value water being clean and available for a full range of uses. Carson and Mitchell's study used a 1983 contingent valuation survey in which a sample of American households was asked how much value they would assign to different hypothetical national minimum levels of quality for the nation's fresh waters (marine waters were not included). The study estimated annual household willingness-to-pay (WTP) for three incrementally higher levels of fresh water quality: boatable, fishable, and swimmable. The survey respondents were provided with a visual aid to understand the different water quality levels and a card listing the major reasons why households might value water quality. These reasons included swimming, fishing and boating uses; indirect uses near water (e.g., picnicking, jogging, walking, camping, sunbathing, photography); getting satisfaction from knowing that other people use fresh water resources; and knowing that the nation's water is cleaner. The survey was worded in a manner such that respondents would not consider commercial in-stream uses (such as commercial fishing or navigation) or withdrawal uses (drinking water, agriculture, and industry) in valuing water quality improvements.

The Carson and Mitchell estimates are used in this analysis because they provide a well respected and relatively comprehensive estimate of the value of different nationwide levels of freshwater quality. They have been used in many other EPA Office of Water benefits analysis, such as the analysis of Clean Water Act reauthorization initiatives (EPA, 1994a) and the Economic Analysis supporting the Phase II Storm Water rules (U.S. EPA, 1999a).

Carson and Mitchell estimated the value of different levels of national freshwater quality as a function of household income, prices, and attitudes. These quantities change over time. Following the approach used in the Phase II Storm Water EA (U.S. EPA, 1999a), we adjusted Carson and Mitchell's estimates of average household 1983 WTP to current, 1999 levels by accounting for inflation and growth in real per capita income, as shown in Table 2-3. One adjustment made in the Phase II Storm Water EA -- which we did not make in this study -- was to reflect a positive change over time in attitudes toward the environment.

Table 2-3: Adjusted Carson and Mitchell WTP values

Improvement in National Minimum Level of Fresh Water Quality	**Annual Household WTP (1983 dollars)**	**Adjusted Corrected Bid[4] (1999 dollars)**
Nonboatable to Boatable	$106	$196
Boatable to Fishable	$80	$148
Fishable to Swimmable	$89	$164

* Adjusted bid (following U.S. EPA, 1999a approach, but not adjusting for changes in attitudes toward the environment): {unadjusted bid x correction for unit and item bias x adjustment for inflation x adjustment for changes in real income} = [($106) x (.88) x (1.662) x (1.265)].

Whereas Carson and Mitchell's studies provide values for improving <u>all</u> of the nation's fresh waters

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[4] Calculations to obtain the adjusted bid follow the approach adopted by SAIC in U.S. EPA, 1999a, with the exception that no adjustment was made for a change in attitudes toward the environment. The adjustment for inflation is based on the change in the consumer price index. The CPI, as reported by the Bureau of Labor Statistics at http://www.stls.frb.org/fred/data/cpi/cpiaucsl, has increased from an index value of 100 in 1983 to 166.2 in June, 1999. Nominal per capital disposable personal income (PCDPI) has increased by a factor of 2.209 from the first quarter of 1983 through the first quarter of 1999 (U.S. Department of Commerce, 2000). Using the CPI index as a deflator, the real increase in PCDPI over this period was 32.9 %. Substituting this increase in real income into Carson and Mitchell's equation explaining WTP yields a 26.5 % increase in adjusted WTP.

to the various minimum quality levels, eliminating SSOs will result in the improvement of only some of the nation's waters to each of these levels. For such improvements affecting only some waters, we assume that people would be willing to pay a proportional share of their total WTP value. For example, if eliminating SSOs would cause 1 percent of the nation's fresh waters to improve from boatable to fishable, we assume that the average household would value this water quality improvement at 1 % of their total WTP value of $148/yr, or $1.48 annually.

Methodology for applying the Carson and Mitchell results

Estimating the total amount that people would be willing to pay for improvements in fresh-water quality associated with the elimination of SSOs involves several steps, as follows:

Step 1:	Calculate Carson and Mitchell's total national willingness-to-pay (WTP) amounts for the three increments of fresh-water quality, and subdivide WTP amounts into portions involving: a) rivers; and b) lakes (the water quality data we use is reported separately for rivers and for lakes).
Step 2:	Estimate the amount of the nation's fresh waters that would improve from impaired to non-impaired if SSOs were eliminated. Estimates will be developed for both rivers and for lakes. The process for developing these estimates will involve assumptions about the fraction of the waters impaired by SSOs and other sources that will attain standards if SSOs are eliminated but other sources are not. This step will also involve extrapolating data on conditions in waters with known quality (i.e., waters that have undergone water quality monitoring, surveys, or other assessments) to the remainder of the nation's waters whose quality has not been assessed.
Step 3:	Develop further estimates of the degree to which eliminating SSOs will remedy use impairments in relation specifically to Carson and Mitchell's three levels of boatable, fishable and swimmable.

Step 4: Combine steps 2 and 3 to estimate the percentage of all river miles and lake acres that will improve to boatable, fishable and swimmable as a result of eliminating SSOs.

Step 5: Estimate national household WTP for eliminating SSOs by combining information from step 1 on WTP for water quality improvements with information from step 4 on the water quality improvements expected from eliminating SSOs.

The following discussion explains each of these steps in turn.

Step 1: Calculate Carson and Mitchell's total national willingness-to-pay (WTP) amounts for the three increments of fresh-water quality, and subdivide WTP amounts into portions involving: a) rivers; and b) lakes

Total national willingness to pay (WTP) for improvements in water quality from non-boatable to boatable, from boatable to fishable, and from fishable to swimmable was calculated by multiplying the total number of households in the nation (104,870,244)[5] by the applicable household WTP amount. These calculations are presented in Table 2-4. We assume that half of all WTP for fresh-water quality improvements is focused on rivers and streams, and half is focused on lakes. Carson and Mitchell provide no information on the allocation of WTP between rivers and lakes. The specific assumption on this issue has little impact on the ultimate results of the benefits analysis, since, as will be seen subsequently, eliminating SSOs has a roughly similar impact in improving the quality of rivers as it does in improving the quality of lakes.

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[5] As of October 1998, the total combined population of the U.S. and Puerto Rico was 274,760,038 persons (270,933,000 in U.S., 3,827,038 in Puerto Rico) (http://www.census.gov/population/estimates/nation/intfile1-1.txt). Average household size is 2.62 persons per household (http://www.census.gov/population/estimates.housing/ prhuhht1.txt). Thus, there are approximately 104,870,244 households in the U.S. and Puerto Rico.

INSERT Table 2-4: Subdivided willingness-to-pay for cleaner water

In the next several steps in the analysis, we will determine the extent to which eliminating SSOs will improve water quality in rivers and lakes. These projected improvements will then be multiplied by the WTP values derived in this section in order to estimate the value of eliminating all SSOs.

Step 2: Estimate the amount of the nation's fresh waters that would improve from impaired to non-impaired if SSOs were eliminated

The States' submissions under Section 305(b) of the Clean Water Act provide the most comprehensive data available on the quality of the nation's waters and the sources that are responsible for impairments. We use the 1996 National Inventory -- into which the 1996 data submitted by the States has been compiled -- as the source of information for this analysis. We perform four sets of calculations with this data in order to meet our specific needs in this step of the analysis:

a. The source categories responsible for impairments and analyzed in the National Inventory do not include SSOs. The impact of SSOs is subsumed within two of the source categories that are covered by the National Inventory: municipal discharges, and urban runoff/storm sewers. We collect the data from the National Inventory on the extent of the nation's waters that is impaired by municipal discharges and by urban runoff/storm sewers.

b. We make a range of assumptions about the proportion of waters impaired by municipal discharges or urban runoff/storm sewers that would attain standards if these discharges were eliminated. This is not a straight-forward issue. Clearly a water body that is impaired only by municipal discharges would attain standards if municipal discharges were eliminated. However, what of a water body that is impaired by several sources, including municipal discharges? For some such multiple-impairment-source water bodies, the other sources might still prevent attainment even if municipal discharges were eliminated. For other such water bodies, eliminating municipal discharges would be sufficient to yield attainment, in some cases even when municipal discharges were a relatively lesser source of impairment.

c. We estimate the share that SSOs contribute of the impairment caused by municipal discharges and the share that they contribute of the impairment caused by urban runoff/storm sewers. We then apply these "SSO shares" to the amounts of waters calculated in (b) that would attain standards if municipal discharges and urban runoff/storm sewers were eliminated. If, for example, SSOs were responsible for 30 % of impairment by municipal discharges and eliminating municipal discharges would result in 10 % of the nation's fresh waters improving from non-attainment to attainment, then we would assume that eliminating SSOs would result in 3 % (30 % x 10 %) of the nation's waters improving from non-attainment to attainment.

d. The National Inventory includes water quality data for all waters whose quality has been assessed through monitoring, aquatic life surveys or other techniques. However, only a portion of the nation's waters have had their quality assessed or surveyed, and we need to estimate the impact of SSOs on <u>all</u> waters. We therefore develop a procedure to extrapolate data on conditions in waters with known quality to the remainder of the nation's waters whose quality has not been surveyed.

These calculations and related assumptions are described below.

a. Data on impairment by source categories relating to SSOs. EPA believes that the impact of SSOs is subsumed within the impact of two larger source categories that are reported on in the National Inventory: "municipal discharges", and "urban runoff/storm sewers". SSOs are explicitly included in "municipal discharges", which are defined to include "discharges from publicly owned sewage treatment plants and collection systems." SSOs likely also contribute some of the pollutants that reach water bodies through "urban runoff/storm sewers". Table 2-5 shows data from the National Inventory on impairment of rivers by municipal discharges and urban runoff/storm sewers, while Table 2-6 shows similar data for lakes. Note that both tables show data only for those rivers and lakes whose quality is known because it has been assessed or "surveyed" in some manner (e.g., through monitoring, aquatic life evaluations, etc.). Little is known about the impairment status and sources affecting rivers and lakes that have not been surveyed. The 1996 National Inventory shows that:

- 1.41 % of surveyed river miles are impaired by municipal discharges (MD) where MD is identified as a major source of impairment. An additional 3.82 % of surveyed river miles are impaired by MD where it is classified as a moderate or minor source of impairment.

- 1.30 % of surveyed river miles are impaired by urban runoff/storm sewers (UR/SS) where UR/SS is identified as a major source of impairment. An additional 3.56 % of surveyed river miles are impaired by UR/SS where it is classified as a moderate or minor source of impairment.

- 1.45 % of surveyed lake acres are impaired by MD where MD is identified as a major source of impairment. An additional 6.95 % of surveyed lake acres are impaired by MD where it is classified as a moderate or minor source of impairment.

- 2.85 % of surveyed lake acres are impaired by urban runoff/storm sewers (UR/SS) where UR/SS is identified as a major source of impairment. An additional 6.92 % of surveyed lake acres are impaired by UR/SS where it is classified as a moderate or minor source of impairment.

b. Assumptions regarding attainment if municipal discharges and/or urban runoff/storm sewer discharges were eliminated. A water body that is impaired by MD and/or UR/SS may also be impaired by other sources. Eliminating MD and/or UR/SS thus may or may not improve water quality in such a water body sufficiently so that the water body attains standards. For our calculations, we adopt a lower and upper estimate that we believe spans the range of reasonable possibilities of what would happen if MD and UR/SS were eliminated:

- Upper estimate. If MD and UR/SS are eliminated, we assume that 100 % of the waters impaired to a major extent by MD and/or UR/SS will attain standards, and 30 % of the waters impaired to a moderate/minor extent by MD and/or UR/SS will attain standards.

- Lower estimate. If MD and UR/SS are eliminated, we assume that 50 % of the waters impaired to a major extent by MD and/or UR/SS will attain standards, and none of the waters impaired to a moderate/minor extent by MD and/or UR/SS will attain standards.

The range between these assumptions reflects uncertainty about whether waters impaired by MD and/or

UR/SS are: a) Typically impaired only by these sources, or typically impaired by other sources also; and b) Typically near attainment (in which case elimination of MD and/or UR/SS will likely resolve the impairment) or far from attainment. In the future, we may be able to conduct research on these issues that will narrow the range between the upper and lower estimates.

c. Estimate the share that SSOs contribute of the impairment caused by municipal discharges and the share that they contribute of the impairment cause by urban runoff/storm sewers. Calculations to develop these share estimates are shown in Appendix D to this report. To determine this share for municipal discharges, we estimate the volume of pollutants from SSOs reaching U.S. waters and compare this with the volume of pollutants reaching waters of the U.S. from municipal discharges in total (from SSOs plus from treated POTW effluent). For urban runoff/storm sewers we use a similar approach, comparing the volume of pollutants entering UR/SS from SSOs with the total volume of pollutants in UR/SS. As shown in Appendix Table D-5, for both MD and UR/SS, we develop upper and lower estimates of the share contributed by SSOs:

- SSOs are responsible for an estimated 25.89 % - 31.33 % of the impairment caused by municipal discharges; and

- SSOs are responsible for an estimated 10.17 % - 14.92 % of the impairment caused by urban runoff/storm sewers.

We apply these "SSO shares" to the amounts of waters that we estimate would attain standards if municipal discharges and urban runoff/storm sewers were eliminated. We assume a linear relationship here -- if eliminating municipal discharges would, hypothetically, end impairment in 5 % of the nation's river miles, then we assume that eliminating SSOs would end impairment in 25.89 % - 31.33 % of 5 % of all river miles, or 1.29 % - 1.57 % of the river miles in the nation. The following pages show the calculations to develop estimates of the percentage of the nation's surveyed river miles (Table 2-5) and surveyed lake acres (Table 2-6) that would attain standards ("move up" to attainment) as a result of eliminating SSOs. For both rivers and lakes,[6] two estimates are developed:

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[6] We did not develop a separate analysis for the Great Lakes specifically. Since 8 States border the Great Lakes but only 3 of these States listed the particular causes of impairment of their Great Lakes

- A lower estimate, combining: 1) The lower estimate of the amount of surveyed waters that would “move up” if municipal discharges and urban runoff/storm sewers were eliminated (50 % of the waters with major impairment from these source categories), with 2) The lower estimate of the share of MD and UR/SS impairment that is due to SSOs; and

- An upper estimate, combining: 1) The upper estimate of the amount of surveyed waters that would “move up” if municipal discharges and urban runoff/storm sewers were eliminated (all of the waters with major impairment from these source categories, plus 30 % of the waters with moderate/minor impairment), with 2) The upper estimate of the share of MD and UR/SS impairment that is due to SSOs.

Note that these estimates of the amount of waters that would attain standards if SSOs were eliminated apply only to surveyed waters. These estimates will be extended to all waters -- surveyed and non-surveyed -- in the next step of the analysis.

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waters, we did not believe we had sufficient data to draw conclusions about the extent to which eliminating SSOs would reduce impairments in the Great Lakes specifically.

Insert Table 2-5: Lower and upper estimates of the percentage of surveyed river miles that would “move up” if SSOs were eliminated

Insert Table 2-6: Lower and upper estimates of the percentage of surveyed lake acres that would “move up” if SSOs were eliminated

d. Extrapolate the estimates of the degree to which eliminating SSOs will improve waters that have been surveyed to all of the Nation's waters. The preceding analysis reflects the impact of eliminating SSOs on surveyed waters -- those whose quality has been assessed through monitoring or other techniques. However, only a portion of the nation's waters have had their quality surveyed, and we need to estimate the impact of eliminating SSOs on all waters.

In general, the quality of unsurveyed waters is likely to be better than the quality of surveyed waters. States typically target their resources for assessing water quality on waters where there are known or suspected problems and on areas where water quality is of particular concern (e.g., heavily used urban waters).[7] The percentage of unsurveyed waters that is impaired by MD and UR/SS is likely to be lower than the percentage of surveyed waters that is impaired by these sources. The fraction of waters that will "move up" upon eliminating SSOs is therefore likely to be lower for non-surveyed waters than it will be for surveyed waters. In addressing this issue, to develop an upper estimate we assume that unsurveyed waters show impairment at the same rate as surveyed waters -- in effect, that surveyed waters represent a fair sample of all waters in terms of quality. This assumption has been made in previous Office of Water benefits analyses, including that for the Phase II storm water rule (U.S. EPA, 1999a). The result of this upper estimate assumption is that eliminating SSOs would have the same degree of impact in improving the quality of non-assessed waters as would be the impact for assessed waters. As a lower estimate, we assume that unsurveyed waters show impairment at half the rate of surveyed waters. Thus, in the lower estimate, municipal discharges and urban runoff/storm sewers impair non-surveyed waters at half the rate at which they impair surveyed waters, and the impact of eliminating SSOs would be half as high for non-surveyed waters as it would be for surveyed waters.

With the previously developed information on the impact of eliminating SSOs on impairment in surveyed waters and these assumptions regarding unsurveyed waters, we need only information on the proportion of waters that are surveyed in order to project the impact of eliminating SSOs on all of the nation's waters. According to data compiled for the 1996 National Water Quality Inventory, about 19% of the nation's 3.63 million river miles and 40 % of the nation's 41.68 million lake acres are surveyed (U.S. EPA,

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[7] Personal communication with Susan Holdsworth, EPA, January 26, 1999 (Holdsworth, 1999).

1998a).

At this point, we have estimated the degree to which eliminating SSOs would improve surveyed rivers and lakes (Tables 2-5 and 2-6), the relative response in surveyed vs. non-surveyed waters (non-surveyed waters are assumed to show improvements at 50 to 100 percent of the rate at which surveyed waters will show improvements), and the fraction of waters that are surveyed. By combining these data, we can estimate the degree to which eliminating SSOs will affect all of the nation's waters, including both surveyed and non-surveyed waters. Table 2-7 summarizes these calculations. In this Table, we have paired the lower estimates of improvement from eliminating SSOs in surveyed waters with our lower estimate assumptions on the degree to which non-surveyed waters are impaired (and similarly matched our upper estimate figures) in order to obtain lower and upper estimates of the degree to which eliminating SSOs will affect all waters.

Table 2-7: Percentage of all waters that will "move up" if SSOs are eliminated

		% of surveyed waters that will "move up"	**% of waters surveyed**	**Degree to which unsurveyed waters are impaired relative to surveyed waters**	**% of all waters that will "move up" upon eliminating SSOs**
Rivers	lower estimate	0.25%	19%	50%	0.15%
	upper estimate	1.16%		100%	1.16%
Lakes	lower estimate	0.33%	40%	50%	0.23%
	upper estimate	1.84%		100%	1.84%

We project that eliminating SSOs will bring 0.15 - 1.16 % of the nation's stream miles and 0.23 - 1.84 % of the nation's lake acres from impaired to meeting standards. These estimates of the extent to which impairments will be ended (waters will "move up") if SSOs are eliminated are used in several other portions of this Benefits Report in addition to this section.

Step 3: Estimate the degree to which eliminating SSOs will remedy use impairments in relation specifically to Carson and Mitchell's three levels of boatable, fishable and swimmable.

Table 2-7 shows the proportion of rivers and lakes that will improve from impaired to unimpaired if SSOs are eliminated. In these waters, which particular uses are currently impaired? What are the new uses that these waters will support when SSOs are eliminated? Carson and Mitchell provide WTP values for improving water quality sufficiently to achieve three specific uses: boating, fishing and swimming. In this step of the analysis, we will extend our estimates of the water quality improvements expected upon eliminating SSOs and will develop estimates relating specifically to these three uses.

The 305(b) report provides data on the degree to which surveyed waters support four different uses: aquatic life support, fish consumption, primary contact (swimming), and secondary contact (boating). We assume that these four uses correspond to the three water quality categories referenced in the Carson and Mitchell survey: 1) secondary contact (boating) use support corresponds to "boatable"; 2) aquatic life support and/or fish consumption support corresponds to "fishable"; and 3) primary contact (swimming) use support corresponds to "swimmable".

There are several difficulties in adapting the 305(b) data on use support to our purposes. First, the 305(b) data base provides national information on the degree to which specific uses are supported and on the degree to which various sources cause impairments, but does not allow for cross-tabulation between use support and causes of impairment. No information is available on whether one specific source (e.g., SSOs, municipal discharges, urban runoff/storm sewers, CSOs, air deposition) causes a different mix of use impairments than any other specific source. One might speculate that among the waters identified as impaired by CSOs, the primary variety of use impairment expected would be swimming, due to pathogens. Among waters identified as impaired by air deposition, the most common sort of use impairment would likely be different -- perhaps, we would guess, involving impairment of fish consumption as a result of deposition of mercury, PCBs and other toxics in lakes and estuaries. However, such cross-tabulated information relating sources of impairment to varieties of use impairment is not available. For this analysis, we are left with making the assumption that the pattern of use impairments caused by SSOs as a source category is identical to the pattern of use impairments caused by all other source categories. This is likely not a very accurate assumption. The most important pollutants associated with SSOs may be pathogens, which will tend most frequently to impair swimming and secondary contact (boating) uses. Relative to other sources of impairment, SSOs perhaps involve lesser quantities of toxic pollutants and they might thus impair fish consumption uses relatively less frequently (insofar as many of the fish consumption impairments involve bioconcentrated or bioaccumulated toxics). Compared with the impairments caused by other source categories, a higher proportion of the impairments caused by SSOs will likely involve swimming and boating uses, and a lower proportion will involve fishing uses. We nevertheless have no data available with which to develop a specific estimate of this sort, and we make the assumption that impairments from SSOs involve different uses in the same proportion as do impairments from all sources generally.

A second difficulty in using the 305(b) database to estimate the specific uses that are impaired by SSOs (or, for that matter, by any other source category) is that only a subset of the waters whose quality has been surveyed has been assessed for support of any particular use. For example, 693,905 miles of rivers have been assessed for use support nationwide. However, only 641,611 of these river miles have been assessed for aquatic life support, only 434,421 have been assessed for swimming use support, etc.. We need to determine whether the remaining miles that have not been assessed for a specific use (e.g., the 52,294 miles not assessed for aquatic life support and the 259,484 miles not assessed for swimming) support that specific use or not.

In general, only waters that are designated for a particular use will be surveyed to determine if that use is supported. This would suggest that waters that are <u>not</u> designated for a particular higher use (e.g., domestic water supply, swimming, fishing) are more likely to be impaired for that use than waters that <u>are</u> designated for that use. To take an extreme example, the Houston Ship Channel, which would probably not support swimming or fishing, is not designated for these uses because few would think of swimming or fishing there. Based on this reasoning, waters that are not surveyed for swimming, but that are surveyed for other uses, will show the same degree or higher degree of impairment for swimming as waters that actually are surveyed for swimming. Similarly, waters that are not surveyed for fishing, but that are surveyed for other uses, will show the same or higher degree of impairment for fishing as waters that actually are surveyed for fishing. For both of these uses, in our calculations we adopt an assumption that likely leads to an underestimate of impairment -- we assume that waters not surveyed for swimming or fishing will show the <u>same</u> (not greater) degree of impairment as waters that are surveyed for swimming or fishing.

In estimating the percentage of all impaired waters that are impaired for boating, however, a different approach was taken. It can be expected that water bodies that are not designated for boating (i.e., probably waters that are designated for fishing or swimming -- uses which require higher levels of water quality than boating) will generally show a lesser degree of use impairment for boating than water bodies that are designated for boating. However, it is also likely that the actual rate of use impairment for boating in waters designated for uses other than boating is not zero -- some water bodies designated for fishing or swimming that show impairment for one of these uses may well be impaired for boating as well. Waters not surveyed for boating are likely impaired for boating at a rate somewhere between zero and the rate at which waters surveyed for boating are impaired for boating. This wide range of possibilities poses analytical difficulties. Relatively few waters have been surveyed for boating use support, and many waters have not been surveyed for boating use support. The waters for which we know about boating use support are few, while the waters to which we need to extrapolate regarding boating use support are many. Furthermore, there is great uncertainty (a wide range of possibilities) in what this extrapolation should be. In light of these considerations, we adopted a different approach in estimating the degree to which the nation's waters are impaired for boating than we used for swimming and fishing. Appendix E describes this alternative method. In estimating the fraction of waters that support boating, we relied on the projections of the National Water Pollution Control Assessment Model (NWPCAM), developed by the Research Triangle Institute for EPA (RTI, 2000). NWPCAM can simulate water quality in all of the nation's Reach File 1 water bodies under a variety of historical or policy conditions. NWPCAM projects that approximately 5 % of all waters had less-than-boatable quality as of 1997, which we will assume for our purposes as representing current conditions.

Based on these approaches (305b data for swimming and fishing, NWPCAM projections for boating), Table 2-8 shows our calculations to determine which specific uses are not supported in impaired waters. The following is an explanation for one sample set of calculations involving aquatic life support in rivers.

> 693,905 miles of rivers have been surveyed for use support. 455,827 miles supported their designated uses and 248,028 miles did not (they were impaired). Among the national total of surveyed miles, 641,611 miles were assessed for aquatic life support and 52,294 miles were not assessed for aquatic life support. Among the miles assessed for this use, 201,556 (31%) only partially or did not at all support the designated aquatic life use. Among the 52,294 miles that were not assessed for aquatic life use, we assume that the same percentage (31%) would not support this use as the percentage that did not support this use among the miles that were assessed for aquatic life use. We thus project a total of 217,986 miles as not supporting an aquatic life use (201,556 + [.31 x 52,294]). The 217,986 miles not supporting aquatic life represent 88% of the 248,028 impaired miles. We conclude that 88% of impaired miles do not support aquatic life use.

INSERT Table 2-8: Which uses are not supported in impaired waters?, IN LOTUS 123

The results shown in Table 2-8 are surprising in one important respect. Impaired waters more often do not support uses relating to fishing (aquatic life support, fish consumption) than they do not support uses relating to swimming. One might not expect such an outcome, since swimming is commonly thought to be a more demanding use -- requiring higher water quality -- than is fishing. In fact, this is not true for all pollutants. For some pollutants, aquatic life support or fish consumption uses may need better water quality than is needed for swimming. Bioaccumulative and bioconcentrating toxic pollutants at low water column concentrations (e.g., mercury) may impair fish health and make it inadvisable for humans to consume the fish, yet humans swimming in such waters may be perfectly safe. Or, in some cases, temperature levels may be sufficiently high to impair salmonids in waters designated as a cold water fishery, but swimming may be unharmed.

Table 2-8 shows how often each of the four specific uses relating to swimming, fishing and boating are not supported in waters that are impaired. We assume that this pattern of impairment of specific uses applies particularly for impairments due to SSOs (or for impairments that will be remedied upon elimination of SSOs) as well as generally for impairments from all other sources.

Step 4: Combine steps 2 and 3 to estimate the percentage of all river miles and lake acres that will improve to boatable, fishable and swimmable as a result of eliminating SSOs

In step 2, we calculated the percentage of all river miles and all lake acres that would improve from impaired to non-impaired if SSOs were eliminated (Tables 2-5 and 2-6). In step 3, we calculated the percentage of all impaired miles that do not currently support each of three use categories (boating, fishing and swimming) (Table 2-8). In step 4, we multiply the results of steps 2 and 3 in order to calculate the percentage of the nation's waters that will improve upon elimination of SSOs from non-support to support for each of the different uses. The results of these calculations are presented in Table 2-9. The table shows, for example, that eliminating SSOs will improve an estimated 0.08 - 0.65 % of all river miles from non-swimmable to swimmable. The table thus provides the water quality improvements that can be expected from eliminating SSOs in terms that can be matched against the Carson and Mitchell WTP values for boating, fishing and swimming.

INSERT Table 2-9: Percent of waters that will improve to support boating, fishing and/or swimming upon eliminating SSOs, IN LOTUS 123

Step 5: Estimate WTP for eliminating SSOs by combining information on WTP for water quality improvements with information on the water quality improvements expected from eliminating SSOs

In step 1, using Carson and Mitchell's data, we estimated the WTP by U.S. households for eliminating boating, fishing and/or swimming use impairments in all of the nation's fresh waters (Table 2-4). In step 4, we estimated the fraction of the nation's fresh waters in which boating, fishing and/or swimming use impairments would be eliminated if SSOs were to be eliminated (Table 2-9). We now combine these two sets of information to estimate the value households would assign to the increased amount of water supporting higher uses that is expected from eliminating SSOs. In combining the WTP estimates with the estimated water quality improvements, we assume a proportional allocation of the total WTP. If, for example, 1) Households would value improving all river miles from non-swimmable to swimmable at $8.6 billion annually; and 2) Eliminating SSOs would eliminate swimming use impairments in 0.08 - 0.65 % of all river miles in non-urban areas, then 3) Households would value this particular water quality improvement from eliminating SSOs at $6.9 - $55.7 million annually (0.08% to 0.65% x $8.6 billion).

The resulting national estimated annual WTP for the increased amount of water supporting higher uses that will result from eliminating SSOs is shown in Table 2-10. As a lower estimate, annual WTP for the increased amount of waters available for the three higher uses is $45.9 million. As an upper estimate, WTP is $387.8 million annually.

One further issue arises in performing the final calculations shown in Table 2-10. Either aquatic life support or fish consumption use support may be used to represent the Carson and Mitchell water quality descriptor "fishable". For rivers, SSOs impair fishing use more often based on aquatic life support than they do based on fish consumption, and using aquatic life support to estimate the extent of increased fishing waters upon elimination of SSOs will result in higher WTP estimates. The opposite is true, however, for lakes. Summing the WTP estimates for rivers and for lakes, a higher upper estimate results when we base the boatable to fishable increment on aquatic life support information. We therefore use aquatic life support information in calculating the upper estimate. Summing across rivers and lakes again, a lower lower estimate results when we base the boatable to fishable increment on fish consumption support information. We therefore use the fish consumption support information in calculating the lower estimate.

INSERT Table 2-10: Total annual willingness to pay for increased fresh water uses resulting from elimination of SSOs, IN LOTUS 123

2.1.3 Reduced Illnesses From Swimming in Fresh Water

Overview

Many visitors to the beach are unaware that waters that meet Federal and State standards for bathing water quality nevertheless likely contain sufficient quantities of pathogens to cause illnesses among some percentage of swimmers. Available dose-response functions quantifying the relationship between pathogenic water quality and the rate of swimmer illnesses indicate that some illnesses can be expected even at pathogen concentrations much lower than existing standards. As a result, we can expect that a measure that reduces the concentration of pathogens in swimming waters (such as abating SSOs) will reduce the number of swimmer illnesses that will occur, even for waters that clearly meet existing recreational water quality criteria. If SSOs were eliminated, the concentration of pathogens would be reduced and fewer illnesses would result from swimming at marine beaches and at freshwater swimming areas.

The previous section (2.1.2) of this report estimates some of the benefits associated with improvements in freshwater quality resulting from the elimination of SSOs, using Carson and Mitchell's apparently comprehensive contingent valuation study (Carson and Mitchell, 1993). One may question whether a separate estimate in this section addressing the value of reduced swimmer illnesses resulting from improved fresh water quality would represent double-counting some of the benefits already estimated. After all, respondents to the Carson and Mitchell survey probably assumed, when they stated their WTP for swimmable water, that the swimmable water they were valuing would be clean and would not make them sick. The respondents' WTP value for swimmable water reported to Carson and Mitchell might thus already include whatever value we could calculate in this section due to reduced pathogen concentrations in swimming waters and fewer resulting cases of illness.

An example will show why the value of reduced swimming illnesses does not represent double-counting with the Carson and Mitchell benefit estimates. Begin with the updated Carson and Mitchell estimate that the average household would be willing to pay $164 annually to improve the quality of all of the nation's waters from fishable to swimmable (see Table 2-3). The benefits estimation procedure we used in the previous section in effect allocated this $164 of WTP equally across all waters in the country – we assumed that if some pollution abatement measure were to "move up" 10 % of the nation's waters from non-swimmable to swimmable then the average respondent household would value this improvement at 10 % of $164 or $16.40 annually.[8] This estimation approach, however, ascribes value for improvements in water quality only for those waters that move up from non-swimmable to swimmable. No value has yet been calculated for any quality improvements in waters that do not "move up" to the next higher category of use. Nor has any value yet been calculated for any quality improvements in waters that are already swimmable (the subject of this section).

The household's total WTP of $164 for swimmable water addresses all of the nation's waters. Imagine dividing the nation's waters into subsets:

a. The set of waters whose quality would be unaffected if SSOs were eliminated;

b. The set of waters whose quality would be improved if SSOs were eliminated. This subset includes further subsets:

   b1. The set of waters that are now non-swimmable and that will "move up" to swimmable if SSOs were eliminated;

   b2. The set of waters that are now non-swimmable and that will improve if SSOs were eliminated but not enough to become swimmable; and

   b3. The set of waters that are now swimmable, and whose quality will get even better if SSOs were eliminated.

In short, the nation's waters can be subdivided as follows in terms of how they will be affected by eliminating SSOs:

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[8] Likewise, a different measure that would "move up" 20 % of the nation's waters from fishable-only to swimmable would be valued at $32.80 annually.

Figure 2-2: Different categories of waters as affected by eliminating SSOs

a. Waters whose quality will not be affected	
b. Waters whose quality will be improved	b1. Waters that will “move up” from non-swimmable to swimmable
	b2. Waters that are non-swimmable, but won’t improve enough to become swimmable
	b3. Waters that are already swimmable, and whose quality will become even better

The potential $164 WTP for swimmable water is allocated across all the fresh waters in the country. Some of the potential WTP is focused on those waters that, upon elimination of SSOs, will end up being in category a. Some of the potential WTP is focused on waters that will end up being in category b1. We have estimated how much of the nation’s fresh waters are in category b1 (i.e., 0.08 - 0.65 % of all river miles and 0.14 - 1.16 % of all lake acres), and have attributed a proportional share of the potential total $164/year in WTP to the new swimming use that can be made of these waters as a result of eliminating SSOs. Some of the potential $164/year in WTP is also focused on waters that are in category b3. We do not know from Carson and Mitchell’s work how much WTP to attribute to quality improvements in already swimmable waters, as the researchers did not ask about such improvements. We are confident, however, that whatever WTP is ascribed to improvements in waters in category b3 is not double-counted with the WTP ascribed to improvements in waters in category b1 and estimated in the preceding section.[9]

In the absence of contingent value-based estimates from Carson and Mitchell or other researchers bearing on what WTP would be for improving the quality of already-swimmable waters, we will pursue an

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[9] Some of the WTP is also focused on the b2 waters, whose quality improves upon elimination of SSOs, but not sufficiently to make them swimmable. Carson and Mitchell estimated some WTP for such partial improvements toward a new use, but we have not been able to develop a reasonable way to determine what fraction of this WTP for partial improvement would accrue if SSOs were eliminated. Were we able to estimate the WTP for improvements in these b2 waters, it also would not be double-counted with the WTP estimated for the b1 waters that “move up” to fully support swimming.

alternative approach for estimating these benefits. The benefits from abating SSOs and improving water quality at already swimmable waters should be at least equal to the costs that are avoided from swimming-related illnesses that will no longer occur with improved water quality.

The methodology for estimating the reduction in swimming-related illnesses that would result from eliminating SSOs is the same for fresh waters as for marine waters, with minor exceptions. For ease of presentation and to avoid repetition, the discussion of the benefit of reduced swimming illnesses that follows describes the methodology and calculations for both fresh and marine waters.

The costs associated with illnesses contracted from swimming depend on four factors:

1) The number of person-days spent swimming at fresh water and marine swimming areas;

2) The likelihood of contracting an illness as a function of the concentration of pathogens in the water;

3) The degree to which initial illness among swimmers is followed by secondary transmission of illness to non-swimmers; and

4) The costs associated with contracting these illnesses.

This analysis considers these four factors in order to estimate the value of the illnesses that would be avoided if SSOs were eliminated. The basic relationship underlying this analysis is the following: reducing SSOs will result in improved pathogenic water quality, which in turn will result in fewer swimmers becoming sick. With an appropriate dose-response function, it is possible to estimate the change in factor 2 -- the likelihood of a swimmer contracting an illness -- that would result from the water quality improvements associated with eliminating SSOs. The change in the likelihood of illness can then be multiplied by the number of swimming days (factor 1) to determine the number of avoided illnesses. The number of avoided illnesses is then increased to reflect the transmission of secondary illnesses from swimmers to the general population (factor 3). Finally, unit costs for each avoided illness (factor 4) are applied to obtain a benefits estimate.

Each of the four factors is discussed below in turn.

Factor 1: The number of person-days spent swimming at fresh water and marine swimming areas

Environomics (1995) estimated that Americans participate in approximately 1.2 billion days per year of outdoor swimming in non-pool settings. The estimate was based on combining data from the 1982-1983 Nationwide Outdoor Recreation Survey (U.S. Department of the Interior) and the 1994 National Survey on Recreation and the Environment (U.S. EPA, 1994c). Of this total, marine swimming accounts for approximately 535 million days and freshwater swimming accounts for approximately 665 million days.

Factor 2: The likelihood of contracting an illness as a function of the concentration of pathogens in the water

We determine the extent to which SSO elimination would reduce the likelihood of contracting an illness from swimming in four steps. First, we select an appropriate dose-response function that estimates the quantitative relationship between water quality (i.e., the concentration of indicator bacteria) and the rate of illness among swimmers. Second, we estimate the current average concentrations of the indicator bacteria across all swimming areas for fresh and marine waters. Third, we estimate the impact that eliminating SSOs would have on average concentrations of indicator bacteria. Finally, using the dose-response function, the change in the illness rate associated with the change in average water quality can be calculated. These steps are discussed below.

Step A: Select dose-response functions for fresh and marine waters

Epidemiological studies have investigated illness among beach visitors and swimmers at many locations, including: the U.S. (Cabelli, 1983; Dufour, 1984; Coye and Goldoft, 1989), Canada (Seyfried et al., 1985a and 1985b; Lightfoot, 1989), France (Ferley et al., 1989), Great Britain (Balarajan et al., 1991; Jones et al., 1993; Kay et al., 1994; Fleisher et al., 1996), Israel (Fattal et al., 1987), Hong Kong (Cheung et al., 1991; Holmes, 1989), Australia (Harrington et al., 1993), South Africa (Von Schirnding et al., 1993), and Spain

(Mujeriego et al., 1982). Reviews of this literature have concluded that:

> Scientists working at marine and freshwater sites throughout the world have demonstrated that individuals who swim or participate in other water sports are more likely than non-swimmers to contract gastrointestinal and respiratory illnesses, ear and eye infections, and skin irritations. Dynamac Corporation (1994).
>
> Most studies reported a dose-related increase of health risk in swimmers with an increase in the indicator-bacteria count in recreational waters. Relative risk (RR) values for swimming in polluted water versus clean water were often significant (usually 1.0<RR<3.0)... In both marine and freshwater, increased risk of gastro-intestinal symptoms was reported for water quality values ranging from only a few indicator counts/100 ml to about 30 indicator counts/100 ml. These values are low compared with the water qualities frequently encountered in coastal recreational waters. Pruss (1998).

Despite the consistency of the study findings that swimming significantly increases health risks and that the risk increases with indicator bacteria concentrations, the various studies take differing approaches in several respects that make the results difficult to compare or aggregate. The studies differ in:

C How they define the illnesses of interest. Some studies focus on gastrointestinal illnesses, while others focus on ear infections, respiratory illnesses, skin problems, eye infections, or others among a broad variety of symptoms. Some rely loosely on individuals to self-report mild symptoms, while others require more definitive medical evidence of illness. The studies also differ in how soon after swimming illness is checked for.

C Which indicator parameters are chosen to represent water quality (e.g., total coliform, fecal coliform, E. coli, enterococci, fecal streptococcus, others). Some studies monitored several of these indicators in an attempt to determine which correlated best with rates of illness. Other studies monitored only a single indicator -- this is problematic because it is difficult to contrast a relationship between illness and an indicator derived in one study with a relationship derived in another study between illness and a different indicator. Bacteriological indicators need not bear any consistent relationship to each other across sites, making it difficult to find a common denominator for comparing results across studies that focus on different indicators.

C Protocols for monitoring the indicators and describing the extent of swimmer exposure. The depths and distance from shore at which samples were taken vary significantly across studies. The studies also differ in the way they define exposure. Some studies tested participants for the effects of total head immersion, while others considered someone to be exposed if they went in the water to any degree. Still other tests addressed total head immersion plus splashing, and total head immersion plus swallowing a mouthful of water. In addition to these inconsistencies, the length of exposure also varies across studies.

C How a relationship between the concentration of the indicator and the extent of illness was investigated. Some studies fit a regression equation to multiple data points. This approach provides a fully estimated dose-response relationship between the indicator and the rate of swimmer illness. In other cases, though, the data were pooled in some way and illness rates under more contaminated conditions were compared with illness rates under less contaminated conditions. Often the numerical levels corresponding to "more" or "less" contamination were not reported. Such studies nearly always concluded that illness rates were statistically significantly higher for more contaminated beaches than for less contaminated beaches, but they provided no estimate of the quantitative relationship between the level of contamination and the rate of illness.

Not surprisingly given the differences in research methodologies, there is substantial variation across the dose-response relationships derived in the various studies of pathogens and swimmer illness. One researcher concludes that the diversity of results suggests that this quantitative relation is complex and may even be site-specific (Fleisher, 1991). Others believe that differing levels of pre-existing immunity to different pathogens may contribute to the variation in quantitative relationships obtained across different sites and populations (Pruss, 1998). Another complicating factor is the potentially inconsistent relationship between the concentration of the bacteriological indicator that is measured and the concentration of other unmeasured agents (e.g., viruses) that may actually be responsible for many of the disease cases.

For the purpose of our benefits calculation, we use the dose-response functions derived by Cabelli (1983) and Dufour (1984) that related highly credible gastrointestinal (HCGI) symptoms among swimmers to the concentrations of enterococci (for marine water and for fresh water) or E. coli (for fresh water only).

The equations are as follows. For marine water:

$$\text{HCGI symptoms/1000 swimmers} = 0.2 + 12.17 \log(\text{mean enterococci/100 ml})$$

For fresh water:

$$\text{HCGI symptoms/1000 swimmers} = -6.28 + 9.4 \log(\text{mean enterococci/100 ml})$$

$$\text{HCGI symptoms/1000 swimmers} = -11.74 + 9.4 \log(\text{mean E. coli/100 ml})$$

These equations derive from epidemiological studies at several beach locations in the late 1970s and early 1980s, and provide the basis for EPA's current water quality criteria for recreational waters. EPA's marine water quality criterion of 35 enterococci per 100 ml, for example, was derived by solving the first equation for the water quality that would yield the traditionally accepted illness rate of 19 cases per 1000 swimmers. Several of Cabelli and Dufour's findings are notable:

1. The clearest statistical relationships between water quality and swimmer illness rates were found for gastrointestinal illness. The statistical relationships were even more definitive when only "highly credible" GI symptoms were considered, in contrast to all GI symptoms.

2. Enterococci (marine water) and enterococci or E. coli (fresh water) were found to be the best indicator parameters. They correlated with swimmer illness rates more closely than did other possible indicator parameters (e.g., fecal coliform).

Despite EPA's adoption of the Cabelli/Dufour dose-response functions as the basis for the Agency's recreational water quality criteria, there remains a great deal of uncertainty associated with the number of illnesses predicted by these functions, as discussed above. Nevertheless, EPA believes most other studies generally support the Cabelli/Dufour conclusion that enterococci and E. coli are the best indicators (Dufour, 1998). The most comprehensive recent review of epidemiological studies on health effects from exposure to recreational water concludes similarly that enterococci/fecal streptococci for both marine and fresh water, and E. coli for fresh water, correlate best with health outcomes (Pruss, 1998). In light of these findings, EPA concludes that Cabelli/Dufour remains the most reliable dose-response function available to estimate swimmer illness rates in the U.S. Appendix B provides information about the results that would be obtained using a various other dose-response functions. The results projected using the Cabelli/Dufour equations fall well within the ranges estimated based on the other studies.

Nearly all investigators conducting studies subsequent to Cabelli/Dufour have found that swimming increases the risk of several other types of illness in addition to gastrointestinal. Table 2-11, for example, shows findings from other studies on the increased likelihood of contracting a wide variety of other illnesses from swimming.

Table 2-11: Odds ratios for various illnesses found in several studies

Study	GI	HCGI	Ear	Eye/ear	Eye	Throat	ENT	Skin	Resp.	Total
Balarajan (1991)	1.5	1.9			1.2		1.1		1.4	1.3
Cabelli/Dufour (1983,1984)		2.3								
Cheung/Holmes (1989,1991)	3.2	5.0		4.6				3.9	2.6	2.6
Seyfried (fresh) (1985)		3.9	3.1		1.6			3.1	2.4	2.4
Coye & Goldoft (1989)		2.4	2.0		2.8	2.0		1.8		2.1
Ferley (fresh) (1989)		2.3			1.4		1.4	3.7	1.1	2.1
Harrington (1993)										1.6
Jones (1993)		1.5	3.1		2.1				1.7	
Von Schirnding (a) (1993)	1.4							2.7	1.5	
(b)	1.9							1.6	1.7	
Median	2.3				1.6	ENT: 2.0		2.9	1.7	2.1

Note: The odds ratio is the ratio between the probability of a swimmer contracting the illness and the probability of a non-swimmer contracting the illness.

Given the consistency of these findings, it seems reasonable to assume in our calculations that swimming in contaminated water increases the likelihood of contracting other illnesses in addition to gastrointestinal ones. Several of the studies cited in the table above provide sufficient information to calculate the frequency with which swimming leads to other illnesses, in contrast to the frequency with which it leads to gastrointestinal illnesses. Table 2-12 shows this information.

Table 2-12: Increase in gastrointestinal and other illnesses from swimming

Study	# HCGI Illnesses Per 1,000 Swimmers	# Other Illnesses Per 1,000 Swimmers	Ratio of Other Illnesses to HCGI Illnesses
Balarajan (1991)	2.2	2.6	1.2
Cabelli/Dufour (1983,1984)	17.2		
Cheung/Holmes (1989,1991)	2.0	26.5	13.3
Coye & Goldoft (1989)	12.2	51.5	4.2
Fattal (1987)	34.9	50.6	1.5
Seyfried (fresh water) (1985)	11.4	28.7	2.5

Median ratios of other illnesses to HCGI: 2.5 (across all studies); 1.5 - 4.2 (for marine water studies only)

Each of the five studies subsequent to Cabelli/Dufour clearly shows that swimming causes more cases of the other illnesses than it does gastrointestinal illnesses. The median finding across the studies is 2.5 cases of other illness per case of gastrointestinal illness. Schaub (personal communication, 1995) believes such an excess of other illnesses caused by swimming over gastrointestinal illnesses to be plausible. In his view, there is probably a smaller set of pathogenic organisms in bathing water that cause GI problems than those that can cause other illnesses.

In our calculations, we will assume from 1.5 cases of other illness per GI case (lower estimate assumption, derived as the low end of the median across the marine studies only) to 2.5 cases (upper estimate assumption, representing the median finding across the five studies). We will use the Cabelli/Dufour dose-response relationships to project the number of gastrointestinal illnesses from swimming, and then will increase this by 150 % or 250 % to estimate the number of cases of other illnesses caused by swimming. Given the range in ratios between other and GI illnesses found across the studies, these assumptions are clearly subject to significant uncertainty.

Step B: Determine the average pathogen concentrations at freshwater and marine beaches

Monitoring information on pathogen levels in surface waters is common. Thousands of sites across the country are monitored routinely or episodically for pathogens, and provide their data to STORET, a computerized data base maintained by EPA for the storage (STO) and retrieval (RET) of water quality data. However, STORET data are not compiled in a manner intended to characterize ambient water quality across the nation specifically at the sites at which people swim. Most STORET monitoring sites are on rivers and streams, whereas more than 80% of non-pool swimming occurs at lakes, reservoirs and marine waters (U.S. EPA, 1994c). In addition, most monitoring is for fecal coliform, which is not a preferred indicator parameter in terms of strength of association with swimming illness rates.

In order to isolate those monitored waters that are most representative of waters where people swim, we obtained two targeted searches of the STORET database. Our first search was for monitoring data on enterococci from sites that were likely located at ocean and estuarine beaches. We selected monitoring records for salt water sites for which the word "beach" appears in the location name. Because we were interested in bacteriological water quality only at locations and times where people actually swim, we further wanted to exclude data from locations and times where the recreational water quality criteria were exceeded and swimming was unlikely. Accordingly, we excluded from the data base any group of observations whose mean exceeded EPA's marine recreational water quality criterion of 35 enterococci per 100 ml, based on the assumption that beaches will be closed when this criterion is exceeded.[10] Our final marine swimming water database included over 14,000 observations covering 175 monitoring stations at more than 90 different beaches. The mean enterococci level across the 14,000 observations was 4.55 enterococci per 100 ml. We assume that this average concentration is representative of all marine waters in which people swim.[11]

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[10] This assumption is conservative, in that it is likely to exclude readings from some waters in which people actually swim. Only a few States consistently apply EPA's standard, while many others have less stringent standards and monitor infrequently, if at all. The mean enterococci concentration in the marine waters in our data base is therefore likely to be somewhat lower than actual levels in waters where people swim.

[11] This procedure of eliminating sites and observations where the swimming water quality criteria are exceeded is followed for fresh waters also. This procedure effectively limits this analysis to waters where swimming use is currently supported. The set of waters considered for this analysis of swimming

In our second search, we selected records involving monitoring for E. coli at stations that were likely located at freshwater swimming areas. We selected records for those freshwater sites for which the words "beach" or "swimming area" appeared in the location name. Again, we excluded from the data base any group of observations whose mean exceeded EPA's water quality criterion (in this case, 126 E. coli per 100 ml for freshwater). Our final freshwater swimming area database included 426 observations covering 38 monitoring stations at 38 different beaches in 9 States. The mean E. coli level across the 426 observations was 35.61 E. coli per 100 ml. We assume that this average concentration is representative of all freshwater areas where people swim.[12]

At the estimated national average marine swimming water enterococci concentration of 4.55 per 100 ml, the Cabelli/Dufour dose-response equation for marine water yields an estimated rate of 8.208 HCGI cases per 1000 swimmers. In addition, we assume that there will be 1.5 - 2.5 cases of additional illness among swimmers for each HCGI case, for 12.31 - 20.52 cases of other illnesses per 1000 swimmers. This is the number of illnesses that can be expected to occur given current average bacteria concentrations at marine swimming waters.

At the assumed national average freshwater swimming area E. coli concentration of 35.61 per 100 ml, the Cabelli/Dufour dose-response equation for freshwater yields an estimated rate of 2.845 HCGI cases per 1000 swimmers.. In addition, we assume that there will be 1.5 - 2.5 cases of additional illness among swimmers for each HCGI case, for 4.27 - 7.11 cases of other illnesses per 1000 swimmers. This is the number of illnesses that can be expected to occur given current average bacteria concentrations at freshwater swimming areas.

<u>Step C: Estimate the portion of these average pathogen concentrations attributable to SSOs</u>

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health benefits thus does not overlap the set of waters for which benefits were estimated in the previous section (those waters that will improve from non-swimmable to swimmable upon eliminating SSOs).

[12] We also requested a similar search for data on enterococci levels at freshwater beaches. Since we found much less data for enterococci concentrations in freshwater swimming areas than for E. coli, we chose E. coli as our indicator.

In order to determine the number of illnesses that can be attributed to SSOs impacting marine and freshwater swimming areas, we first need to determine the percentage of bacteria loadings that is due to SSOs. We assume that this percentage is the same as the percentage contribution of SSOs to bacteria-related impairment of marine and fresh waters. EPA's 1996 National Water Quality Inventory (EPA, 1998a, Appendix, Table C5) provides data on the leading sources of pollution impairing surveyed estuaries, rivers and lakes.[13] For each pollution source, data is provided on the percentage of all impairments where that source was a major cause of impairment, where the source was a moderate to minor cause of impairment, or where the source was a "not specified" cause of impairment. To determine the SSO contribution to bacteria-related impairments, we added the major cause percentages for each pollution source that frequently involves bacteria loadings (urban runoff/storm sewers, municipal point sources, agriculture, CSOs, onsite wastewater systems and septic systems), and calculated the fraction of those major cause percentages that is attributable to SSOs.[14]

Table 2-13 summarizes our approach to calculating the SSO contribution to bacteria-related impairment. In our calculations, we considered the SSO contributions to both municipal point sources and urban runoff/storm sewers, and applied the percentage contributions calculated in Appendix D. For the lower benefits estimate, we used our lower estimate SSO percentages – 25.89% for municipal discharges and 10.17% for urban runoff/storm sewers. For the upper benefits estimate we applied the upper estimate SSO percentages – 31.33% for municipal discharges and 14.92% for urban runoff/storm sewers (see Appendix D for a discussion on how these percentages were calculated).

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[13] Although EPA also reports impairment in ocean waters, a far smaller percentage of ocean waters were surveyed compared to estuaries. We therefore used estuary impairment percentages as a proxy for impairment at marine beaches.

[14] We adopted this approach because the major cause percentages do not sum to 100%. 305b survey respondents sometimes do not indicate for an impaired water body what the major source of impairment is, and sometimes indicate more than one. We assume that the frequency with which SSO-related sources were listed as major causes, relative to the frequency with which other sources that often involve bacteria loadings was listed, is the best available indicator of the contribution of SSO-related sources to bacteria-related impairment.

INSERT Table 2-13: Calculating the SSO contribution to bacteria-related impairment, IN LOTUS 123

For estuaries, we estimate that SSOs contribute 14.60% to 18.22% of bacteria loadings, both in general and specifically at beaches where people swim. If SSOs were eliminated as a source of bacteria loadings, we thus estimate that average enterococci concentrations will decline by 14.60% to 18.22% at marine beaches.

For rivers and streams, we calculate that SSOs account for 4.97% to 6.30% of all river impairments caused by sources that frequently involve bacteria loadings. Following the same procedure for lakes, reservoirs and ponds, we calculate that SSOs account for 5.98% to 7.91% of all lake impairments caused by sources that frequently involve bacteria loadings.

Freshwater swimming takes place in lakes, reservoirs and ponds as well as in rivers and streams. We assume that two-thirds of freshwater swimming takes place in lakes, reservoirs and ponds, and that the remaining one-third of freshwater swimming takes place in rivers and streams. Based on this assumption, the weighted average of SSO percentage contributions to both river and lake impairments caused by sources that frequently involve bacteria loadings is 5.64% to 7.37%. We therefore conclude that SSOs contribute 5.64% to 7.37% of freshwater bacteria loadings generally, and 5.64% to 7.37% of bacteria loadings at freshwater swimming areas where people swim. If SSOs were eliminated as a source of bacteria loadings, we assume that average enterococci concentrations at freshwater swimming areas will decline by 5.64% to 7.37%.

<u>Step D: Using the chosen dose-response function, calculate the reduction in swimming illnesses associated with the change in water quality upon eliminating SSOs</u>

As noted above, the estimated current concentration of enterococci in marine waters (4.55 enterococci per 100 ml) will result in 8.208 HCGI illnesses per 1000 swimmers. If SSOs were eliminated, reducing enterococci levels by 14.60% to 4.3407 per 100 ml based on the lower estimate, the number of resulting illnesses would fall to 7.374 HCGI cases per 1000 swimmers. Therefore, eliminating SSOs that affect marine beaches would avoid 0.834 HCGI cases per 1000 swimmers as a lower estimate. In the high estimate case, if SSOs were eliminated, reducing enterococci levels by 18.22% to 4.1760 per 100 ml, the number of resulting illnesses would fall to 7.145 HCGI cases per 1000 swimmers. Therefore, eliminating

SSOs that affect marine beaches would avoid 1.063 HCGI cases per 1000 swimmers. Applying the assumption of 1.5 - 2.5 cases of other illnesses in the low estimate case, an additional 1.251 - 2.085 cases of other illnesses per 1000 swimmers would also be avoided. In the high estimate case, an additional 1.595 - 2.658 cases of other illnesses per 1000 swimmers would also be avoided.

The estimated current concentration of E. coli in fresh waters (35.61 E. coli per 100 ml) will result in 2.845 HCGI illnesses per 1000 swimmers. In the low estimate case, if SSOs were eliminated, reducing E. coli levels by 5.64% to 33.60 per 100 ml, the number of associated illnesses would fall to 2.608 HCGI cases per 1000 swimmers. Therefore, eliminating SSOs that affect freshwater swimming areas would avoid 0.237 HCGI cases per 1000 swimmers. Applying the assumption of 1.5 - 2.5 cases of other illnesses, an additional 0.356 - 0.593 cases of other illnesses per 1000 swimmers would also be avoided. In the high estimate case, if SSOs were eliminated, reducing E. coli levels by 7.37% to 32.99 per 100 ml, the number of associated illnesses would fall to 2.532 HCGI cases per 1000 swimmers. Therefore, eliminating SSOs that affect freshwater swimming areas would avoid 0.313 HCGI cases per 1000 swimmers. Applying the assumption of 1.5 - 2.5 cases of other illnesses, an additional 0.470 - 0.783 cases of other illnesses per 1000 swimmers would also be avoided.

Factor 3: The degree to which initial illness among swimmers is followed by secondary transmission of illness to non-swimmers

After becoming ill from swimming, individuals can subsequently pass on their infections to members of the general population who did not swim or go to the beach. These "secondary infections", as they are called, constitute a loss to society resulting from the contaminated water in addition to the primary infections. Schaub (personal communication, 1995) indicates that it is generally accepted for acute infections like those from swimming that the rate of secondary infection might be 20 - 30 %. In studying similar food-borne gastrointestinal illnesses, Archer and Kvenberg (1985) of the U.S. Food and Drug Administration assume that the rate of secondary infection is 33 %. For our calculations, we will assume a range of 20 to 30 % -- the total number of illnesses resulting from swimming is the number occurring among swimmers plus 20 % more (lower estimate) to 30 % more (upper estimate) assumed to occur among the general population resulting from infections transmitted by ill swimmers.

Factor 4: The costs associated with contracting these illnesses

Environomics (1995) estimated a cost per case for HCGI of $375 (lower estimate) to $2000 (mid-range estimate, which we will use as an upper estimate). One important consideration in deriving these estimates concerns sequellae -- more severe, chronic illnesses that may develop from enteric and other acute bacterial or viral infections contracted while swimming (Archer and Kvenberg, 1985). Though these cases occur infrequently, the costs of serious sequellae are so much higher than the costs of the basic symptoms (Mauskopf and French, 1991) that they might contribute the bulk of the average cost per case. The lower estimate assumes no serious sequellae and uses low estimates from the literature. The upper estimate assumes that 95% of swimming-related cases are mild (1-2 days duration of symptoms), 4% are moderate (7 days duration of symptoms) and 1% are severe (involving chronic sequellae and/or small chance of fatality).

The cost estimate for other symptoms or illnesses that may result from swimming (i.e., headache, earache, eye irritation, respiratory problems, sore throat, and severe rash) is developed from estimates provided by Tolley, et al. (1992). Tolley provides values for various symptoms that range from $35 per day of sore throat to $80 per day of severe rash (in 1991 dollars). We use these values to estimate the average cost for a day of non-GI swimming related illness by: 1) Adjusting Tolley's values to reflect a value of a statistical life (VSL) of $5.8 million (central tendency estimate across 26 VSL studies – U.S. EPA, 1997b) rather than $2.0 million, as Tolley had assumed in estimating the values for two of his symptoms; 2) Updating all values to 1995 dollars; and 3) Averaging the adjusted values across the six different symptoms. The result is an estimate that one day of symptoms from a non-GI swimming-related illness costs an average of $99.52 (in 1995 dollars). Upper and lower estimates for the cost per case are then developed by multiplying the cost per day by an assumed duration of the average illness.

- Lower estimate cost per case. We assume an average of 2.5 days of symptoms per case of swimming-related non-GI illness, thus multiplying the average per day value by 2.5 to obtain an average cost per case. The 2.5 day average duration of illness represents a reasonable lower estimate of the typical duration of swimming-related non-GI illnesses, as shown in Table 2-14. This table shows data on the duration of swimming illnesses from the two epidemiological studies that present such information.

- Upper estimate cost per case. We assume an average of 7 days of symptoms per case of swimming -related non-GI illness. The 7-day estimate for average duration of illness represents an upper estimate based on the data in Table 2-14. It can also be considered to reflect the occasional occurrence of more serious sequellae following the typical case of non-GI swimming-related illness.

The resulting lower estimate of the cost per case for non-GI swimming-related illnesses is $248.79 (assuming average duration of 2.5 days) and the upper estimate is $696.61 (assuming average duration of 7 days).

Table 2-14: Duration of illnesses among swimmers (in days)

	Fleisher, Kay et al (1998)		Cheung, et al (1990)	Average across the two studies
	Mean	Median	Average	
GI	4.1	2	2	3.1
Respiratory	5.7	5	3.5	4.6
Ear	8.1	6	1.5	4.8
Eye	4.5	3.5	2.9	3.7
Skin	N.A.	N.A	4.0	4.0
Fever	N.A	N.A	4.2	4.2

Benefit calculations

Using the reduction in the HCGI rate per 1000 swimmers at marine beaches and freshwater swimming areas, the annual number of swimming days in marine and fresh waters, the number of illnesses that occur in addition to HCGI, the number of illnesses contracted through secondary transmission, the cost for HCGI cases and other cases, and an inflation adjustment figure[15], Table 2-15 calculates the total cost of

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[15] The average seasonally-adjusted CPI for all urban consumers over the 12 months of 1995 was 152.5 (1982-84 =100). The seasonally-adjusted CPI in June, 1999, was 166.2

all illnesses that would be avoided annually if SSOs were eliminated. The total estimated number of annual HCGI cases avoided involving freshwater swimming ranges from 189,126 (157,605 direct plus 31,521 secondary) to 270,589 (208,145 to 62,444). The total estimated annual number of other illnesses avoided involving freshwater swimming ranges from 283,690 (236,408 direct plus 47,282 secondary) to 676,472 (520,363 direct plus 156,109 secondary). To provide context for these estimated health benefits, Appendix C provides national statistics on the annual incidence of gastroenteritis and other illness. Our final benefits estimate for avoided freshwater swimmer illnesses is $154.2 million to $1,103.5 million annually. Benefits for avoided marine water swimmer illnesses are accounted for under the improved marine water subcategory of water quality-related benefits.

(http://www.stls.frb.org/fred/data/cpi/cpiaucsl). To convert 1995 dollars to 1999, we multiply by 1.09 (166.2/152.5 = 1.09).

INSERT Table 2-15: Annual value of avoided swimming illnesses, IN LOTUS 123

2.1.4 Other Freshwater Benefits From SSO Abatement

Willingness-to-pay (WTP) values provided by respondents in the Carson and Mitchell study reflect a number of categories of benefits, as discussed in Section 2.1.2. However, Carson and Mitchell did not intend the respondents to take withdrawal benefits or commercial freshwater fishing benefits into account, and designed their contingent valuation scenario accordingly (Carson and Mitchell, 1993). Therefore, these benefits are not captured by the Carson and Mitchell WTP numbers.

The category of freshwater withdrawal benefits includes the use of freshwater as a drinking water supply, as irrigation for agriculture, and in industrial and commercial processes. One potential source of cost savings from SSO abatement is the reduction in drinking water supply costs. Some drinking water treatment plants treat surface waters that are occasionally subject to pathogen loadings from SSOs. If SSOs were abated, drinking water supply systems might be able to use marginally less chemicals in treating the surface water, and/or adopt less expensive source water protection programs. Additionally, large SSOs occasionally cause downstream water supply plants to shut down their intake facilities as a precautionary measure and obtain alternate water supplies (see, for example, the Brushy Creek case study later in this document). Eliminating SSOs would avoid the increased costs of these alternate water supplies. Eliminating SSOs would also reduce possible health risks when SSOs contaminate drinking water (again, see the Brushy Creek case study).

We were unable to quantify benefits for either enhanced commercial freshwater fishing or drinking water treatment cost savings. In general, we expect them to be relatively small.

We also discussed previously our inability to quantify the expected benefits when SSO abatement improves the quality of some fresh waters, but not sufficiently to support a new use.

2.1.5 Summary of Freshwater Water Quality-Related Benefits

The total freshwater quality-related benefits of eliminating all SSOs amount to $ 0.20 - 1.49 billion annually as summarized below.

Table 2-16: Summary of annual freshwater water quality-related benefits

	Lower estimate (millions)	**Upper estimate (millions)**
Carson and Mitchell freshwater benefits (reflects direct use benefits (boating, fishing, swimming), indirect use benefits (waterside hiking, etc.), and non-use benefits (intrinsic benefits) associated with moving waters to higher uses	$ 45.9	$ 387.8
Reduced swimming illnesses (freshwater)	$ 154.2	$ 1,103.5
Enhanced commercial fishing (freshwater)	Not monetized	Not monetized
Withdrawal benefits	Not monetized	Not monetized
Reduced health risks via drinking water	Not monetized	Not monetized
Value of improved water quality that falls short of allowing a new use	Not monetized	Not monetized
TOTAL	**$ 200.1**	**$1,491.3**

2.2 MARINE WATER BENEFITS FROM ELIMINATING ALL SSOS

SSO controls that reduce the number of SSOs impacting marine water would lead to improvements in marine water quality and produce a wide range of benefits. In this section we discuss the following categories of benefits:

1. enhanced marine commercial fisheries (both finfish and shellfish);
2. enhanced marine recreational fisheries;
3. avoided beach closures;
4. reduced illnesses among marine swimmers;
5. increased wildlife viewing along the coast; and
6. intrinsic (non-use) benefits of improvements in marine water quality.

Total marine benefits are summarized at the end of this section.

2.2.1 Benefits to Marine Commercial Fisheries (Finfish)

Basic assumptions

Because pathogens, nutrients, BOD and toxic substances in SSOs can adversely affect the health and productivity of fish populations, a reduction in SSOs can be expected to produce benefits for both marine commercial fisheries (finfish and shellfish) and marine recreational fisheries. Due to SSO-related impairment, some marine waters are listed in the National Water Quality Inventory as not supporting or partially supporting fishing uses. If SSOs are reduced, there will be more marine waters which support fishing, and fish populations will likely be more productive, leading to larger catches for commercial fisheries and greater participation in recreational fishing.

To quantify the value of improvements in marine waters resulting from fewer SSOs, one would ideally estimate the change in marine water quality resulting from fewer SSOs, the impact of this water quality change on fisheries populations, and the resulting impact on catches. However, there is no existing data to draw upon in making such estimates. Determining the particular impact of SSO controls on fisheries nationwide would require extensive modeling efforts. Because any potential models would be highly site-specific, and results would depend on substitute fisheries and other factors such as over-fishing, extrapolating the results to the national level would involve significant uncertainties.

In light of these limitations, we have made some simplifying assumptions in our analysis. We assume that catch will increase in proportion to the increase in fishable marine waters that will result from eliminating SSOs. For example, suppose 10% of marine waters are currently not fishable due to SSOs, while 90% of marine waters are fishable. If SSOs were eliminated, then the amount of fishable marine waters would increase by 10%/90%, or 11%. Assuming that catch rates in these additional waters would be similar to those in other fishable waters, we would estimate that total catch would increase by 11% from existing levels.

Potential increases in the finfish fishery

Table 2-17 shows the steps in estimating the value of an enhanced commercial finfish fishery. The following discussion reviews each of these steps.

In 1998, the near-coastal finfish harvest had a dockside value of $531,528,000 (U.S. Department of Commerce, 1999). We consider only the near-coastal harvest because catches more distant from shore will presumably not be affected by SSOs.

If SSOs were eliminated, we assume that the harvest would increase in proportion to the resulting increase in area supporting finfishing. Since the 1996 National Water Quality Inventory's (305b report)(U.S. EPA, 1998a) survey of estuarine waters was far more extensive than its survey of ocean waters, we use 305b data on estuarine waters.

The 1996 305b report surveyed estuarine waters for support of fish consumption use. The report surveyed 15,821 estuarine square miles out of a total of 39,839 estuarine square miles in the U.S. 365 square miles, or 2.3% of surveyed miles, did not support fish consumption. For a lower estimate, we assume that non-surveyed estuaries are impaired at 50% of the rate at which surveyed estuaries are impaired. Under this approach, 642 square miles out of 39,839 total estuarine square miles, or 1.61%, do not support fish consumption.[16] If all sources of fish consumption use impairment were eliminated (including SSOs and all other sources), the area supporting fish consumption would increase by 1.61%/98.39%, or 1.64%. For an upper estimate, we assume that non-surveyed estuarine waters are impaired at the same rate at which surveyed estuaries are impaired. Under this approach, 919 square miles out of 39,839 total estuarine square miles, or 2.31%, do not support fish consumption. If all sources of fish consumption use impairment were eliminated (including SSOs and all other sources), the area supporting fish consumption would increase by 2.31%/97.69%, or 2.36%. The potential annual increase in the value of the near-coastal finfish fishery therefore ranges from $8.71 million (1.64% of the harvest value) to $12.55 million (2.36% of the harvest value, as shown in Table 2-17).

The total potential economic benefit of increased finfish catch

To calculate the total potential economic benefit associated with the increased catch, we estimate the net increase in producer and consumer surplus associated with the increased catch. If our benefits estimate applied to a single fishery, we could consider the specific conditions (e.g. free vs. restricted entry) and supply and demand functions for that fishery, and attempt to calculate the actual change in price and producer and consumer surplus brought about by an outward shift in the supply curve (EPA, 1990). However, this approach is impractical for a national benefits estimate in which data on a large number of different fisheries would need to be aggregated in one representative data set. Instead, we adopt the rule of thumb developed by Crutchfield et al (1982) and Huppert (1990) to the effect that the sum of producer and consumer surpluses for commercial fisheries ranges from 50% to 90% of the gross value of ex-vessel

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[16] All figures in this discussion have been rounded for convenience of presentation. Calculations based on figures appearing in the text may therefore produce slightly different results, due to rounding.

landings.[17] We apply these percentages to the potential increase in the value of the near-coastal fishery to obtain a maximum potential economic benefit of restoring fish consumption uses to estuarine waters ranging from \$4.35 million to \$11.30 million annually.

Estimated impact of eliminating SSOs on finfish benefits

This maximum potential economic benefit would prevail if water quality in all estuarine waters currently not supporting finfishing were improved to a level that supported finfishing. In order to determine the portion of this maximum economic benefit that would be realized if SSOs were eliminated, we estimate the contribution of SSOs to impairment of estuarine waters.

To estimate the contribution of SSOs to impairment of estuaries, we use procedures identical to those described earlier to estimate the contribution of SSOs to impairment of rivers and lakes. Based on the calculations presented in Appendix D, we attribute to SSOs 25.89% to 31.33% of the impairments reported in the 305(b) reports as due to municipal discharges and 10.17% to 14.92% of the impairments reported as due to urban runoff/storm sewers. The 1996 305b report identifies municipal point sources as a major source of impairment in 25% of impaired estuaries, and as a moderate or minor source of impairment in 18% of impaired estuaries. The report also identifies urban runoff/storm sewers as a major source of impairment in 11% of impaired estuaries, and as a moderate or minor source of impairment in 35% of impaired estuaries. Our lower estimates count only estuarine square miles for which these sources are major sources of impairment, and assume that 50% of these miles will "move up" to the next water quality level if SSOs are abated. Our upper estimates add to the major-source miles 30 % of the estuarine square miles in which these sources are moderate or minor sources of impairment, and assume that 100% of this larger group of waters will "move up" if SSOs are abated.

The benefit calculations are shown in Table 2-17. The annual benefits from eliminating SSOs range from \$0.165 - \$1.44 million (1998 dollars). Updating these values to 1999 dollars, the estimated benefits of

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[17] Both reports were cited in *Regulatory Impact Analysis of the Proposed Great Lakes Water Quality Guidance* (RCG/Hagler Bailly, 1993), pp. 9-13, and *President Clinton's Clean Water Initiative: Analysis of Benefits and Costs* (U.S. EPA, 1994a), p. D-16.

the enhanced marine commercial fishery range from \$0.168 - \$1.47 million annually.[18]

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[18] The average seasonally-adjusted CPI for all urban consumers over the 12 months of 1998 was 163.1 (1982-84 =100). The CPI in June, 1999 was 166.2 (http://www.stls.frb.org/fred/data/cpi/cpiaucsl). We therefore adjust 1998 dollars by 1.9% to account for inflation ((166.2-163.1)/163.1 = 1.9%).

Table 2-23: Annual value of an enhanced commercial fishery – finfish

	Benefits of enhanced fishery		
	Lower Estimate	Upper Estimate	Calculations
I. **Near-coastal finfish catch value**	$531,528,000		(1)
II. **Maximum financial benefit from eliminating all impairments**			
Potential increase in fishing area	1.64%	2.36%	(2)
Potential increase in fishery value	$8.71 million	$12.55 million	(3)=(1)*[(2)/(100%-(2)]
Estimated consumer and producer surplus	50%	90%	(4)
Maximum potential benefit	$4.35 million	$11.30 million	(5) = (3)*(4)
III. **Percent of impairments due to SSOs**			
Municipal point sources, major source %	25%		(6)
Municipal point sources, minor source %	18%		(7)
Munic. impairment % of impaired miles	25% **	30.4%	** (8) = (6)+[30%*(7)]
Urban runoff/storm sewer major source %	11%		(9)
Urban runoff/storm sewer minor source %	35%		(10)
Runoff impairment % of impaired miles	11% **	21.5%	**(11)=(9)+[30%*(10)]
SSO contribution to municipal pt. sources	25.89%	31.33%	(12)
SSO contribution to urban runoff	10.17%	14.92%	(13)
IV. **Potential benefits from eliminating SSO contribution to municipal point sources**	$0.14 million **	$1.08 million ***	** (15)=(5)*(6)*(50%)*(12) *** (15)=(5)*(8)*(12)
V. **Potential benefits from eliminating**	$0.02 million	$0.36 million	** (16)=(5)*(9)*(50%)*(13)

VI. **Total potential benefits from eliminating all SSOs ($1998)**	$0.17 million	$1.44 million	(17) = (15) + (16)

2.2.2 Benefits to Commercial Fisheries (Shellfish)

Basic assumptions

As in the case of commercial finfish fisheries, we assume that catch will increase in proportion to the increase in fishable marine waters attributable to SSO reduction.

Potential increase in shellfish fishery

Table 2-24 shows the steps in estimating the value of an enhanced commercial shellfish fishery. The steps are similar to those in estimating the value of an enhanced finfishery.

In 1998, the near-coastal shellfish harvest had a dockside value of $978,644,000 (U.S. Department of Commerce, 1999). We consider only the near-coastal harvest because catches more distant from shore will presumably not be affected by SSOs.

If SSOs were eliminated, then the harvest would increase in proportion to the resulting increase in area supporting shellfishing. The 1996 305b report surveyed 16,567 estuarine square miles out of a total of 39,839 estuarine square miles in the U.S. 1939 square miles, or 11.7% of the surveyed miles, did not support shellfishing. We make our standard assumptions regarding unsurveyed waters, and calculate that 8.29 - 11.70 % of all estuarine square miles do not support shellfishing. If all sources of shellfishing use impairment were eliminated, the area supporting shellfishing would increase by 9.03 - 13.26 %. The potential increase in the value of the near-coastal finfish fishery therefore ranges from $88.4 million to $129.7 million.

The total potential economic benefit of increased shellfish catch

Applying the 50 - 90 % range for consumer surplus, we estimate that the maximum potential economic benefit of restoring shellfishing uses to estuarine waters ranges from $44.2 million to $116.8 million.

Estimated impact of eliminating SSOs on shellfish benefits

SSOs are responsible for the same fraction of estuarine shellfish impairments are they are responsible for estuarine finfish impairments. The commercial shellfish benefit calculations are shown in Table 2-18. The annual benefits from eliminating SSOs range from $1.68 - $14.86 million (1998 dollars). Updating these values to 1999 dollars, the estimated benefits of the enhanced marine shellfishing range from $1.71 - $15.15 million annually.

Table 2-18: Annual value of an enhanced commercial fishery – shellfish

	Benefits of enhanced fishery		
	Lower Estimate	Upper Estimate	Calculations
I. **Near-coastal shellfish catch value**	$978,644,000		(1)
II. **Maximum financial benefit from eliminating all impairments**			
Potential increase in fishing area	8.29%	11.70%	(2)
Potential increase in fishery value	9.03%	13.26%	(3) = (1)*[(2)/(100%-(2)]
Estimated consumer and producer surplus	50%	90%	(4)
Maximum potential benefit	$44.2 million	$116.8 million	(5) = (3)*(4)
III. **Percent of impairments due to SSOs**			
Municipal point sources, major source %	25%		(6)
Municipal point sources, minor source %	18%		(7)
Munic. impairment % of impaired miles	25% **	30.4%	** (8) = (6)+[30%*(7)]
Urban runoff/storm sewer major source %	11%		(9)
Urban runoff/storm sewer minor source %	35%		(10)
Runoff impairment % of impaired miles	11% **	21.5%	**(11)=(9)+[30%*(10)]
SSO contribution to municipal pt. sources	25.89%	31.33%	(12)
SSO contribution to urban runoff	10.17%	14.92%	(13)
IV. **Potential benefits from eliminating SSO contribution to municipal point sources**	$1.43 million **	$11.12 million ***	** (15)=(5)*(6)*(50%)*(12) *** (15)=(5)*(8)*(12)
V. **Potential benefits from eliminating**	$0.25 million	$3.75 million	** (16)=(5)*(9)*

VI. **Total estimated benefits from eliminating all SSOs ($1998)**	$1.68 million **	$14.86 million ***	(17) = (15) + (16)

2.2.3 Benefits to Marine Recreational Fishing

Basic assumptions

As in the case of commercial finfish and shellfish fisheries, we assume that participation in marine recreational fishing will increase in proportion to the increase in fishable marine waters attributable to SSO reduction.

Potential increase in marine recreational fishing

Table 2-19 shows the steps in estimating the value of increased marine recreational fishing. The following discussion reviews each of these steps.

In 1997, 7 million Americans participated in recreational fishing trips in the Atlantic Ocean and the Gulf of Mexico, while 1.8 million took recreational fishing trips in the Pacific Ocean (U.S. Department of Commerce, 1998). In a 1993 literature review, Freeman concluded that one year's access to a multi-species marine fishery could be valued as much as $122-$1223 per participant (Freeman, 1993).[19] The total value of saltwater recreational fishing for Americans in 1997 therefore ranged between $1.076 billion and $10.76 billion.

If SSOs were eliminated, then the total area supporting recreational fishing would increase. As discussed above, we assume that participation will increase in proportion to the increase in fishable area resulting from SSO elimination. Again, because data on ocean waters is relatively limited, we use data on estuarine waters.

The 1996 305b report (appendix table C-3b) surveyed estuarine waters for support of fish consumption use. As was calculated for marine commercial finfishing, if all sources of fish consumption impairment were eliminated, the area supporting fish consumption would increase 1.64 - 2.36%. Applying

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[19] Freeman provided estimates in 1998 dollars ($120 to $1200). We updated these values to 1999 dollars as described previously.

the lower and upper estimate percentage increases to the lower and upper estimated value of marine recreational fishing yields a potential increase in the value of marine recreational fishing ranging from $17.63 million to $254.1 million annually.

Estimated impact of eliminating SSOs on marine recreational fishing

SSOs are responsible for the same fraction of estuarine recreational fishing impairments are they are responsible for estuarine commercial finfish and shellfish impairments. The recreational fishing benefit calculations are shown in Table 2-19. The estimated benefits of increased marine recreational fishing range from $0.67 - $32.35 million annually. These estimates are understated to the extent that they represent only the benefits of increased participation in marine recreational fishing and do not reflect the potential increase in the value of the fishing experience as a result of improved water quality.

Table 2-19: Annual value of increased marine recreational fishing

	Benefits of increased fishing		
	Lower Estimate	Upper Estimate	Calculations
I. **Number of recreational fishing participants in U.S. (1997)**	8,800,000		(1)
II. **Value per recreational fishing trip**	$122	$1,223	(2)
III. **Total value of all recreational fishing trips in U.S.**	$1,076,064,000	$10,760,640,000	(3)
II. **Maximum financial benefit from eliminating all impairments**			
Potential increase in fishing area	1.64%	2.36%	(4)
Maximum potential increase in value of recreational fishing trips	$17.63 million	$254.1 million	(5) = (3)*[(4)/(100%-(4)]
III. **Percent of impairments due to SSOs**			
Municipal point sources, major source %	25%		(6)
Municipal point sources, minor source %	18%		(7)
Munic. impairment % of impaired miles	25%	30.4% **	** (8) = (6)+[30%*(7)]
Urban runoff/storm sewer major source %	11%		(9)
Urban runoff/storm sewer minor source %	35%		(10)
Runoff impairment % of impaired miles	11%	21.5% **	**(11)=(9)+[30%*(10)]
SSO contribution to municipal pt. sources	25.89%	31.33%	(12)
SSO contribution to urban runoff	10.17%	14.92%	(13)
IV. **Potential benefits from eliminating SSO contribution to municipal point sources**	$0.57 million **	$24.20 million ***	** (15)=(5)*(6)*(50%)*(12) *** (15)=(5)*(8)*(12)
V. **Potential benefits from eliminating SSO contribution to urban runoff/storm sewer sources**	$0.10 million **	$8.15 million ***	** (16)=(5)*(9)*(50%)*(13) *** (16)=(5)*(11)*(13)

VI. **Total potential benefits from eliminating all SSOs ($1999)**	$0.67 million ** $32.35 million ***	(17) = (15) + (16)

2.2.4 Avoided Marine Beach Closures

Sanitary sewer overflows that reach coastal or estuarine waters may lead to beach closures to protect public health. The benefit associated with eliminating SSOs as a cause of beach closures can be estimated based on the value people assign to a day of beach recreation multiplied by the number of beach days lost due to SSO-related closures.

The number of marine beach closures due to SSOs

We analyze data on marine beach closures in 1997, the most recent year for which such closure data have been compiled. We assume that this year is representative.

In 1997, EPA conducted a survey on beach closings and beach water quality monitoring as a part of its Beach Environment and Coastal Health (BEACH) program. EPA provided this data to the Natural Resources Defense Council (NRDC), which supplemented the EPA data with its own survey data from an additional 36 communities in its report (NRDC, 1998). NRDC recorded 4,143 closings in 1997 where at least part of a marine beach was closed for a day (i.e. a beach that is closed for a week is counted as seven closings), 16 extended closures (between 6 and 12 weeks), and 54 permanent closures (longer than 12 weeks). 9 of these closures occurred at Imperial Beach and Coronado City Beach in San Diego County, California. The NRDC report notes that these beaches are polluted by heavy runoff from Mexico's Tijuana River. For the purposes of this analysis, we have decided to exclude these 9 closures, and to focus on the causes of the remaining 4,134 closures.

Information on the 4,134 closings is summarized in Table 2-20. 67 % of all the closings (2,790) are attributed to causes -- "elevated bacteria levels", "rain/preemptive" and "unknown" -- for which specific sources have not been identified. The NRDC report does not specify whether these elevated bacteria levels and two other reasons for closure derived from stormwater runoff, SSOs, CSOs, inadequately treated sewage, or other sources. We regard these closures as having unknown sources.

Among the known sources responsible for the remaining 1344 marine beach closures, NRDC did not include SSOs as a distinct category. Sewage spills, sewage overflows, malfunctioning pump stations, and sewer line breaks were listed as separate categories. Since all of these sources would be addressed by investments in additional collection system storage or treatment capacity, I/I reduction, and/or O&M, we include them in a combined SSO category. It is possible that some of these closures we designate as SSO-related may in fact have been caused by CSOs. Some States listed CSOs explicitly as a cause of beach closures, but other States may have chosen not to identify CSO-related closures explicitly, instead including them in the more general "sewage-related" causes. We believe this is relatively infrequent, and that CSOs are responsible for only a small portion of the "sewage-related" causes. We believe this for two reasons:

- Among States that chose to cite CSOs explicitly as a cause of closure, CSOs were cited very infrequently. They were cited in only 23 instances (less than 1% of all closures reported by NRDC, and less than 2% of all closures with known sources).

- We investigated New York State in more detail as an example of a State that did not cite CSOs explicitly as a cause of closure, but instead chose to cite only more general sewage-related causes. Of the 106 sewage-related beach closures in New York State in 1997, 101 occurred in Westchester County, and of them, 5 were due to CSOs and the remaining 96 were due to SSOs. The remaining 5 closures in the State were also due to SSOs.[20] In New York, then, about 5 % of the sewage-related closures were due to CSOs, and the remainder were due to SSOs.

In order to account for CSO-related closures that could be included in the sewage spill, sewage overflow, malfunctioning pump station, and sewer line break categories, based on the New York example, we decided to attribute 5% of all closures in these categories to CSOs, and the remaining 95% to SSOs.

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[20] Telephone discussion between Laura Palmer, EPA Office of Wastewater Management, and Gabriel Sganga, Associate Public Health Sanitarian, Westchester County Health Department, July 18, 2000.

INSERT Table 2-20: Causes of beach closings in 1997, IN LOTUS 123

SSOs are estimated to account for 638.4 closures, which represents 15% of all closures and 48% of all closures from known sources. The 638.4 beach closures due to SSOs represent a lower estimate of the impact of SSOs because this number does not reflect any of the possible contribution of SSOs to the large number of closures with unspecified sources (i.e., closures resulting from high bacteria levels, rain/preemptive, and unknown causes).

As an upper estimate for the contribution of SSOs to marine beach closures, we add a portion of the closings in the high bacteria, rain/preemptive and unknown categories that might perhaps be attributed to SSOs. We assume that the same pollution source patterns seen in the closures with known sources can be found in the unspecified categories. Thus, we assume that 48% of all closures with unspecified sources (i.e. 48% of 2,790 closings, or 1,339.2 closings) were caused by SSOs, bringing the upper estimate to a total of 1977.6 closings caused by SSOs. Thus SSOs account for 638.4 to 1977.6 of the 4134beach closures in 1977, or 15 to 48 % of all closures.

<u>The value of avoiding the beach closures due to SSOs</u>

The U.S. Department of Interior's (DOI's) NaturalResource Damage Estimate Model for Coastal and Marine Environments (U.S. Department of Interior, 1994) is used to estimate the value of natural resources that are damaged or lost as a result of pollution incidents. The model includes a submodel that estimates the economic losses when beaches are closed. The model assumes that all benefits associated with a beach are lost during the period when the site is closed. The model generates estimates of the economic loss per meter of beach closed per day for each of the coastal regions in the nation. To estimate the value of avoiding SSO-related beach closures, we combine adjusted DOI unit values with estimates we develop regarding the frequency with which SSOs cause beach closures in each region of the country.

In developing the model, DOI reviewed seven recreation valuation studies and estimated that a beach day was worth an average of $11.65 per person in 1991 dollars. Environomics (1995) reviewed the DOI analysis, its supporting studies, and several other larger and more recent compilations of estimated values for a day of beach recreation (Walsh et al., 1990, 1992; Freeman, 1993). Environomics noted several shortcomings in DOI's analysis and recommended adopting a higher value of $30.82/person/day for beach recreation, in 1995 dollars. This figure was derived primarily from the Walsh et al. (1992) review of the 120 recreation valuation studies undertaken between 1968 and 1988. The $30.82 figure has subsequently been used in other EPA regulatory impact analyses (e.g., EPA's 1999 economic analysis supporting the phase II storm water regulations (U.S. EPA, 1999a)). We use this figure in our calculations, and inflate our total estimate to 1999 dollars to obtain our final benefit estimate.

The DOI report provides estimates of the economic loss when a beach is closed in dollars per linear meter of beach closed per day. These estimates incorporate extensive data on the number of people using different beaches, total visitor hours, value per day, and beach length. Specific values per linear meter per day estimates are developed for the Acadian (ME and MA beaches), Virginian (MA, CT, NY, NJ, VA, MD and NC beaches), Carolinian (SC, GA and FL beaches), West Indian (FL and TX beaches), Louisianian (MS, AL, FL, LA and TX beaches), Californian (CA beaches), and Columbian (WA, OR and CA beaches) economic provinces. DOI also develops different estimates for national and for State public beaches. Because State beaches are far more numerous and more heavily visited, we used DOI's State public beach data.

Appendix A presents the set of tables that were used to develop State-specific values for meters of beach that were closed due to SSOs. Tables A-1 through A-6 list the DOI beach values per linear meter per day in 1991 dollars for public beaches in the economic provinces affected by SSO-related closures. For this analysis, we assume that 2/3 of all beach closures take place during the 4 months of the year in which beach visitation is highest. Based on this assumption, we calculated a weighted average for the value of a meter of beach per day. Since this weighted average is based on DOI's original estimate of $11.65 per person-day, we increased this figure by a factor of 2.65 to reflect our $30.82/person/day mean value and arrived at an adjusted average value per meter closed per day in 1995 dollars for each economic province.

In several cases, States affected by SSO-related closures extend across more than one of the DOI economic provinces. Table A-7 shows how the State values per meter closed per day were weighted according to province, and also shows the final adjusted State-by-State values we used in calculating the benefits of avoided closures.

The NRDC closure data does not include figures on the number of meters of beach closed for each closure. To estimate the average number of meters per closure, we used data developed by SAIC for an earlier version of this benefits analysis. This data is shown in Table A-8, which provides data for beach closings in 1994 due to SSOs. Based on the number of days each beach was closed, the State in which the closure occurred, and the value per meter of beach for month(s) in which the closure occurred, we calculate in Table A-9 the average number of meters of beach that were closed per closure in (1,084 meters of beach closed for the average SSO-related closure in 1994). We assume that this 1994 figure is applicable also for the average SSO-related closure in 1997.

Table 2-21 adapts the NRDC data on closures in 1997, and estimates the number of SSO-related beach closures in each State that had them. Lower and upper estimates are provided, with the lower estimate based only on the SSO portion (95%) of closures listed in the NRDC report under the categories of sewer spill, sewer overflow, pump station malfunction, and sewer line break. The upper estimate total is developed by adding 48% of the closures from the unspecified source categories (high bacteria levels, rain/preemptive, unknown) to the lower estimate total, based on the assumption that the patterns seen in the closures with known sources also prevail among the closures with unspecified sources.

Table 2-22 shows the final benefits estimates in 1999 dollars. The benefits of eliminating SSOs as a cause of beach closures are estimated by multiplying the lower and upper estimates of the number of SSO-related closures by the adjusted average value per meter closed per day in 1995 dollars from Table A-7, by the average meters per closure figure (1,084) from Table A-9, and by the adjustment figure for inflation.[21] The estimated annual benefits range from $36.0 million to $137.8 million.

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[21] The average seasonally-adjusted CPI for all urban consumers over the 12 months of 1995 was 152.5 (1982-84 =100). The seasonally-adjusted CPI for June, 1999, is 166.2 (http://www.stls.frb.org/fred/data/cpi/cpiaucsl). We therefore adjust 1995 dollars by 9% to account for inflation ((166.2-152.5)/152.5 = 9%).

INSERT Table 2-21: SSO-related beach closures and causes, by State, 1997, IN LOTUS 123

INSERT Table 2-22: Estimated annual benefits of avoiding SSO-related marine beach closures, IN LOTUS 123

2.2.5 Reduced Illnesses From Swimming in Marine Waters

Section 2.1.3 describes our methodology for estimating the number of illnesses from swimming in fresh waters that would be avoided if SSOs were eliminated, and the associated costs of these avoided illnesses. The same methodology applies to estimating the reduction in illnesses from swimming in marine waters. Since Section 2.1 addresses freshwater water quality-related benefits, Section 2.1.3 only counts the benefit of freshwater swimming illnesses avoided, leaving marine swimming illnesses to this Section.

To estimate the number of swimming illnesses at marine water beaches that would be avoided if SSOs were eliminated, we took the following steps as described in Section 2.1.3. First, we estimated the annual number of person-days spent swimming at marine water swimming areas. Second, we applied the Cabelli/Dufour dose-response function to the current average bacteria concentration at marine beaches (calculated from STORET data) to estimate the rate at which highly credible gastroenteritis illnesses (HCGI) are occurring. We then added 1.5 - 2.5 additional cases of other illness per HCGI case, based on the findings of several epidemiological studies. Third, we estimated the fraction of the current average pathogen concentration at marine beaches that can be attributed to SSOs using EPA's National Water Quality Inventory data. Fourth, we applied the Cabelli/Dufour dose-response function to the average pathogen concentration that would be expected after the elimination of all SSOs. The number of HCGI cases avoided as a result of SSO elimination was then scaled-up to reflect other illnesses that swimmers contract, as well as secondary transmission of illnesses from swimmers to the general population. Finally, the total numbers of HCGI and other illnesses were multiplied by the unit costs for HCGI and other illnesses in order to obtain a lower and upper benefits estimate. The specific calculations are detailed in the tables in Section 2.1.3.

The total estimated number of annual HCGI cases associated with marine swimming that would be avoided if SSOs were eliminated ranges from 535,428 (446,190 direct plus 89,238 secondary) to 739,317 (568,705 direct plus 170,612 secondary). The total annual estimated number of other illnesses avoided ranges from 803,142 (669,285 direct plus 133,857 secondary) to 1,848,292 (1,421,763 direct plus 426,529 secondary). Our final benefits estimate for avoided marine swimmer illnesses is \$436.7 - \$3,015.1 million annually (see Table 2-15).

2.2.6 Reduced Illnesses from Consumption of Shellfish Contaminated by SSOs

Raw or partially cooked shellfish taken from contaminated waters can be a source of concentrated pathogenic bacteria, viruses, and other disease-causing organisms. These pathogens are associated primarily with sewage contamination of marine waters, although some may occur naturally (e.g., *Vibrio* spp.). Food from an unsafe source was cited as a contributing factor in nearly 90 percent of the shellfish foodborne disease outbreaks reported during 1973–1987 (Bean and Griffen, 1990).

The approach for estimating the benefits of reduced illnesses from contaminated shellfish consumption involves three steps:

- Estimate the number of shellfish consumption illnesses that occur;

- Estimate the fraction of these illnesses attributable to SSOs;

- Estimate the cost of these illnesses.[22]

<u>Documented occurrence and under-reporting of shellfish consumption illnesses</u>

Bean et al. (1996) note approximately 679 CDC-reported cases of shellfish-vectored disease from 1988 to 1992 in 34 outbreaks, for an average incidence rate of 136 cases per year. This number reflects only those cases for which the cause of the outbreak could be identified. In order for CDC to count an incident as an occurrence, a physician or physicians must have reported at least two illnesses from the same source of contamination.

Several publications discuss under-reporting factors for food-borne illnesses:

- For the 1988-1992 period, only 48,475 of two million to eight million cases of foodborne illness could

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[22] This section draws extensively on work previously conducted by ERG, Inc. for an earlier version of this benefits analysis.

be traced to an outbreak of a known cause (Bean et al., 1996; see also CDC, 1993b, for a reported 6.5 million cases and 9,000 deaths per year from food-borne illnesses). The reported data concern only "outbreaks" in which two or more individuals fall ill; single cases do not appear in the data set. In other words, the cause of the illness is known in only 0.6 to 2.4 percent of the estimated number of foodborne illnesses. This could mean that the 136 clearly identified cases from outbreaks with a known cause might under-represent the number of illnesses due to shellfish-vectored disease by a factor of 40 to 160.

C Rippey (1994) suggests a possible under-reporting factor of 20.

C Buzby, et al. (1996) cite information that only 1 to 5 percent of *Salmonella* cases are reported. The publication uses under-reporting factors of 20 to 100 when estimating the national costs from food-borne *salmonella*.

C Buzby and Roberts (1996) and Altekruse, et al. (1997) cite under reporting factors of 20 to 50 for *Salmonella*.

For estimating the benefits of avoided shellfish consumption illnesses, this report assumes under-reporting factors of 20 and 50 for the lower and upper benefits estimates, respectively. We apply these factors to the frequency rate of 136 illnesses per year to obtain a lower estimate of 2,716 illnesses annually related to consumption of contaminated shellfish, and an upper estimate of 6,790 illnesses per year.

<u>The fraction of these illnesses attributable to SSOs</u>

We will assume that the fraction of marine beach closings due to SSOs provides a reasonable indication of the fraction of contamination in near-coastal and estuarine waters that is caused by SSOs. On this basis, we estimate that approximately 15 to 48 percent of these cases might be associated with SSOs (407 to 3,259 cases annually).[23]

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[23] See discussion on beach closures due to SSOs in Section 2.2.5.

Cost of these illnesses

The cost of these illnesses depends on the distribution of illness severity. Buzby, et al. (1996), estimated the distribution of illness severity and the corresponding cost of illness for six bacterial pathogens: *Salmonella* spp., *Campylobacter jejuni*, *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Staphylococcus aureus*, and *Clostridium perfringens*. We chose to model the distribution of illness severity for contaminated shellfish based on the distribution for illnesses from *Salmonella* because it is the most frequently cited bacterial pathogen in shellfish-vectored foodborne illness outbreaks (4 of 28 outbreaks, Bean, et al., 1996).

The distribution of illness severity and corresponding costs for salmonellosis presented in Buzby, et al., (1996) are:

Table 2-23: Severity and cost of salmonellosis

Outcome	Likelihood	Cost per Case
No physician visit	93.0 %	$391
Physician visit	5.0 %	$837
Hospitalized and recover	1.9 %	$9,584
Hospitalization and death	0.1 %	$406,423

Buzby's cost figure are in 1995 dollars, and represent a "cost of illness" (COI) approach, measuring the sum of medical expenses, foregone earnings, and productivity losses to employers. These costs likely represent an underestimate of full WTP to avoid these outcomes, as they omit the costs of pain and suffering, anxiety, lost leisure time, averting actions, and more. The difference between a COI estimate and a full WTP estimate is perhaps most evident for the cost of a death. Studies based on a WTP approach place the value of a statistical life from $0.7 to $15.7 million (in 1995 dollars), and a comprehensive review of 26 higher quality studies on the value of life suggests using $5.6 million as a point estimate.[24] This is in contrast to

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[24] Literature review conducted for EPA's Office of Air and Radiation (Unsworth et al., 1992; Neumann and Unsworth, 1993)

Buzby's COI estimate of $406,423.

Benefits estimate

Table 2-24 summarizes the calculations and findings in estimating the benefits of eliminating SSO-related illnesses from contaminated shellfish. The calculations combine the CDC-reported annual incidence of shellfish-vectored illnesses, an under-reporting factor, the percentage of these illnesses attributable to SSOs, and unit cost figures for the various severity outcomes that may result. For the upper estimate we combine a relatively high under-reporting factor of 50, an attribution of 48 % of all cases to SSOs, and costs of illnesses based on Buzby's estimates with the exception of an assumed value of life of $5.6 million. For the lower estimate, we assume an under-reporting factor of 20, attribute 15 % of all cases to SSOs, and consider only the value of the lives that would be saved (and not the other health effects that would be avoided) if SSO-related contamination of shellfish were eliminated. We also present another possible estimate, using only the CDC-reported cases and assuming no under-reporting. Updated to1999 dollars, the estimated benefits of avoiding illnesses due to ingesting shellfish contaminated by SSOs ranges from $2.49 - $21.98 million annually.[25]

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[25] The average seasonally-adjusted CPI for all urban consumers over the 12 months of 1995 was 152.5 (1982-84 =100). The seasonally-adjusted CPI in June, 1999 is 166.2 (http://www.stls.frb.org/fred/data/cpi/cpiaucsl). We therefore adjusted 1995 dollars by 9% to account for inflation ((166.2-152.5)/152.5 = 9%).

INSERT Table 2-24: Annual benefits of avoided illnesses from contaminated shellfish, IN LOTUS 123

2.2.7 Increased Wildlife Viewing Along the Coast

To estimate the benefits of increased wildlife viewing along the coast, we estimate the increase in the number of wildlife viewing days that would occur if SSOs were eliminated, and the value of a wildlife viewing day. Table 2-25 summarizes the steps in developing this estimate.

Wildlife viewing days

Our methodology for estimating the benefit of increased wildlife viewing along the coast follows the approach in EPA's analysis supporting the Clean Water Initiative (U.S. EPA, 1994a). In 1996, 6,353,000 people engaged in oceanside wildlife viewing, and 10,420,000 people engaged in wildlife viewing in wetlands, marshes, and swamps.[26] We adopt the U.S. EPA (1994a) assumption that 50% of the wildlife viewing in wetlands, marshes and swamps took place in marine wetlands, marshes and swamps. The total number of coastal wildlife viewing participants is therefore 11,563,000 per year. According to the 1996 National Survey of Fishing, Hunting, and Wildlife-Related Recreation, participants spent an average of 13 days per year viewing wildlife (U.S. Department of Commerce/U.S. Department of Interior, 1997).[27] We use EPA's lower (5) and upper (10) bound estimates for the number of days of wildlife-viewing per year per participant. This gives us a lower estimate total of 57,815,000 coastal wildlife-viewing days per year and an upper estimate total of 115,630,000 coastal wildlife-viewing days per year.

Increase in number of wildlife viewing days that would occur if SSOs were eliminated

If SSOs were eliminated, then aquatic life use impairment of ocean waters and saltwater wetlands would decrease, thereby increasing the total area supporting wildlife viewing. We assume that participation will increase in proportion to the increase in area supporting aquatic life that would result from SSO elimination.

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[26] U.S. DOC/U.S. DOI 1997, Table 38, p. 89.

[27] Ibid, p. 87.

Given the figures from the 305(b) data base on impairment of aquatic life uses in estuaries, we estimate that the increase in the available area for wildlife viewing near oceans and saltwater wetlands resulting from the elimination of all sources of aquatic life use impairment in estuarine waters would range from 3.83% to 5.87%. The portion of aquatic life use impairment attributable to SSOs is calculated in Table 2-25. After several additional steps, we calculate that eliminating SSOs would increase by 0.15% to 0.71% the area supporting aquatic life (step 10). Following our assumption that wildlife-viewing participation would increase in proportion to the increase in area supporting aquatic life that results from SSO controls, the number of wildlife-viewing days near oceans and saltwater wetlands would increase by 84,003 to 820,299 days annually (step 11).

Value of increased wildlife-viewing days

EPA estimated that the value of a day of wildlife observation ranges from $10 to $20, in 1994 dollars. Updating these figures to 1999 dollars, we obtain a range of $11 to $22.[28] Multiplying these figures by the increase in wildlife-viewing days resulting from SSO controls, we obtain a benefits estimate ranging from $0.92 million to $18.05 million annually.

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[28] The average seasonally-adjusted CPI for all urban consumers over the 12 months of 1994 was 148.3 (1982-84 =100). The seasonally-adjusted CPI in June 1999 is 166.2 (http://www.stls.frb.org/fred/data/cpi/cpiaucsl). We therefore adjust 1994 dollars by 12% to account for inflation ((166.2-148.3)/148.2 = 12%).

Table 2-25: Annual value of increase in number of wildlife-viewing days near oceans and wetlands resulting from implementation of SSO controls

	Lower est.	Upper est.	Calculations
I. Number of wildlife-viewing days (baseline)	57,815,000	115,630,000	(1)
II. Increase in area supporting aquatic life if all sources of impairment were eliminated	3.83%	5.57%	(2)
III. Municipal point source contribution to all estuarine impairment	25%	30.4%	(3)
IV. SSO contribution to municipal point source impairment	25.89%	31.33%	(4)
V. SSO contribution to all estuarine impairment (via municipal point sources)	3.24% *	9.52% **	* (5) = (3)*(50%)*(4) ** (5)=(3)*(4)
VI. Urban runoff/storm sewer contribution to all estuarine impairment	11%	21.5%	(6)
VII. SSO contribution to urban runoff/storm sewer impairment	10.17%	14.92%	(7)
VIII. SSO contribution to all estuarine impairment (via urban runoff)	0.56% *	3.21% **	* (8) = (6)*(50%)*(7) ** (8) = (6) * (7)
IX. Total SSO contribution to all estuarine impairment	3.80%	12.73%	(9) = (5) + (8)
X. Increase in area supporting wildlife-viewing resulting from implementation of SSO controls	0.15%	0.71%	(10) = (2) * (9)
XI. Increase in number of wildlife-viewing days resulting from implementation of SSO controls	84,003	820,299	(11) = (1) * (10)
XII. Value per day of wildlife observation	$ 11	$ 22	(12)
XIII. Annual value of increase in wildlife-viewing days	$924,029	$18,046,570	(13)=(11)*(12)

2.2.8 Intrinsic (Non-Use) Benefits of Improvements in Marine Water Quality

Individuals may assign value to improvements in the quality of a natural resource even if they do not currently use the resource, or have a desire or intention to use the resource in the future.[29] To estimate these "intrinsic" benefits, we use a rule of thumb developed by Fisher and Raucher (1984) and applied in other benefit analyses for EPA.[30] According to this rule of thumb, non-use benefits are estimated as being at least one-half as great as recreational use values.

In this benefits analysis, we have monetized values for recreational uses associated with improved freshwater quality (i.e., freshwater swimming, fishing and boating), and improved estuarine and marine water quality (i.e., saltwater beach use, marine recreational fishing, and wildlife viewing along the coast). The recreational use value associated with improved freshwater quality is based on a contingent value survey in which respondents were presented with a values card listing the major reasons why households might value water quality. These reasons included two non-use values -- getting satisfaction from knowing that other people use fresh water resources, and getting satisfaction from knowing that the nation's fresh water is cleaner. As a result, it is likely that the values that respondents placed on improvements in freshwater quality included non-use values. In order to avoid double-counting of these non-use values, we therefore do not consider improved freshwater quality recreational use values in our calculation of intrinsic benefits.

Our estimated monetized benefit for avoided beach closures represents the recreational use value associated with increased saltwater beach use resulting from marine water quality improvements. Since the values we use for an individual's day at the beach are based on responses from people who use the beach, we assume that non-use values are not included in these beach-day values. Our benefits estimate for avoided beach closures ranges from $ 36.0 - $137.8 million annually. Our estimated monetized benefit for recreational fishing ranges from $ 0.7 - $ 32.4 million annually. Our estimated monetized benefit for wildlife viewing along the coast ranges from $0.92 - $18.05 million annually. Our total recreational use benefit, excluding freshwater recreational use benefits, therefore ranges from $ 37.6 - $ 188.2 million annually. We use the Fisher and

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[29] See U.S. EPA, 1994a, p. 56.

[30] See, for example, RCG/Hagler Bailly, 1993, p. 8-24; U.S. EPA, 1985, p. 9-4.

Raucher rule of thumb that intrinsic (non-use) values equal 50% of monetized recreational use values (in this case, saltwater recreational use values). Our estimate of intrinsic benefits therefore ranges from $ 18.8 - $ 94.1 million annually.

2.2.9 Other, Non-Monetized, Benefits of Improvements in Marine Water Quality

There are other benefits associated with marine water quality improvement to which we were unable to assign a monetary value.

If SSOs were eliminated, the aesthetic quality of marine water and oceanfront land would be enhanced. It is likely that people who live near coastal areas and enjoy them on a regular basis (beachcombers, joggers, bicyclists, photographers, and people who simply enjoy waterfront views) would value such enhancements. Given that 53 percent of all Americans now live in coastal areas (NOAA, 1998), the total value that would be assigned to marine aesthetic enhancements could be substantial. Moreover, the millions of people who visit beaches and coastal areas on a less-regular basis -- on weekends and during vacations, for example -- would also probably assign some value to an improvement in the aesthetic quality of marine water and coastal areas. Finally, property values in scenic coastal areas that are currently impacted by SSOs would probably increase if SSOs were eliminated. In light of the importance of coastal tourism, as well as the proportion of the U.S. population living near or visiting the coast, it is reasonable to expect that monetized benefits for this category would be significant.[31]

In the absence of any study which attempts to estimate the value of improvements in the aesthetic quality of marine waters and coastal areas, it was not possible to monetize these benefits. While the Carson and Mitchell study captures some of the value people assign to aesthetic improvements in fresh waters, there appears to be no comparable study for marine waters.

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[31] The benefits of enhancing the aesthetic quality of marine water and oceanfront land are separate and distinct from the benefits of avoiding SSO-related beach closures, which are estimated in this report. People assign a value to going to the beach, and it can be expected that they would assign a separate value to enhancing the aesthetic quality of marine water and oceanfront land in beach and non-beach coastal areas.

Marine water quality improvements could also enhance recreational shellfishing by presenting increased opportunities for shellfishing and higher yields of shellfish per trip. We could not quantify these benefits, which are probably not very large.[32] In addition, marine water quality improvements would enhance the general health of marine ecosystems. Elimination of SSOs would reduce pollutant loadings affecting not only shellfish and finfish, which are valued by people engaged in commercial and recreational fishing, but also the entire ecosystems on which all marine fauna and flora depends. Available data regarding the specific impacts of SSOs on marine ecosystems is not sufficient to monetize these benefits.

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[32] See U.S. EPA, 1997, p. 4-53.

2.2.10 Summary of Marine Water Quality-Related Benefits

Total annual monetized marine water quality-related benefits amount to $ 710.1 million - $ 4.67 billion as summarized in Table 2-26 below.

Table 2-26: Annual marine water quality-related benefits

	Lower estimate (million $/yr)	**Upper estimate (million $/yr)**
Commercial fishing benefits - finfishing	$0.2	$1.5
Commercial fishing benefits - shellfishing	$1.7	$15.1
Recreational fishing benefits	$0.7	$32.4
Avoided beach closures	$36.0	$137.8
Increased wildlife viewing along the coast	$0.9	$18.0
Increased intrinsic benefits	$18.8	$94.1
Reduced swimming illness (marine)	$436.7	$3,015.1
Reduced illness from shellfish consumption	$2.5	$22.0
Improved aesthetic quality	Not monetized	Not monetized
Enhanced recreational shellfishing	Not monetized	Not monetized
TOTAL	**$497.5**	**$3,336.0**

SECTION 3 NON-WATER-QUALITY BENEFITS OF SSO ABATEMENT

3.1 REDUCTION IN BASEMENT BACKUPS

Every time a sewer backs up into a basement, the homeowner or the community incurs costs.[33] For the purpose of estimating benefits, who pays the bill is not relevant. A literature search revealed numerous cases in which sewers backed up into basements, but no data were found on the number of affected homes. Table 3-1 summarizes the frequency of SSOs for selected communities. It is not always clear from the report on a particular community, however, whether SSOs are being described in terms of a location -- which can have several overflow events per year -- or as an individual event. Thus the frequency of occurrences in Table 3-1 may be understated if the count of SSOs represents locations and not individual SSO events.

Data collection included telephone contact with several agencies. Responses indicated that the information -- when available -- is very sensitive because of the question of liability for cleanup costs. In some cases, a commission has chosen to pay for property damage but the payments are not tantamount to an admission of liability (Hannan, 1997).

The information sources listed in Table 3-1 all identified basement backups and/or property damage as a main concern. Assuming that at least one basement was flooded in each event listed, the eight communities represent roughly 1,700 to 2,100 basement backups per year.

Table 3-2 lists sources of information that specifically address basement backups in selected communities. Backups per storm for the areas listed ranged from 8 (Midland, PA) to nearly 300

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[33] This section draws extensively on work previously conducted by ERG, Inc. for an earlier version of this benefits analysis.

INSERT TABLE G-1 FROM THE ERG REPORT -- THIS SHOULD BE RELABELED AS

Table 3-1: Number of reported SSOs in selected communities)

INSERT TABLE G-2 FROM THE ERG REPORT -- THIS SHOULD BE RELABELED AS

Table 3-2: Number of reported SSOs resulting in basement backups in selected communities and service areas)

INSERT SECOND PAGE OF TABLE 3-2

(Deerfield, IL).[34] Based on this, the estimated number of backup events derived from Table 3-1 could be two orders of magnitude too low. The count of basement backups for the Washington Suburban Sanitary Commission is notable because only 5 percent of them are attributable to wet weather events.

Gilbert (1986) estimates that approximately 400,000 sewer backups occur in basements nationwide each year. We adopt this estimate as the starting point in estimating the benefits associated with avoided cleanup costs. The Needs Report cost model examines approximately 15,000 sanitary sewer collection systems. To reach the estimated 400,000 basement backups, the average number of backups per system need only be 27 per year. The information in Tables 3-1 and 3-2 indicate that this is at the low end of reported occurrences.

Basement cleanup costs range from $700 to $10,000 per case. This range is based on (1) information in 54 articles from major U.S. newspapers and relevant conference proceedings and (2) from cleanup service providers on the average size of a U.S. basement (Table 3-3). EPA estimates a range for cleanup costs at $700 to $1,500 per basement backup. This range was used to estimate benefits.

Eliminating basement backups would save between $280 million and $600 million per year in cleanup costs. However, some of these basement backups are attributable to combined sewer overflows, and not SSOs. While it is reasonable that 400,000 SSO-related basement backups occur nationwide on an annual basis, it is not clear whether Gilbert (1986) includes CSO-related backups as well. Golden (1996) estimates the relative length of separate sanitary and combined sewer systems. Sanitary sewers are approximately 81 percent of the total pipe miles. Scaling our benefit estimate accordingly, we estimate that avoiding SSO-related basement overflows would save between $227 million and $486 million per year in 1995 dollars. Updated to June, 1999 dollars, our estimate ranges from $247.2 million to $529.7 million.[35]

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[34] The more than 900 basements flooded with sewage during the October 20–21, 1996, storm in the Boston area storm is an example of an extreme event and not included in the upper end of the range.

[35] The average seasonally-adjusted CPI for all urban consumers over the 12 months of 1995 was 152.5 (1982-84 =100). The seasonally-adjusted CPI in June 1999 is 166.2 (http://www.stls.frb.org/fred/data/cpi/cpiaucsl). We therefore adjust 1995 dollars by 9% to account for inflation ((166.2-152.5)/152.5 = 9%).

INSERT TABLE G-3 FROM THE ERG REPORT -- THIS SHOULD BE RELABELED AS
Table 3-3: Typical basement cleanup costs)

3.2 AVOIDED SSO RESPONSE COSTS

When SSOs occur, wastewater utilities may undertake various sorts of response tasks. Wastewater utility staff (one or several, depending on the size of the spill) are often dispatched to the SSO site, where they use a vactor truck and spread lime to flush out and clean up the spill. Spills in manholes may be pumped out into the stormwater sewer system to avoid backups. Damaged property may be repaired. In some cases, staff may perform water quality monitoring at the site, and send samples to a laboratory for testing. Occasionally warnings will be posted at a spill site. After the initial response, the utility may be required to report the spill to the NPDES authority. Some utilities may also spend time to investigate and analyze the specific causes of the SSO.

Some of the categories of costs incurred in responding to an SSO include staff hourly salary and benefits costs; vehicle and equipment use costs; materials costs; lab fees; pump maintenance costs; and contractor costs, for cases when response tasks are contracted out. SSO response costs vary according to the size of the spill, the location of the spill, the extent to which reporting is required, the extent to which the utility investigates the cause of the spill, and other factors.

In our review of existing literature, we were unable to find any data on average SSO response costs. To get a range for SSO response costs, we conducted telephone interviews with five wastewater utilities (Kane, 1998; Hannan, 1998; Yoloye, 1998; Williams, 1999; Singleterry, 1999). The approximate average response cost per SSO, as estimated by specialists at the five utilities, ranged from $287 to $6000 per SSO.[36] In Table 3-4 below, we summarize the categories of costs and tasks that are reflected in each of the estimates. As can be seen, each estimate reflects a different combination of cost factors. It is possible that each estimate is lower than actual costs because information on all relevant costs was not available for any of the estimates.

Although the methodology in estimating SSO response cost was clearly not consistent across the five utilities, and although the estimates are based on limited data and best professional judgment, we assume that the reported response costs are representative of average SSO response costs for all utilities. One of the

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[36] The specialists made best-guess estimates using professional judgment and whatever data was available.

estimates, however, is likely atypical. EBMUD's figure includes $4,500 in salary costs for an "incident review team", which investigates the causes of the SSO. According to Jimi Yoloye of EBMUD, the utility has chosen, and is able, to dedicate these resources to SSO investigation in large part because SSOs are relatively rare in the utility's East San Francisco Bay service area. Based on our conversations with utilities, we believe that such circumstances are unusual. In order to maintain a conservative upper estimate, we exclude EBMUD's $6000 SSO response cost. Our estimate of the average cost to respond to an SSO therefore ranges from $287 to $3000.

Table 3-4: Cost factors reflected in SSO response cost estimates

City	SSO response cost estimate	salary	benefits	vehicle	equipment	materials	lab	pump maintenance	contractor	cleanup	pumping	monitoring	posting	reporting	investigation
San Diego	$287	**T**				**T**	**T**			**T**		**T**	**T**	**T**	
WSSC	$761	**T**	**T**						**T**	**T**		**T**			
EBMUD	$6000	**T**					**T**					**T**		**T**	**T**
Louisville	$3000	**T**			**T**			**T**		**T**	**T**				
Portland	$600	**T**	**T**		**T**	**T**				**T**			**T**		

To calculate the savings in SSO response costs if SSOs were eliminated, we multiply EPA's estimate of the number of SSOs that occur each year (37,840) by the average cost per response ($287 - $3000). Total SSO response cost savings range from $ 10,860,080 to $ 113,520,000 annually.

3.3 OTHER NON-WATER-QUALITY BENEFITS OF SSO ABATEMENT

There are at least three additional categories of non-water quality-related benefits to be considered. First, SSOs cause property damage in people's homes, the cost of which is not completely reflected in our estimate for basement backup cleanup costs. Second, SSOs are unsightly, cause offensive odors, and can leave unpleasant traces in basements and on streets and land. Third, SSOs can contaminate drinking water supplies and cause illnesses.

Property damage from basement backups

When basement backups occur, carpets, furniture and other property is often damaged. Information on the cost of basement backup-related property damage is difficult to obtain. In our estimate of basement backup cleanup costs, we used EPA's unit cleanup cost estimate of $700 to $1,500 per case, which is less than reported estimates ranging from $700 to $10,000 per case. It is highly likely that this cleanup cost estimate does not completely reflect the total cost of cleanups and of indoor furnishings, decorations, structural elements and other items that are damaged or destroyed. Insurance company data on the frequency and amount of claims under sewer backup policies could potentially provide a more accurate figure, at least for tangible property losses. Unfortunately, insurance companies charge high fees to provide such data, and we have not been able to obtain it. We therefore used EPA's cleanup cost estimate, which likely understates total benefits from reduced backups. In addition, costs associated with other types of SSO-related property damages are not included in these estimates. For example, these estimates do not include costs associated with damage to low-lying lawns and landscaping, costs associated with loss of use of flooded basements, aesthetic damages, health risks, reductions in property value, etc.. No data on these costs could be identified.

Aesthetic impacts of SSOs

When they do not flow directly into a water body, SSOs affect the aesthetic quality of the land areas over which they flow. Sites where raw sewage overflows from collection systems include busy streets, residential areas, and green spaces that people normally see and use. Sewer overflows occurring in these areas are unsightly, cause offensive odors, and typically provoke feelings of disgust. Although crews are often sent out to clean up spills that take place on land and streets, people's sensibilities are offended during the overflow, and sometimes after the overflow as well, if traces from the overflow are left behind in the form of toilet paper, etc. We believe it is very likely that people place a value on avoiding the aesthetic impacts of SSOs that occur on land and streets,[37] and that this benefit is not insignificant. However, we are unaware of any study that attempts to quantify this value.

Illnesses from SSO-contaminated drinking water

The toll associated with waterborne disease outbreaks -- in lost work days, medical costs, and even lives -- can be large. Section 5 of this report presents a case study of a sewage spill in Brushy Creek, Texas. The Brushy Creek overflow contaminated drinking water supplies, and resulted in approximately 1,400 people becoming sick. The estimated cost of lost work days associated with the spill ranged from $224,000 to $480,000. In Cabool, Missouri, SSOs were linked with a pathogenic strain of E. coli which "killed 4 people, hospitalized 32 and caused diarrhea and other problems in 243 people (U.S. EPA, 1996a)." In Ocoee, Florida, periodic sewage overflows flooded a mobile home park from November 1988 to April 1989, resulting in 39 cases of hepatitis A among residents, and an additional 100 cases in Fort Lauderdale spread by four infected food handlers living in the park. Diarrhea and other symptoms continued for 2 years (U.S. EPA, 1996a). Given the local health and economic impacts of these SSO-related outbreaks, the monetized benefits of avoiding illnesses from SSO-contaminated drinking water could be significant.

Currently, there is insufficient data to quantify the benefits of avoiding illnesses caused by SSO-contaminated drinking water. It is difficult to pinpoint the actual number of disease outbreaks caused by SSOs. In a 1996 report on waterborne disease outbreaks, the Centers for Disease Control (CDC) noted that "not all water-borne disease outbreaks may be recognized, investigated, and/or reported to the CDC or the EPA (CDC, 1996)." In addition, when such outbreaks are investigated, it can be difficult to isolate the source of contamination. For example, a significant amount of effort was dedicated by the City of Austin and other

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[37] The Carson and Mitchell willingness-to-pay figure used to calculate the benefit of enhanced freshwater quality included people's valuation of the aesthetic benefits of cleaner freshwater bodies. It did not, however, include the value of avoiding the aesthetic impacts of SSOs occurring on land and in streets.

Texas governmental agencies to identifying the source and pathway of contamination in Brushy Creek. Establishing the causal link between SSOs and illnesses can require extensive efforts, which are likely to be undertaken only in dramatic instances when the connection appears clear, and when many people become ill. As a result, the actual number of waterborne outbreaks that are due to SSOs is not known.

3.4 SUMMARY OF NON-WATER QUALITY-RELATED BENEFITS

The non-water quality-related benefits of eliminating SSOs amount to $ 256.1 - $ 638.4 million annually as summarized in Table 3-5 below.

Table 3-5: Annual non-water quality-related benefits

	Lower estimate (millions)	**Upper estimate (millions)**
Reduced basement backups	$ 247.2	$ 529.7
Reduced SSO response costs	$ 10.9	$ 113.5
Reduced property damage	Not monetized	Not monetized
Avoided aesthetic impact	Not monetized	Not monetized
Avoided illnesses from contaminated drinking water	Not monetized	Not monetized
TOTAL	**$ 258.1**	**$ 643.2**

SECTION 4 SYSTEM BENEFITS FROM SSO ABATEMENT MEASURES

4.1 OVERVIEW OF SYSTEM BENEFITS

The Needs Report estimates for each of the country's publicly owned separate sanitary sewer collection systems the least-cost combination of additional storage capacity, wet weather treatment capacity, and infiltration/inflow (I/I) reduction that would achieve a particular systemwide wet weather SSO control target (e.g., 1 wet weather overflow event per year). In addition these investments to reduce wet weather SSOs and basement backups, investments in enhanced O&M are also needed, to reduce dry weather SSOs as well as additional wet weather overflows. These investments in enhanced O&M not only reduce overflows, but they also provide benefits to the utility making these investments in the form of avoided costs. We categorize this type of savings under the heading of system benefits. A discussion of the system benefits of investments in enhanced operations and maintenance follows.

4.2 ENHANCED OPERATIONS AND MAINTENANCE (O&M)

Several recent collection systems benchmarking studies (Arbour and Kerri, 1997; WERF, 1997; ASCE, 1998; Faria and Larson, 1996) provide information on the average amount collection systems spend on long-term system rehabilitation, repair and replacement per mile of sewer per year; on emergency repairs per mile of sewer per year; and on spot repairs per mile of sewer per year. Based on this information, and our lower and upper estimate assumptions on the impact of enhanced O&M on these categories of expenditures, we estimate the system benefits of enhanced O&M.

Relationship between enhanced O&M and cost savings

A considerable amount of qualitative information suggests that enhanced O&M reduces these categories of expenditure.[38] Enhanced O&M slows the deterioration of the collection system over time, reduces the number of trouble spots in the system, and extends the life of the system. As a result, the portion

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[38] See Arbour and Kerri, 1997, p. 80; ASCE, 1998, p. 7-9; U.S. EPA, 1991.

of the system requiring scheduled rehabilitation, repair or replacement each year under a long-term Capital Improvement Program (CIP) can be expected to decrease as enhanced O&M is implemented. The number of spot repairs, or rehabilitation jobs performed as part of preventive maintenance can also be expected to decline as O&M targets trouble spots in the system and addresses them before deterioration occurs and rehabilitation is needed. In addition, the number of costly emergency repairs associated with pipe failures can also be expected to decline as enhanced O&M identifies areas in danger of failure and addresses them through less-expensive rehabilitation or repair.

Data showing that maintenance expenditures have increased by 14% between 1989 and 1996, despite the absence of new requirements, suggests that collection system managers are aware of the cost savings that an effective O&M program can provide. However, clear statistical relationships between O&M activities and overall spending on long-term CIP rehabilitation, repair and replacement, spot repairs or emergency repairs have not yet been established. Three factors may account for this.

First, every collection system is unique. The age and type of system, the effectiveness of maintenance programs over time, the accessibility of sewers at repair sites, the degree to which these sites are in heavily-trafficked areas, the amount of debris in the pipe during backups, and other factors vary widely from system to system, making direct comparison between any two systems' performance and expenditures nearly impossible (Arbour and Kerri, 1997, p. 63). In a system where insufficient historical O&M and other factors contribute to a proliferation of problems and high expenses, a utility may spend heavily on O&M and still see many problems cropping up because existing conditions and deterioration cannot immediately be overcome by enhanced O&M. A clear relationship between enhanced O&M and rehabilitation and repair expenditures may become clear only after the consistent application of enhanced O&M over several years, if not longer.

Second, existing O&M programs also vary considerably from system to system. Some existing O&M programs are more effective and better-targeted than others because they incorporate predictive management and other strategies of enhanced O&M. Other programs may use predictive management, but are hobbled by insufficient funding. Because of budget shortfalls, the entire sewer system may be cleaned less frequently than would be optimal. Finally, other systems may suffer from both a failure to effectively target resources and limited funding. In light of inconsistencies among O&M programs, and the variation in system-specific factors discussed above, a clear relationship between generic O&M spending and reduced rehabilitation and repair expenditures is unlikely to be seen.

Third, the effort to quantify the relationship between O&M spending and spending on system rehabilitation and repair needs is a fairly recent development. Several more years of data may be needed to demonstrate that, over time, enhanced O&M does in fact reduce other system expenditures.

Despite the current absence of proven statistical relationships between enhanced O&M and reduced rehabilitation and repair expenditures, it is clear that savings can be achieved through the application of a well-targeted enhanced O&M program, particularly in cities where less effective techniques have been used and/or where O&M has been underfunded. The SSO Needs Report estimates current national spending on collection system maintenance activities at $1.6 billion per year (U.S. EPA, 2000b). The report also estimates that an additional $1.5 billion in annual O&M spending is required in order for all systems to meet existing regulatory requirements regarding SSOs. This additional spending would represent an increase of nearly 100 % over current O&M expenditures. Based on the relationship between increased O&M spending and cost savings on various repairs to and investments in the collection system, it can be expected that this SSO-related near doubling of spending will yield significant benefits.

Our methodology for estimating the system benefits from this additional O&M spending is to assume a lower and upper estimate for the fraction of expenditures on spot repairs, emergency repair, and long-term rehabilitation, repair and replacement that will be saved as a result of enhanced O&M. We estimate that, on average over the long run, enhanced O&M spending of the magnitude projected in the Needs Report (nearly 100 % increase) will ultimately save:

- 25-50% of annual expenditures on spot repairs;

- 5-25% of annual expenditures on long-term rehabilitation, repair and replacement; and

- 25-50% of annual expenditures on emergency repairs.

Spot repair savings

Table 4-1 shows the number of spot repairs completed per year per mile of sewer in 13 different collection systems (adapted from Arbour and Kerri, 1997). The average number of spot repairs completed per mile per year was 0.22. The average cost of a spot repair ranged from $2,295 (Faria and Larson, 1996) to $3,035 (Arbour and Kerri, 1997). If we use these cost estimates as our lower and upper estimate, and multiply them by the number of spot repairs saved per mile per year as a result of O&M (25-50% of the current 0.22 spot repairs per mile per year) and the number of miles of municipally owned sanitary sewer pipe (500,000), we arrive at an estimate of $63.1 million to $166.9 million in annual savings on spot repairs attributable to the enhanced O&M necessary to meet current SSO requirements.

Table 4-1: Spot repairs
(adapted from Arbour and Kerri, 1997)

Agency	Population Served	Length of Gravity Sewer (miles)	Spot Repairs Completed per Year	Spot Repairs Completed per Mile of Sewer per Year
A	10,444	44.5	10	.22
B	40,000	114	8	.07
C	75,560	400	105	.26
D	88,250	348	87	.25
E	150,000	500	107	.21
F	177,000	630	180	.28
G	284,000	1481	200	.14
H	347,000	1537	150	.10
I	456,445	1385	18	.01
J	475,000	2664	5	.002
K	700,000	2289	400	.18
L	737,877	2946	66	.02
M	950,000	2543	2698	1.06
AVERAGE				**.22**

Capital Improvement Program (CIP) savings

Table 4-2 shows the annual level of CIP expenditures on long-term repair, replacement and rehabilitation for 11 different collection systems. The average expenditure in this category is $3,643 per mile of sewer per year. If we eliminate the two systems with the highest expenditure levels per mile per year, the average expenditure declines to $1,944 per mile per year. Using these two figures as lower and upper estimates and multiplying by the number of miles of municipally owned sanitary sewer pipe (500,000) and the estimated cost savings per mile per year due to enhanced O&M (5-25%), we arrive at an estimate of $48.6 million to $455.4 million in annual savings on long-term repair, replacement and rehabilitation.

Table 4-2: CIP expense
(adapted from Arbour and Kerri, 1997)

Agency	**Population Served**	**Length of Gravity Sewer (miles)**	**Annual CIP Expense for Repair, Replacement, or Rehabilitation**	**CIP Expense per Mile of Sewer per Year**
A	10,444	44.5	up to $250,000	$5618
B	40,000	114	$100,000	$877
C	75,560	400	$200,000	$500
D	88,250	348	0	
E	150,000	500	$4,877,703	$9,755
F	177,000	630	$330,400	$524
G	284,000	1481	$1,800,000	$1,215
H	347,000	1537	$6,000,000	$3,904
I	456,445	1385	N/A	
J	475,000	2664	$5,000,000	$1,877
K	700,000	2289	$1,000,000	$437
L	737,877	2946	$7,500,000 (not pump stations)	$2,546
M	950,000	2543	$32,609,198	$12,823
AVERAGE				**$3,643**
AVERAGE without 2 highest values				**$1,944**

Emergency repair savings

To estimate the savings in emergency repair expenditures that will result from enhanced O&M, we used data from several recent benchmarking surveys. Collection systems reported an average of 0.05 pipe failures per mile of sewer per year (ASCE, 1998). The average crew size for repairs is 3.2 (WERF, 1997). The percentage of work orders completed in one day was 62%, and in two days was 22%. We assumed that emergency repair crews typically worked 4 hours on one-day repairs, 12 hours on two-day repairs, and 30 hours on the 16% of repairs completed in more than two days. The average wage rate of a collections worker was $31,825 (WERF, 1997). Taking benefits into account, we assume that the average hourly wage rate of an emergency repair worker was approximately $20 per hour.

Using these inputs, we arrived at a weighted labor cost per emergency repair of $635. To estimate a total cost per emergency repair, we assumed that labor accounted for one-half of the total cost, bringing the average total cost per emergency repair to $1,270. Multiplying the cost per repair by the number of pipe failures per mile per year (.05) and by the total miles of publicly owned sanitary sewer pipe (500,000) yields an estimate for the total cost of emergency repairs for all municipal collection systems in the country. Based on our lower and upper estimate impacts of enhanced O&M on emergency repairs (25% and 50%, respectively), we estimate that enhanced O&M would save $7.9 million to $15.9 million in annual emergency repair expenditures.

4.2.1 Estimated Savings Due to Enhanced O&M

Summing the savings estimates for spot repairs, capital improvement programs, and emergency repairs, our estimate of total system benefits resulting from enhanced O&M ranges from $119.7 million to $638.2 million annually. Most of these savings occur in CIP programs ($48.6 - $455.4 million/yr) and in spot repairs ($63.1 - $166.9 million/yr), while the savings in emergency repairs are smaller ($7.9 - $15.9 million/yr). Note that these quantified benefits sum to substantially less than the projected $1.5 billion/year in enhanced O&M spending. This is not meant to imply that benefits of this increased O&M spending are not commensurate with its costs. The benefits of enhanced O&M are very difficult to quantify.

4.3 SUMMARY OF SYSTEM BENEFITS

Total estimated system benefits amount to $ 119.7 - $ 638.2 million/year as summarized in Table 4-3.

Table 4-3: System benefits

	Lower estimate (million $/yr)	**Upper estimate (million $/yr)**
From enhanced O&M	$ 119.7	$ 638.2
TOTAL	**$ 119.7**	**$ 638.2**

SECTION 5 BENEFIT CASE STUDY FOR SSO ABATEMENT MEASURES

5.1 OVERVIEW OF CASE STUDY

In this section, we take a closer look at the particular damages associated with a specific sanitary sewer overflow that took place in the community of Brushy Creek, Texas.[39] Our case study is intended to complement and provide some context for our national SSO abatement benefit estimates by examining a real-world example of some of the actual costs associated with an overflow. As is illustrated by the case study, the benefits of avoiding SSOs – particularly health benefits – can be significant at the local level, and may be very significant when considered nationally.[40]

5.2 BRUSHY CREEK, TEXAS

Brushy Creek is a community of about 10,000 residents located near Austin, Texas. It lies outside the jurisdiction of any city, and forms a select residential community with a few schools and churches. The Brushy Creek MUD is essentially the only local government entity in that area. The MUD provides drinking water and sewage collection and treatment services for the Brushy Creek community. A portion of the community's wastewater is treated at Brushy Creek MUD's wastewater treatment plant, and the remainder is treated at a plant in the city of Round Rock. The Brushy Creek community is named after Brushy Creek itself, a perennial stream that flows 9 or 10 months out of the year and eventually joins the Brazos River, which empties into the Gulf of Mexico.

On July 13, 1998, a freak lightning strike during a thunderstorm knocked out the electricity and emergency telephone back-up system at the Onion Branch Lift Station, which adjoins the creek. The lift

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[39] The two principal sources of information for this case study are a Texas Department of Health report on the Brushy Creek outbreak (Texas Department of Health, 1999) and a telephone conversation with Mike Ergman of the City of Austin Water/Wastewater Utility (Ergman, 1999). When other sources are used, they are cited individually.

[40] Data could not be identified relating to the nationwide incidence of SSO-related illnesses other than those contracted from swimming. Consequently, we were not able to estimate the benefits of many of the illnesses that would likely be avoided upon elimination of SSOs.

station is owned by the City of Austin. Under an agreement between Austin and the Brushy Creek MUD, the lift station pumps a portion of Brushy Creek's sewage to the city of Round Rock for treatment. As a result of the power outage, sewage backed up in the lift station and overflowed at a manhole located near Brushy Creek. On July 14, a Brushy Creek MUD staff member discovered and reported the overflow (Texas Natural Resource Conservation Commission (TNRCC), 1998). The lift station was out of service for 12 hours and flow records indicated approximately 167,000 gallons of raw sewage spilled into Brushy Creek.

The location of the spill was particularly unfortunate. 5 public wells operated by Brushy Creek MUD are located approximately 1/4 mile downstream from the Onion Branch Lift Station and about 1/4 mile from the edge of the creek.

Brushy Creek MUD operating personnel collected bacteriological samples from the drinking water distribution system on July 16, which were reported negative (TNRCC, 1998). On July 17, the Texas Natural Resource Conservation Commission (TNRCC) Public Water Section staff became aware of the spill and asked MUD staff to collect samples from Brushy Creek's public wells for testing. On July 21, MUD personnel reported to TNRCC that 4 of the 5 MUD wells tested positive for *E. coli*. TNRCC ordered the five wells taken off line and instructed the MUD to buy their drinking water from the neighboring city of Round Rock. By this point, Brushy Creek residents may have been exposed to contaminated drinking water for 7 days.

On July 24, the Williamson County and Cities Health District (WCCHD) notified TNRCC that citizens of Brushy Creek were calling complaining of gastroenteritis. The Texas Department of Health (TDH) gave WCCHD specimen containers for distribution to Brushy Creek residents.

From July 28-30, the TDH conducted a phone survey of randomly sampled households as part of a case control study. The survey investigated whether or not respondents had experienced gastroenteritis since July 4, what their symptoms were, onset data, duration of illness, and exposures relevant to cryptosporidiosis. Exposures evaluated included drinking unfiltered tap water, bottled water, filtered tap water, exposure to diapered children, exposure to pets and livestock, travel history, swimming or other recreational exposures, and the consumption of raw or fresh produce. Analysis of the survey results found that the only exposure that was significantly associated with illness was drinking water from the contaminated wells.

Among the 10,000 residents of Brushy Creek, approximately 6,000 people were exposed to drinking water from contaminated Brushy Creek MUD wells between July 14-21, 1998. The remainder of Brushy Creek's population was receiving drinking water from the city of Round Rock's public wells. TDH estimates that 1,440 Brushy Creek residents became ill with gastroenteritis during the outbreak. In addition, TDH received laboratory reports confirming cryptosporidiosis in 89 Brushy Creek residents, and 45 additional cases were reported in the region between September-December 31, 1998. It is unclear whether these additional cases were linked to the Brushy Creek spill. The symptoms of cryptosporidiosis include diarrhea, abdominal cramps, headaches, nausea, vomiting, and low-grade fever. For people in good health, the average recovery period is 10 to 14 days. For immuno-compromised people, the disease can last for months and in some cases may be fatal (Lindell, 1998).

On July 31, two of the four contaminated wells were reported positive in a Microscopic Particulate Analysis. This result dictated that the wells were to be designated as "Groundwater Under the Influence" (GUI) of surface water, and that treatment would need to be installed prior to returning the wells to service. Later, it was reported that the other two wells were also GUI. The wells that were contaminated were more than 1/4 mile distant from Brushy Creek, and were more than 100 feet deep and encased in cement. These types of wells traditionally have been assumed to be immune from the influence of surface waters. However, the spill occurred under very unusual circumstances. Central Texas was under extreme drought conditions in July 1998, with near record temperatures and nearly no rainfall for months. TNRCC believes that because of the drought conditions, the springs that normally feed Brushy Creek acted instead to draw the spilled sewage down into the karst limestone aquifer and through a geologic fissure underground into the wells. If the water table had not been drawn down so low due to high water demand and weeks without rainfall to recharge the aquifer, the outbreak might not have occurred, even in the event of a large scale sewage spill.

Costs associated with the spill

Residents of Brushy Creek incurred significant costs in the wake of the Brushy Creek spill. A large number became sick and missed work days. Some people needed to go to a hospital to have their symptoms treated. The MUD incurred monitoring and testing costs, and other governmental agencies, such as the City of Austin and the Texas Department of Health, had to devote resources to responding to the event and providing people with information. Some of these costs have been quantified, and appear in the discussion below. We have also included non-quantified costs.

Lost work days: 1440 people became sick directly as a result of the spill. Illnesses generally lasted 3 to 5 days (according to David Bergmire-Sweat, the TDH epidemiologist in charge of the survey). Approximately 2/3 of the 1440 affected residents were adults who probably missed work days as a result of their illness. Using data on mean income in the two affected counties, Mr. Bergmire-Sweat made a rough estimate of the cost of lost work days ranging from $223,920 to $479,562 (Bergmire-Sweat, 1998).

Medical expenses: Between 100 and 200 residents reported that they went to see a physician. Approximately 13 people went to a hospital emergency room for treatment. At least two people (including a 2-year-old) were hospitalized for one day or more (Bergmire-Sweat, 1998).

Alternate Water Supply: A Brushy Creek MUD official estimated the cost of buying drinking water from Round Rock at approximately $1,500 per day (Davenport, 1998a). In a telephone conversation, another official estimated that the public wells were closed for about a month (Arguijo, 1998), which would bring total alternate water supply costs to about $45,000.

Hydrological Testing Contractor Costs: The City of Austin contracted CH2M Hill to perform a hydrological and water quality investigation focusing on the interactions between Brushy Creek and the underlying aquifer. The cost of the study and report was approximately $40,000 (Arguijo, 1998).

Public Outreach and Legal Costs: A significant amount of time has been spent by City of Austin staff, and staff of other organizations involved in spill response to provide information to the public and to the media, and to respond to the lawsuit. The City of Austin does not appear to be willing to provide information on exactly how much time has been spent on these activities.

Public Well Sampling, Testing and Disinfecting Costs: A number of tests were performed on the

MUD wells after the spill. Crews were sent to clean and disinfect the 4 wells over a period of several days, and subsequently to test the wells. Again, information on the number of tests; the cost of the tests; the amount of staff time spent on testing, cleaning and disinfecting; and any other associated costs appears not to be available.

Ecological Costs: A fish kill resulted from the spill. The Texas Parks and Wildlife Department reported that 2,523 fish were killed with a total value of $2,245 (Texas Parks and Wildlife Department, 1998).

Swimming Pool Disinfection Costs: Brushy Creek community swimming pools were closed and disinfected on a rotating basis.

Conclusion

The Brushy Creek spill was perhaps not a typical SSO. The spill occurred under unusual circumstances that were particularly conducive to the contamination of local drinking water wells. As a result, 1440 people became sick, and approximately 2/3 of them missed work as a result. It would be incorrect to assume that illnesses occur from every overflow. However, SSOs do frequently enter surface or ground waters that provide drinking water. It is reasonable to assume that a non-negligible number of illnesses are contracted each year as a result of SSO contamination of drinking water supplies, and that the medical costs associated with SSOs nationwide are potentially significant. These costs were not reflected in any of the benefit categories in this report.[41] Although we were unable to estimate the benefit of avoiding these costs, the importance of this benefit category should not be overlooked.

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[41] The monetized health benefits in this report pertain to swimmers at freshwater and marine beaches, and not to people who are exposed to pathogens through drinking water.

SECTION 6 CONCLUSIONS AND SUMMARY

A summary of the benefits of abating SSOs and improving the performance of sanitary sewer collection systems (SSCSs) is presented in Table 6-1.[42] Total quantified benefits for the three categories of benefits -- water quality-related benefits, non-water quality-related benefits, and system benefits -- are estimated as $ 1.1 billion to $ 6.1 billion per year. Water quality-related benefits account for 65 % (lower estimate) to 79 % (upper estimate) of total quantified benefits. Three subcategories of water quality-related benefits -- fresh water direct use, indirect use, and non-use benefits ("Carson and Mitchell benefits"); reduced fresh water swimming illnesses; and reduced marine water swimming illnesses -- account for 91 % to 93 % of all water quality-related benefits, and 60 % to 73 % of quantified benefits in all categories.

6.1 UNCERTAINTIES ASSOCIATED WITH THE BENEFITS ANALYSIS

To address uncertainties, this analysis develops lower and upper estimates for many of the inputs used in calculating estimated benefits. Table 6-2 lists the inputs by benefit category, provides the lower and upper estimate for that input, and explains the basis for using these lower and upper estimates.

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[42] An identical table is presented in the Executive Summary of this report.

Table 6-1: Summary of monetized benefits from eliminating SSOs (in 1999 $/yr)

	Lower Estimate (millions)	**Upper Estimate (millions)**
Water Quality-Related Benefits		
Improved Freshwater Quality		
Direct Use Benefits - Boating, Fishing, Swimming, etc.		
Indirect Use Benefits - Waterside Hiking, Picnicking, etc.		
Non-Use (Intrinsic) Benefits		
Total of Direct Use, Indirect Use, and Non-Use Benefits[43]	$45.9	$387.8
Reduced Swimming Illnesses (Fresh Water)	$154.2	$1,103.5
Enhanced Commercial Fishing	NM[44]	NM
Withdrawal Benefits	NM	NM
Reduced Health Risks (via Surface Drinking Water)	NM	NM
Improved Water Quality (Short of New Uses)	NM	NM
Improved Marine Water Quality:		
Commercial Fishing Benefits - Finfishing	$0.2	$1.5
Commercial Fishing Benefits - Shellfishing	$1.7	$15.1
Recreational Fishing Benefits	$0.7	$32.4
Avoided Beach Closures	$36.0	$137.8
Increased Wildlife Viewing Along Coast	$0.9	$18.0
Increased Intrinsic Benefits	$18.8	$94.1
Reduced Swimming Illnesses (Marine Water)	$436.7	$3015.1
Reduced Illnesses from Shellfish Consumption	$2.5	$22.0
Improved Aesthetic Quality	NM	NM
Enhanced Recreational Shellfishing	NM	NM
Non-Water Quality-Related Benefits		
Reduced Basement Backups	$247.2	$529.7
Reduced SSO Response Costs	$10.9	$113.5
Reduced Property Damage	NM	NM
Avoided Aesthetic Impacts	NM	NM
Avoided Illnesses from Contaminated Drinking Water	NM	NM
System Benefits		
From Enhanced O&M	$119.7	$638.2
TOTAL	$1,075.2	$6,108.8

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[43] Each of these subcategories of benefits is reflected in the total benefit figure, which was estimated using the results of a contingent valuation survey. Because the survey did not ask respondents to indicate their willingness to pay for each type of benefit separately, we cannot disaggregate the total.

[44] NM= Benefit could not be monetized.

Table 6-2: Ranges adopted in benefits analysis to address uncertainties

Issue	Basis for Lower Estimate	Basis for Upper Estimate
General/cross-cutting assumptions		
Percentage of municipal discharge impairment that would be avoided if SSOs were eliminated	25.89%, estimated in Appendix D	31.33%, estimated in Appendix D
Percentage of urban runoff/storm sewer impairment that would be avoided if SSOs were eliminated	10.17%, estimated in Appendix D	14.92%, estimated in Appendix D
Amount of waters (rivers, lakes, estuaries) impaired by municipal point sources and by urban runoff/storm sewers	50 % of amount impaired where these sources are cited as major sources of impairment. Source: 305(b)	100 % of major impairments + 30 % of moderate/minor impairments. Source: 305(b).
Degree to which non-surveyed waters (rivers, lakes, estuaries) are impaired	50 % of the rate at which surveyed waters are impaired	100 % of the rate at which surveyed waters are impaired
Carson & Mitchell freshwater benefits		
Which measure should be used for "fishable" – aquatic life support or fish consumption?	Whichever gives the lower benefits estimate.	Whichever gives the higher benefits estimate.
Fresh and salt water swimming health benefits		
Number of cases of other swimming-related illnesses in addition to HCGI	1.5 cases of other illness (respiratory, ear, skin, eye) per case of HCGI	2.5 cases of other illness (respiratory, ear, skin, eye) per case of HCGI
Rate of secondary illness transmission	20 %. Ill swimmers infect 20 % more people	30 %. Ill swimmers infect 30 % more people
Cost per case for HCGI	$375. Based on average cost of illness for mild case only	$2000. Includes range of severities and sequellae. Based on average cost for each of: mild cases (95 % of all), moderate (4 % of all), severe (1 % of all, with sequellae and/or chance of fatality)
Cost per case for other illnesses	$249. Based on 2 ½ days of symptoms as costed by Tolley (1992) and updated	$697. Based on 7 days of symptoms as costed by Tolley and updated. Intended to reflect some chance of sequellae

Marine commercial finfishing and shellfishing		
Fraction of value of catch that is producer + consumer surplus	50 %	90 %
Marine recreational fishing		
Value of marine fishing per participant per year	$122 (Freeman, 1993, low estimate)	$1223 (Freeman, 1993, high estimate)
Avoided marine beach closures		
Fraction of closures due to SSOs	15 %. Counts only those closures that are specifically cited as being due to SSO-related causes. (15 % of all closures, but 48 % of all closures with known causes)	48 %. Counts closures that are specifically cited as being due to SSO-related causes, plus a 48 % share of closures with unknown causes
Reduced illnesses from shellfish consumption		
Percentage of shellfish illnesses due to SSOs – Assume it is the same as the % of beach closures due to SSOs	15 %. Lower estimate, see above.	48 %. Upper estimate, see above.
Under-reporting factor for these illnesses	20. Twenty times as many cases occur as are reported.	50. Fifty times as many cases occur as are reported.
Cost per case for these illnesses	$6,110. Accounts only for risk of death and VSL	$6,745. Weighted average across all outcomes
Increased wildlife viewing along the coast		
Average number of days/yr of marine wildlife viewing per participant	5. Lower estimate from U.S. EPA (1994)	10. Upper estimate from U.S. EPA (1994)
Value per day of marine wildlife viewing	$11. Lower estimate from U.S. EPA (1994), updated	$22. Upper estimate from U.S. EPA (1994), updated
Avoided basement backups		
Cleanup costs per backup	$700. Low end of EPA estimate	$1,500. High end of EPA estimate
Reduced SSO response costs		
Average response/cleanup cost per SSO	$287. Low end from survey of five communities	$3000. 2nd highest figure from five communities
Systems benefits		
Eventual savings in CIP costs from near doubling of O&M spending	5 % of annual CIP expenditures	25 % of annual CIP expenditures
Eventual savings in emergency and spot repair costs from near doubling of O&M spending	25 % of annual emergency and spot repair spending	50 % of annual emergency and spot repair spending

6.2 LIMITATIONS OF THE BENEFITS ANALYSIS AND ASSOCIATED EFFECTS OF LIMITATIONS ON FINAL BENEFITS ESTIMATES

Table 6-3 summarizes the key limitations of the benefits estimates provided in this report, and indicates the likely direction of the impact on total estimated benefits. Perhaps the most important limitation of this analysis is the inability to monetize several subcategories of benefits, which probably results in an underestimate of total benefits. It is expected that future analyses, supported by methodologies and data that were not available for this report, will assign significant monetized benefits to these subcategories. In particular, it is expected that five benefits subcategories could potentially contribute considerably to the total monetized benefits estimated in this report – the value of freshwater quality improvements that fall short of allowing for new uses; avoided illnesses from contaminated drinking water; avoided aesthetic impacts on marine beaches and coastal recreation areas; avoided aesthetic impacts on the land over which SSOs flow; and reduced property damages in associated with basement backups.

A different limitation of this report could result in an overestimate of total benefits. All estimated monetized benefits, apart from system benefits, represent the benefits that would result from the elimination of all SSOs. However, as discussed in the introduction to this report, there are several factors which preclude a collection system from being completely free from overflows. The Needs Report estimates financial needs for reducing collection system infrastructure deficiencies to very low levels in accordance with existing control objectives of minimizing SSOs. To the extent that all SSOs are not abated by the control measures in the Needs Report, the benefits presented in this Benefits Report would be proportionally less.

In summary, some of the limitations and assumptions in this report are expected to result in an underestimation of benefits, while others are expected to result in an overestimation of benefits. The net effect of all of the limitations and assumptions is unknown.

Table 6-3: Summary of impacts of major technical assumptions and limitations

Factor	Likely Direction of Impact on Benefits Estimate	Comments
Water Quality-Related Benefits		
Some categories of benefits could not be monetized: 1) Enhanced commercial freshwater fishing; 2) Enhanced quality of freshwater for withdrawal uses; 3) Value of freshwater quality improvements that fall short of allowing new uses; 4) Improved aesthetic quality of marine beaches and recreation areas; and 5) Enhanced marine recreational shellfishing.	-	It is expected that the values assigned to water quality improvements short of those needed to support new uses, and those for aesthetic improvements at marine beaches and coastal areas could be significant. Other non-monetized water quality-related benefits are expected to be smaller.
All monetized water quality-related benefits represent the benefits that would result from the elimination of <u>all</u> SSOs. However, there are several factors that preclude a collection system from being completely free from overflows.	+ To the extent that all SSOs are not abated by the control measures in the Needs Report, the benefits presented in this Benefits Report would be proportionally less.	The overestimation effect of this factor may be tempered by the following consideration: reducing SSOs by nearly 100% will probably be almost as effective in "moving up" water bodies to higher use support levels as reducing SSOs by 100%.
The method used to estimate a value for improved freshwater quality treats the nation as an undifferentiated whole. In contrast, a spatially disaggregated approach would recognize that SSO abatement focuses on waters in urbanized areas, where the majority of the population lives, where water quality is more often degraded, and where water quality improvements would be more highly valued.	- Total estimated WTP would be much higher if the analysis were disaggregated	A draft analysis that recognizes the concentration of people, WTP for cleaner water and SSOs in urban areas estimated benefits 6 to 17 times higher than those estimated using the current non-disaggregated approach.

Factor	Likely Direction of Impact on Benefits Estimate	Comments
The calculations in Appendix D that project the fraction of municipal discharge and urban runoff/storm sewer impairment that is due to SSOs are strongly influenced by assumptions about the volume of SSOs that occur. A wide range was adopted for these assumptions.	+ or -	Substantial case example data exists on SSO volume that could be used to refine the assumptions. However, this data is extremely difficult to interpret. Further work may be possible to narrow the range of estimates here.
The Appendix D calculations also depend strongly on how the various key pollutants in SSOs (pathogens, BOD, nutrients, TSS) are weighted in terms of their relative importance. We assumed equal importance for each pollutant.	+ or - SSOs contribute heavily to pathogens in municipal discharge and urban runoff/storm sewers, and less so to other pollutants. The importance of SSOs depends on the importance of pathogens relative to the other pollutants in MD and UR/SS.	Data can be acquired that will allow refinement of assumption to weight the pollutants equally.
Analysis assumes that waters that are not assessed for fishing, but which are surveyed for other uses, will show the same degree of impairment for fishing as do waters that are assessed for fishing use. A similar assumption is adopted for waters that are not assessed for swimming, but which are surveyed for other uses. A range rather than a uniform assumption could have been used.	+ or -	No information is available regarding the extent to which waters that are not assessed for fishing, but are assessed for other uses, are impaired for fishing (and likewise for swimming). If waters that are not assessed for fishing, but are assessed for other uses, actually show no impairment for fishing, the "Carson & Mitchell" benefits in this analysis would be overstated roughly by a factor of 2. This possibility is expected to be very slight, as discussed in Section 2.1.2 of this report.

Factor	**Likely Direction of Impact on Benefits Estimate**	**Comments**
The approach using the Carson & Mitchell WTP values allows monetization only for freshwater quality improvements for the waters that “move up”. No values are estimated for waters that either: a) Improve but do not move up; or b) Already support boating and fishing uses and improve to support these uses even better.	-	The underestimate resulting from the lack of information required to monetize these benefits may be substantial
Two dose-response functions (Dufour for freshwater, Cabelli for marine water) were used to estimate benefits of avoided swimming illnesses. Other dose-response functions were not used to derive a range of avoided illnesses.	+ or -	The number of illnesses per 1000 swimmers is estimated using several different dose-response functions in Appendix B of this report. Some functions predict a higher rate of illness than those selected for estimating benefits, while others predict a lower rate of illness. The Dufour and Cabelli functions were selected because the statistical relationships between enterococci and gastrointestinal illness in marine water, and E coli and gastrointestinal illness in freshwater, are particularly robust and provide the basis for the current national water quality criteria for recreational waters.
It is assumed that swimmers will contract 1.5 - 2.5 cases of other illnesses for each HCGI case	+ or -	Cabelli/Dufour did not find a statistically significant relationship with illnesses other than HCGI, suggesting perhaps that this assumption could lead to a substantial overestimate. However, most other studies have found such relationships, and often the ratio between other illnesses and HCGI is in excess of the range assumed here.

Factor	**Likely Direction of Impact on Benefits Estimate**	**Comments**
Non-Water Quality-Related Benefits		
This analysis uses 400,000 as the number of basement backups that occur annually (based on Gilbert, 1986).	%	ASCE's 1998 benchmarking study of 42 sanitary sewer collection systems found that an average of 0.11 backups occur per mile of sewer per year. If this average is multiplied by the total number of sewer miles (500,000), we obtain a total of 55,000 backups per year. It is unclear whether or not this estimate counts all backups associated with a particular storm event as one backup. If this is not the case, this analysis may overestimate benefits by using 400,000 as the number of backups.
This analysis uses EPA's range of $700 to $1,500 per backup to estimate the costs of cleaning up basement backups.	- Basement backups impose substantial additional costs besides clean-up costs, such as costs associated with property damage and loss of use of furnishings or basements. People are also likely to assign some value to avoiding the irritation associated with experiencing a basement backup. In addition, the per-backup cost range in this analysis may be too low regardless of whether non-cleanup costs are considered. ERG found that basement cleanup costs range from $700 to $10,000 per case, based on information: (1) in 54 articles from major U.S. newspapers and relevant conference proceedings; and (2) from cleanup service providers on the average size of a U.S. basement.	It is expected that using the $700 to $1,500 per-backup range results in a moderate underestimation of benefits.

Factor	**Likely Direction of Impact on Benefits Estimate**	**Comments**
All monetized non-water quality-related benefits represent the benefits that would result from the elimination of <u>all</u> SSOs. However, there are several factors which preclude a collection system from being completely free from overflows.	+ To the extent that all SSOs are not abated by the control measures in the Needs Report, the benefits presented in this benefits report would be proportionally less.	This factor could result in a moderate overestimation of benefits.
Overall impact on benefits estimates	+ or -	There is not sufficient information on the combined overall impact of limitations and assumptions to assess the direction of potential bias in the analysis of benefits.

'-' = causes benefits to be understated
'+ or -' = unclear impact on benefits
'+' = causes benefits to be overstated

APPENDIX A BENEFITS OF AVOIDED MARINE BEACH CLOSURES: SUPPORTING TABLES AND CALCULATIONS

INSERT Table A-1: Californian province values

INSERT Table A-2: Carolinian province values

INSERT Table A-3: West Indian province values

INSERT Table A-4: Louisianan province values

INSERT Table A-5: Acadian province values

INSERT Table A-6: Virginian province values

INSERT Table A-7: Beach unit values ($/meter/day) by State

INSERT Table A-8: 1994 beach closings due to SSOs

INSERT Table A-9: Average number of meters per closure

APPENDIX B ESTIMATED NUMBERS OF ILLNESSES AVOIDED USING SEVERAL DIFFERENT DOSE-RESPONSE FUNCTIONS

In this report, we estimate the reduction in swimming-related illnesses associated with SSO elimination based on the Cabelli dose-response function for enterococcus in marine water (Cabelli, 1983) and the Dufour dose-response function for E. coli in fresh water (Dufour, 1994). As discussed in section 2.1.3, many epidemiological studies on the health effects of exposure to recreational waters have been conducted, and several of these include dose-response functions that can potentially be used to estimate the number of illnesses that will be avoided with elimination of SSOs. To provide a context for the numbers of avoided illnesses estimated using the Cabelli/Dufour functions, this appendix presents the results obtained when other dose-response functions are used to analyze our water quality data.

As a preface to the discussion on alternative dose-response functions that follows, it should be noted that the Cabelli and Dufour dose-response functions have been selected for use in this benefits analysis because they constitute the basis for EPA's bacteriological ambient water quality criteria for marine and fresh recreational waters.[45] EPA's Office of Research and Development (ORD) recently reviewed the epidemiological literature to assess the continuing validity of Cabelli's and Dufour's findings, and came to the following conclusion:

> The epidemiological studies conducted since 1984, which examined the relationships between water quality and swimming-associated health effects, have not established any new or unique principles that might significantly affect the current guidance EPA recommends for maintaining the microbiological safety of marine and freshwater bathing beaches. Many of the studies have, in fact, confirmed and validated the findings of the U.S. EPA studies. There would appear to be no good reason for modifying the Agency's current guidance for recreational waters at this time.[46]

In light of this conclusion, as well as the statistical significance of Cabelli's and Dufour's estimated dose-response relationships, we believe that the Cabelli and Dufour dose-response functions offer the most reliable

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[45] EPA, *Ambient Water Quality Criteria for Bacteria – 1986*, Office of Water, Regulations and Standards, Criteria and Standards Division, EPA440/5-84-002, January 1986 [U.S. EPA, 1986b].

[46] EPA, *Draft Implementation Guidance for "Ambient Water Quality Criteria for Bacteria – 1986*," Office of Water, EPA-823,D-00-001, January 2000.

method available for estimating the number of avoided swimming illnesses.

To provide perspective on the results obtained using the Cabelli and Dufour functions, this appendix compares them with the results obtained using alternative dose-response functions. As shown in Table B-1 below, the number of avoided illnesses estimated in this Benefits Report using Cabelli/Dufour is well within the range of results that would be obtained using other studies in the literature. Calculations based on some of the other epidemiological studies predict that eliminating SSOs would yield a much higher number of avoided illnesses per 1000 swimmers than the estimates based on Cabelli and Dufour.

Methodology

The number of swimming-related illnesses that would be avoided as a result of eliminating SSOs was estimated for 5 different dose-response functions for freshwater swimmers (in addition to Dufour's) and 6 different functions for marine water swimmers (in addition to Cabelli's).

The initial step in calculating the numbers of avoided illnesses per thousand swimmers predicted by each dose-response function is to determine bacterial indicator concentrations at swimming beaches now, and to estimate the concentrations that would prevail if the SSO contribution to pathogens at beaches was eliminated. We follow the procedure that is described in more detail in section 2.1.3. In summary, all available water quality data for beaches for each of several bacteriological indicators was obtained from EPA's STORET database. We eliminated from these data sets all monitoring records where indicator bacteria exceeded standards or criteria defining acceptable water quality for swimming.[47] We assumed conservatively that beaches would be closed when standards or criteria were exceeded and people would not swim in such circumstances. We believe that the remaining, reduced data sets thus fairly represent current water quality at areas where people actually swim. Using information from the 1996 National Water Quality Inventory (U.S. EPA, 1998a), we estimated the percentage contribution by SSOs to total pathogen

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[47] For enterococcus and E. coli, we eliminated all water quality observations exceeding the existing EPA marine water standard of 35 enterococci/100 ml, and the fresh water standard of 33 enterococci/100 ml, or 126 E. coli/100 ml (U.S. EPA, 1986). For fecal coliform (FC), we eliminated observations exceeding the 200 FC/100 ml EPA standard for all recreational waters, which preceded the 1986 enterococci/E. coli-based standards, and which is still used by about two-thirds of all States (U.S. EPA, 1998b). For fecal streptococcus (FS), we eliminated all observations exceeding 400 FS/100 ml, which was the lower bound for the U.S. Geological Survey's definition of fecal-contaminated surface water (http://water.usgs.gov/owq/FieldManual/Chapter7.1/7.1.html).

loadings to fresh and marine waters, and assumed that eliminating SSOs would reduce the current average indicator concentration by a similar percentage. We then used the various dose-response functions to estimate the number of illnesses that would be avoided by reducing the current average indicator concentrations by the percentage of indicator loadings contributed by SSOs.

We used the various epidemiological studies in either of two ways in calculating the number of avoided illnesses:

- Preferably, we used the actual dose-response equations from the original epidemiological studies. In addition to those presented by Cabelli and Dufour, we obtained four other dose-response equations from other studies: Seyfried (1985b, for fecal coliform in freshwater); Seyfried (1985b, for fecal streptococcus in freshwater); Kay (1994, for fecal streptococcus in marine water); and Cheung (1991, for fecal coliform in marine water).

- In other cases, we interpolated from graphs of additional dose-response functions presented in a epidemiological literature review article by Pruss (1998). For several epidemiological studies, either: 1) We could not obtain the study; or 2) The study included neither the numerical dose-response function nor the original data allowing us to calculate the function. In these cases, we relied on Pruss' article, which included graphs showing the dose-response relationships that she and others had calculated from the original data in other studies. As best we could, we read from the graphs the reduction in swimmer illness rates that would occur as a result of the change in indicator bacteria concentrations upon elimination of SSOs.

The following discussion first reviews our approach for estimating reduced risk among swimmers for the dose-response functions we were able to identify in the literature, and then addresses our approach for other dose-response functions.

Dose-response functions obtained from the studies – Seyfried, Kay, and Cheung

To calculate the number of avoided swimmer illnesses predicted by the Seyfried, Kay and Cheung functions, we performed the following steps. First, we estimated the number of swimming-related illnesses that currently are contracted at beaches where people are assumed to swim, using the dose-response function. For example, Seyfried's dose-response function for fecal coliform in freshwater is:

$$\log_{10}(\text{total illnesses}/1000\ \text{swimmers}) = -1.4441 + 0.18177\log_{10}(\#FC/100ml)$$

Computing the number of illnesses per 1000 swimmers at a particular beach requires data on the concentration of fecal coliform at that beach. Our STORET freshwater data provides concentrations of fecal coliform and other indicator bacteria for different beaches at different times. In some cases, data from several different monitoring stations at a single beach is provided. The concentrations shown in the database are based on varying numbers of samples; sometimes a record in the database (a row of data from a particular beach and/or monitoring station) reflects only one sample, while sometimes the record reflects the mean from as many as 100 samples. For each record in our freshwater fecal coliform database, we entered that fecal coliform concentration into Seyfried's dose-response equation to obtain the number of illnesses per 1000 swimmers at that beach/monitoring station/time. We then weighted the estimated number of illnesses per 1000 for each beach data record by the number of monitoring observations reflected in that beach record. Lastly, we averaged these weighted illness estimates, dividing the total by the total number of monitoring observations in our database. Thus, the number of illnesses per 1000 estimated for a beach/station/time where 10 monitoring observations were taken is given ten times as much weight as the number of illnesses per 1000 estimated for a beach where only 1 observation was taken. This weighted averaging scheme presumes that the intensity of the monitoring effort (as measured by the number of observations taken) relates roughly to the number of swimmers at a beach/monitoring station/time – we assume that the beaches that are heavily used by swimmers will tend to be monitored more frequently by States. Using this approach to account roughly for differing intensity of swimmer use at different locations, we obtain the weighted average illness risk currently faced by all swimmers at freshwater beaches where people are presumed to swim.

After determining the average number of illnesses per 1000 swimmers that the dose-response function estimates will occur based on current bacteria concentrations reported in STORET, we calculate the average number of illnesses that will occur if beach pathogen levels are reduced as a result of SSO abatement. As discussed in section 2.1.3, we estimate that SSO abatement will reduce average pathogen levels at marine beaches by 14.60% to 18.22%, and freshwater beaches by 5.64% to 7.37%. We therefore reduce the indicator bacteria concentration for each record in our database by the appropriate percentage to obtain the post-SSO abatement concentration. Separate calculations are performed for the lower estimate, in which we reduce the bacteria concentration for each record by the lower-estimate reduction percentage (14.60% for marine beaches, 5.64% for freshwater beaches), and for the upper estimate. We then apply the dose-response function to each post-abatement concentration in the same manner as described above (i.e. weighting the resulting illness estimates by the number of observations) in order to obtain the average number of illnesses per 1000 swimmers that would occur if SSOs were abated. The difference between the average illness rate pre-SSO abatement and the average illness rate post-SSO abatement is the number of illnesses per 1000 avoided as a result of SSO abatement. This number is reported in Table B-1.

Applying the Seyfried dose-response function for fecal coliform in freshwater, we estimate that 0.57 total illnesses/1000 swimmers (based on a 5.64% reduction in bacteria concentrations) to 0.75 total illnesses/1000 swimmers (based on a 7.37% reduction in bacteria concentrations) will be avoided upon elimination of SSOs. Her function for fecal streptococcus yields an estimate that 0.46 to 0.61 illnesses/1000 swimmers will be avoided. Compared with the Dufour freshwater dose-response function for e-coli, which we used as the basis for our freshwater swimming-illness benefits estimate, the Seyfried functions predict about two to two-and-a-half times more avoided illnesses (although Seyfried's function estimates the number of <u>total</u> illnesses per 1000 swimmers, while Dufour's estimates the number of HCGI cases per 1000).

The Kay dose-response function for fecal streptococci (FS) in marine water differs from many other dose-response functions in that it involves a relatively high threshold (32 fecal streptococcus/100 ml) below which the concentration of bacteria appears to have no impact on the swimmer illness rate. However, at FS levels exceeding 32/100 ml, Kay finds a steep dose-response relationship between the concentration of indicator bacteria and the swimmer GI illness rate, and the benefits of eliminating SSOs in these circumstances would be substantial. In our database of FS concentrations at marine beaches, we found that 78.3% of observations taken at beaches where people are presumed allowed to swim were lower than the 32 FS/100 ml threshold. Kay's dose-response function projects zero swimmer risk in these instances. Thus, for more than 78% of our samples, Kay's function would project zero swimmer risk currently and zero risk reduction upon eliminating SSOs. In the remaining 21.7% of samples taken at beaches where people are presumably allowed to swim, the baseline FS concentration exceeds Kay's threshold, there is a non-zero swimmer illness risk, and there will be benefits from SSO abatement. We followed the approach described above to estimate the risk reduction at the beaches where current FS levels exceed the zero-risk threshold. We then calculated a weighted average risk reduction from SSO abatement across all 1,867 of our samples, including the samples where concentrations were below the threshold and for which the risk reduction was therefore zero. This weighted average risk reduction is 10.85 GI cases per thousand swimmers (based on a 14.60% reduction in bacteria concentrations) to 13.88 GI cases per thousand swimmers (based on a 18.22% reduction in bacteria concentrations). As can be seen in Table B-1, this estimated risk reduction from eliminating SSOs using Kay's function is 13 times higher than that estimated using the Cabelli marine dose-response function for enterococcus.

Cheung (1991) provides a dose-response function for E. coli in marine water. However, we were not able to use this function to estimate risk reduction because E. coli is apparently rarely monitored for at marine beaches -- we could find no data on this parameter from marine beaches in STORET. In addition, though, Cheung provided sufficient information in his study to estimate an alternative dose-response function for his beaches based on fecal coliform (FC).[48] STORET does include extensive FC data at marine beaches, and thus we were able to apply a marine FC dose-response function that we estimated using Cheung's data. Using the same functional form as Cheung chose for E. coli, regression analysis on Cheung's data yields the following relationship between the concentration of FC and the rate of swimmer HCGI plus skin symptoms:[49]

$$\text{HCGI+skin symptoms/1000} = -18.48 + 10.92 \log_{10}(\text{FC/100ml})$$

Using this calculated dose-response relationship, we estimated the reduction in risk associated with SSO reduction at the beaches for which marine FC data was available. As for the Kay function, our calculated Cheung dose-response function involves a relatively high threshold (approximately 49 fecal coliform/100 ml) below which water quality appears to have no effect on the rate of illness from

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[48] Cheung investigated the correlation between the concentrations of several different indicator bacteria and several different measures of swimmer illness across 9 Hong Kong beaches. The highest correlation he found (0.73) was between E. coli and the combined rate of swimming-related HCGI and skin symptoms. Consequently, Cheung chose to focus on E. coli in the remainder of his study, and estimated a dose-response function relating e-coli to the combined swimming-related HCGI and skin symptom rate. However, Cheung also found a high correlation (0.71) between fecal coliform (FC) and the combined rate of swimming-related HCGI and skin symptoms. We use regression analysis on Cheung's data to estimate the relationship between FC concentration and the rate of these illnesses.

[49] The estimated relationship is significant beyond the 95% confidence level.

swimming. In our reduced database of FC concentrations at marine beaches where people are assumed to swim, we found that 72.7% of the samples were lower than the 49 FC/100 ml threshold. Thus, for 72.7% of our equally weighted samples, we project zero risk currently and zero risk reduction from SSO abatement. In the remaining 27.3% of samples taken at beaches where people are allowed to swim, the baseline FC concentration exceeds our calculated Cheung dose-response curve threshold, and there is a non-zero swimmer illness risk. We calculated a weighted average risk reduction from SSO abatement across all 14,991 of our samples, including the samples where concentrations were below the threshold, and for which the risk reduction was therefore zero. This weighted average risk reduction is 0.19 cases of HCGI or skin symptoms per thousand swimmers (based on a 14.60% reduction in bacteria concentrations) to 0.23 cases per thousand (based on a 18.22% reduction in bacteria concentrations) – about one-fifth of the rate predicted by the Cabelli marine dose-response function for enterococci.

Dose-response functions shown in graphs presented in the Pruss literature review

In instances when we could not obtain the original studies or the studies did not include sufficient information for specifying a numerical dose-response function, we referred to a recent review of epidemiological studies (Pruss, 1998), which provided graphs of each of the dose-response relationships. By interpolating, we were able to estimate for each of the graphed dose-response relationships the approximate reductions in swimmer illness rates that would result from the projected water quality improvement upon eliminating SSOs. We used this approach for the remaining dose-response functions shown in Pruss that we had not already analyzed numerically. These included three freshwater dose-response functions (Ferley's dose-response function for FC, Ferley's for FS, and Lightfoot's for FC) and two marine water dose-response functions (Mujeriego's for FS, and Fattal's for FC). In each case, we calculated the average concentration of the relevant indicator bacteria at all swimmable beaches before and after SSO abatement. We then marked this change in concentration on the graph of the dose-response function presented in the Pruss review, and visually estimated the magnitude of the resulting change in the number of illnesses per 1000 swimmers. This approach is admittedly imprecise, in that it is difficult to read accurately from Pruss' graphs to the corresponding numbers on her log-log axes. We substantially improved our visual ability to estimate the impact of small reductions in bacteria concentrations by greatly magnifying Pruss' graphs.

Fleisher's dose-response functions for FC and FS in marine water were also presented in Pruss's graph. However, we could not use the graphs of these functions to estimate the risk reduction associated with SSO abatement because the mean bacteria indicator concentrations across swimming beaches before and after SSO abatement are outside the range displayed in Pruss' graphs for these functions.

Summary of results

As indicated in the table, the estimated number of illnesses avoided varies considerably depending on the dose-response function selected. Freshwater results ranged from 0.1 objective GI cases avoided per 1000 swimmers (Ferley, 1989) to 0.746 total illness cases avoided per 1000 swimmers (Seyfried, 1985). The estimate based on Dufour and used in the benefits analysis was roughly in the middle of this range. Marine water results ranged from 0.187 gastrointestinal plus skin cases avoided per 1000 (Cheung) to 13.88 GI cases per 1000 (Kay, 1994). The estimate based on Cabelli and used in the benefits analysis was toward the lower end of this range. The results for both the Dufour and the Cabelli dose-response functions fall well within the ranges estimated for the other fresh and marine water dose-response functions.

Table B-1: Number of avoided illnesses estimated using different dose-response functions

Fresh or marine water?	**Indicator**	**Study**	**Type of illness considered**	**Cases avoided/1000 swimmers – lower estimate**	**Cases avoided/1000 swimmers – upper estimate**
Fresh	FC	Seyfried	Total illness	0.566	0.746
Fresh	FS	Seyfried	Total illness	0.464	0.610
Fresh	e-coli	Dufour	HCGI	0.237	0.313
Fresh	FC	Ferley	Objective GI	0.10*	0.15*
Fresh	FS	Ferley	Objective GI	0.2*	0.3*
Fresh	FC	Lightfoot	GI	0.4*	0.5*
Marine	FC	Cheung (calculated)	HCGI + skin symptoms	0.187	0.233
Marine	FC	Fleisher	Ear infection	Unknown**	Unknown**

Marine	FS	Fleisher	Acute febrile respiratory illness	Unknown**	Unknown**
Marine	FS	Mujeriego	Ear symptoms	1*	1.5*
Marine	FC	Fattal	GI	0.5*	0.8*
Marine	FS	Kay	GI	10.845	13.880
Marine	enterococci	Cabelli	HCGI	0.834	1.063

* The estimated number of illnesses per 1000 swimmers was estimated by interpolating from the graph of this dose-response function presented in Pruss's literature review.

** We are unable to estimate the number of illnesses avoided per 1000 swimmers because the mean FC levels across swimming beaches before and after SSO abatement are outside the range displayed in Pruss' graphs.

APPENDIX C REALITY CHECK ON SWIMMING ILLNESS PROJECTIONS USING CABELLI/DUFOUR DOSE-RESPONSE RELATIONSHIPS

There is substantial uncertainty associated with the swimmer illness dose-response functions. Are the projections generated by the Cabelli/Dufour relationships reasonable? In this Appendix, we compare the number of swimming related illnesses projected using these relationships against the number of such illnesses known to occur in the U.S. from all causes. We would expect that swimming causes a rather small proportion of total cases of gastrointestinal or other illnesses.

At the average indicator bacteria concentrations estimated to prevail at fresh and marine water swimming locations, the Cabelli/Dufour relationships project the following rates of HCGI illness (see Section 2.1.3):

- In fresh water, 2.845 HCGI cases per 1,000 swimmers;

- In marine water, 8.208 HCGI cases per 1,000 swimmers.

Multiplying these rates by the estimated 665 million fresh water and 535 million marine water swimming days annually, we estimate approximately 6.4 million cases of HCGI annually among swimmers that result from swimming. Is this estimate plausible?

No statistics are available regarding the national incidence of HCGI precisely. Highly credible gastrointestinal symptoms are defined in Cabelli's epidemiological study as all cases of vomiting, instances of diarrhea which were accompanied by a fever or which were disabling, and cases of nausea and stomachache which were accompanied by a fever (Cabelli, 1983). Several estimates were obtained regarding the incidence of roughly similar illnesses:

- The National Institutes of Health provides two estimates regarding infectious diarrhea: 1) Approximately 99 million new cases of infectious diarrhea occurred in 1980; and 2) 8 to 12 million physician office visits to treat infectious diarrhea were made in 1985.[50]

- The Centers for Disease Control indicates that 11,721,000 visits to physicians' offices were made in 1996 to treat stomach and abdominal pain, cramps and spasms (hereafter referred to as SAPCS) (CDC, 1997).

Neither infectious diarrhea nor SAPCS match exactly against HCGI. Presumably infectious diarrhea includes some cases that would not qualify as HCGI (e.g., diarrhea that is without a fever and not disabling), while HCGI includes some cases that are not infectious diarrhea (e.g., vomiting without diarrhea). Similarly SAPCS likely includes some cases that are not HCGI (e.g., ulcers), while HCGI includes some cases that are not SAPCS (diarrhea and fever that do not produce cramps or abdominal pain).

On balance, we might guess that some substantial fraction of infectious diarrhea would qualify as HCGI, probably well more than half. In addition, a lesser fraction of the SAPCS that is not also infectious diarrhea -- probably less than half of all SAPCS -- might also qualify as HCGI. A very rough estimate might be as follows:

- There might be 100 - 200 million cases annually of infectious diarrhea. 100 million might represent the 99 million figure for 1980 inflated to reflect the increased current population, but deflated to reflect better current general health status. 200 million might represent the 8 - 12 million physician office visits increased by a factor of roughly 20 for non-reported and self-treated cases.

- Assuming that 75% of the cases of infectious diarrhea are HCGI would yield about 75 - 150 million HCGI cases annually.

- There might be roughly 200 million cases annually of SAPCS. This figure might represent the nearly 12 million physician office visits in 1996 increased by a factor of roughly 20 again for non-reported and self-treated cases.

- Assuming that 25 % of the cases of SAPCS are HCGI and not also infectious diarrhea, there might

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[50] Digestive Diseases Statistics, National Digestive Diseases Information Clearinghouse. Http://www.niddk.nih.gov/health/digest/pubs/ddstats/ddstats.htm

be an additional 50 million cases annually of HCGI.

These estimates are little more than speculative, but these assumptions would lead to a number of annual HCGI cases of about 125 - 200 million.

If so, the projected number of swimming-induced HCGI cases would constitute roughly 3 - 5 % of all HCGI cases in the nation. This at least seems plausible.

APPENDIX D DATA AND CALCULATIONS TO SUPPORT EPA ESTIMATES OF SSO CONTRIBUTION TO MUNICIPAL DISCHARGES AND URBAN RUNOFF/STORM SEWERS

Overview

Despite SSOs being an important contributor to water quality impairment, there is no single pollution source category in EPA's 305(b) report (EPA, 1998a) that addresses SSOs. The two 305(b) categories in which SSOs play a contributing role are municipal discharges and urban runoff/storm sewers. The municipal discharge source category covers discharges from publicly owned treatment works (POTWs) and collection systems, while the urban runoff/storm sewer category covers runoff from impervious surfaces including streets, parking lots, buildings, and other paved areas (see Table 2-1 in Section 2 of this report). SSOs are understood by EPA as being captured under these two pollution source categories because in practice, it is most likely that States categorize SSOs that reach U.S. waters with discharges from sewage collection and treatment systems, and SSOs that flow over pavement into storm sewers with urban runoff.

This appendix provides data and calculations to estimate the SSO portion of municipal discharge- and urban runoff/storm sewer-related impairment.

SSO portion of municipal discharge-related impairment

SSOs currently account for a certain fraction of the pollutants which cause impairment attributed to municipal discharges. To determine this fraction, the volume of pollutants from SSOs reaching U.S. waters was calculated, and was added to the volume of pollutants discharged from POTWs to obtain an estimate of total pollutant loadings from the municipal discharge source category. The main pollutants generated by SSOs and by treated POTW discharges that cause impairment are BOD (biochemical oxygen demand), nutrients (measured as total nitrogen and total phosphorus), and pathogens (measured as number of fecal coliform bacteria).

Table D-1 calculates the total amount of pollutants contained in SSOs that reach U.S. waters directly, and which therefore are believed to contribute to impairment that is attributed to municipal discharges. As discussed below, two versions of Table D-1 – Case 1 and Case 2 – are presented to reflect two different assumptions regarding the percentage of SSO pollutants that reaches U.S. waters directly vs. the percentage that reaches U.S. waters via storm sewers. The total amount of pollutants contained in SSOs which reaches U.S. waters directly is calculated as follows:

- (Pollutant concentration in sewage; A) x (annual wet weather SSO volume; B) x (dilution factor; C) =
  (wet weather SSO loading; D);
- (Pollutant concentration in sewage; A) x (annual dry weather SSO volume; E) =
  (dry weather SSO loading; F);
- (Wet weather SSO loading; D) + (dry weather SSO loading; F) = (total SSO loading; G);
- (Total SSO loading; G) x 95% = (total SSO loading that reaches U.S. waters; H)
- (Total SSO loading that reaches U.S. waters; H) x (% of SSO volume that reaches U.S. waters directly; I) = (total loading in SSOs reaching U.S. waters directly; J)

For the concentrations of fecal coliform, suspended solids and BOD in SSOs (i.e. raw sewage), the midpoints of the range of concentrations presented in a wastewater treatment textbook were adopted (Metcalf & Eddy, 1991). For concentrations of phosphorus and nitrogen in SSOs, a different wastewater treatment textbook, which provided both pre- and post-treatment concentrations, was consulted to ensure that the pre- and post-treatment values would be logically consistent (Benefield et al., 1985). The lower estimate of the volume of wet weather SSOs was set at 1% of total POTW flow from sanitary sewer collection systems, based on a case study of Greenville, South Carolina summarized in the Needs Report (EPA, 2000b). The total POTW flow figure was obtained from Metcalf & Eddy, and was generated by the hydrological model which Metcalf & Eddy developed for the Needs Report (U.S. EPA, 2000b) . For the upper estimate of the volume of wet weather SSOs, the wet weather SSO volume figure generated by Metcalf & Eddy's hydrological model was adopted.[51]

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[51] The hydrological model was one component of the Needs Report model used to develop cost estimates for the amount of additional collection system storage, treatment capacity, and infiltration and inflow (I/I) reduction that would be needed to reduce the average number of SSOs per system to different levels. In order to gauge the accuracy of the hydrological model, this analysis compared the model's

The upper estimate for dry weather SSO volume was estimated by taking 25% of the upper-estimate wet weather SSO volume. 25% is a best estimate of the upper-bound for dry weather SSO volume -- very little data exists on the relative volumes of dry and wet weather SSOs. The lower estimate of dry weather SSO volume was developed based on data from the City of Los Angeles and Orange County. In 1995 and 1996, Los Angeles' dry weather SSO volume was equal to 0.00033% of its yearly total sanitary sewer collection system flow (Westhoff, 2000). In 1999, Orange County experienced dry weather SSO flows equal to 0.00035% of total system flow (Mehta et. al, 2000; Orange County Sanitary District, 2000). The lower estimate of dry weather SSO volume was obtained by taking the average of two values: 1) the midpoint of the percentages of total flow reported by Los Angeles and Orange County (0.00034% of the total POTW flow estimated by the hydrological model); and 2) the upper-estimate dry weather SSO volume (25% of the wet weather SSO volume estimated by the hydrological model).

Sewage in wet weather SSOs is diluted by stormwater that enters into the collection system during wet weather events, causing an overflow. To estimate the total pollutant volume in wet weather SSOs, a dilution factor was selected based on the peaking factors for sewers recommended in the "10-State standards" report (GLUM, 1978). The 10-State standards report indicated that acceptable peaking factors for sewers range from a ratio of 3.5 parts stormwater to 1 part sewage to a ratio of 5 parts stormwater to 1 part sewage. The midpoint in this range – 4.25 parts stormwater to 1 part sewage – was adopted as the dilution factor for wet weather SSOs.

The total volume of SSO pollutants was calculated by adding the volume of pollutants in dry weather SSOs and the volume of pollutants in wet weather SSOs. Some SSOs, such as basement backups that are captured using vacuum equipment, never enter U.S. waters, and therefore do not

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estimates with 1996 Clean Water Needs Survey data on the total volume of wastewater treated by POTWs. The model estimates that annual wet weather SSO volume is 311,378 million gallons. This figure was scaled up by 25% to account for the additional volume of dry weather SSOs. The model also estimates that the total annual flow from sanitary sewer collection systems that is treated by POTWs is 5,866,280 million gallons. After combining the SSO and POTW volume estimates, the total was scaled up to account for combined sewer system (CSS) flow to POTWs (based on the number of Americans served by CSSs -- 80 million -- and that served by sewer systems -- 130 million). The scaled-up estimate of the total volume of wastewater flow to POTWs derived from the Metcalf & Eddy hydrological model was within 12% of the 1996 Clean Water Needs Survey figure for the total volume of wastewater treated by POTWs (U.S. EPA, 1996b). Based on the model's reasonable approximation of Needs Survey data, the model's estimate for the annual volume of wet weather SSOs was adopted for use in this analysis.

contribute to pollution reported as municipal discharge or urban runoff/storm sewer pollution. It was

INSERT Table D-1: Volume of pollutants directly reaching waters of the U.S. from SSOs (Case 1)

INSERT Table D-1A: Volume of pollutants directly reaching waters of the U.S. from SSOs (Case 2)

INSERT Table D-2: Fraction of pollutants in municipal discharges contributed by SSOs (Case 1)

INSERT Table D-2A: Fraction of pollutants in municipal discharges contributed by SSOs (Case 2) assumed that such SSOs constitute 5% of the total volume of SSO pollutants. The remaining 95% of SSO pollutants do reach U.S. waters, either directly or via storm sewers. No data is available to help estimate the fraction of SSO pollutants that reaches U.S. waters directly or via storm sewers. Two cases, or scenarios, were developed to reflect uncertainty about how SSOs should be apportioned between municipal discharge and urban runoff/storm sewers. In Case 1, 50% of SSO pollutants reaching U.S. waters are assumed to reach U.S. waters directly, and therefore to be counted as municipal discharge. The remaining 50% are assumed to reach U.S. waters via storm sewers, and to be counted as urban runoff/storm sewer pollution. In Case 2, 90% of SSO pollutants reaching U.S. waters are assumed to reach U.S. waters directly, and therefore to be counted as municipal discharge. The remaining 10% are assumed to reach U.S. waters via storm sewers, and to be counted as urban runoff/storm sewer pollution. These two cases reflect a best estimate of the range of possible allocations of SSO pollution between municipal discharge and urban runoff/storm sewer pollution. Two versions of Table D-1 are provided, one for each case.

Table D-2 estimates the SSO portion of municipal discharge-related impairment. The SSO portion is estimated by calculating the total pollutant volume in POTW discharges, adding this volume to the total volume of SSO pollutants reaching U.S. waters estimated in Table D-1, and calculating the SSO portion of total SSO and POTW pollutant loadings. Two versions of Table D-2 are provided for each case. Table D-2, Case 1 uses the total SSO pollutant volume reaching U.S. waters that was estimated in Table D-1, Case 1. Similarly, Table D-2, Case 2, uses the total SSO pollutant volume reaching U.S. waters that was estimated in Table D-1, Case 2. The steps to obtain the SSO portion of municipal discharge-related impairment in Table D-2 are as follows:

- (Total POTW volume treated; K) x (pollutant concentration after POTW treatment; L) = (total POTW loading; M)
  [loadings of fecal coliform from POTWs are calculated differently, using removal percentages, as described below];

- (Total POTW loading; M) + (total loading in SSOs reaching U.S. waters directly; J [from Table D-1]) = (total municipal discharge loading; N);

- (Total BOD loading in SSOs reaching U.S. waters directly ; O [a portion of J]) ÷ (total BOD loading by all municipal discharge sources; P [a portion of N]) = (SSO portion of all municipal discharge source loadings of BOD; Q) [The same procedure is followed for each of the pollutants.]

- [(SSO portion of all municipal discharge loadings of BOD; Q) + (SSO portion of all municipal discharge loadings of total nutrients; R) + (SSO portion of all municipal discharge loadings of fecal coliform; S)] ÷ 3 = (SSO loadings as weighted average % of all municipal discharge source loadings; ANSWER).

The concentration of BOD per liter remaining after secondary treatment at a POTW was obtained from data supporting EPA's final BCT rule, and reflects the average concentration that is achieved by secondary treatment POTWs in practice (U.S. EPA, 1986). The concentrations of total nitrogen and total phosphorus per liter reflect the midpoint values of concentration ranges for secondary treatment provided in Benefield's wastewater treatment textbook (Benefield et. al, 1985). In Part II of Table D-2, the number of fecal coliform in wastewater influent to POTWs was estimated based on the concentration of fecal coliform in sewage and the volume of wastewater treated annually by POTWs (U.S. EPA, 1996b). In order to estimate the post-treatment concentrations of fecal coliform, a best estimate removal percentage of 99.9% was used. This removal percentage represents the midpoint in the range of removal efficiencies (99% to 99.99%) that is typically assumed for fecal coliform.

The SSO percentage contribution to total pollutant volume from the municipal discharge source category was calculated by assigning an equal weight to each of the three pollutants – to the SSO portion of total BOD loadings, the SSO portion of total nutrient loadings, and to the SSO portion of total pathogen loadings. As indicated in the two far-right columns in Table D-2, Case 1, the lower-estimate SSO percentage of total pollutant loadings from municipal discharge sources is 23.52%, and the upper estimate is 29.13%. In Table D-2, Case 2, the lower-estimate SSO percentage of total pollutant loadings from municipal discharge sources is 28.25%, and the upper estimate is 33.52%. As shown in Table D-5, the lower estimate from Table D-2, Case 1 and the lower estimate from Table D-2, Case 2 are averaged to arrive at a final lower-estimate SSO percentage of total pollutant loadings from municipal discharge sources [(23.52% + 28.25%) / 2 = **25.89%**], and the two upper estimates are averaged to arrive at a final upper estimate [(29.13% + 33.52%) / 2 = **31.33%**].

<u>SSO portion of urban runoff/storm sewer source impairment</u>

A similar approach was taken to estimate the SSO portion of the pollutant loadings that cause impairment attributed to urban runoff/storm sewer sources. To determine this percentage, the volume of pollutants from SSOs that reach U.S. waters via storm sewers was calculated, and was added to the volume of pollutants from stormwater to obtain an estimate of total pollutant loadings from the urban runoff/storm sewer source category. The main pollutants generated by SSOs and by urban runoff and storm sewer discharges that cause impairment are BOD, nutrients, suspended solids, and pathogens.

Table D-3 calculates the total amount of pollutants in stormwater. This amount was calculated as follows:

- (Pollutant concentration in stormwater; a) x (volume of stormwater; b) = (stormwater pollutant loadings; c).

The midpoints of the range of concentrations presented in an EPA handbook on urban runoff pollution prevention were adopted in calculating total stormwater pollutants (U.S. EPA, 1993b). The volume of stormwater runoff was obtained from the Economic Analysis of the Stormwater Phase II final rule (U.S. EPA, 1999). Using the total amount of pollutants in stormwater calculated in Table D-3, Table D-4 estimates the SSO percentage of urban runoff/storm sewer impairment. This percentage is calculated as follows:

- (Total loading in all SSOs that reach U.S. waters; d [‘H’ from Table D-1]) x (% of SSO volume that reaches U.S. waters via storm sewers; e) = (total loading in SSOs that reach U.S. waters via storm sewers; f);

- (Stormwater pollutant loading; c [from Table D-3]) + (total loading in SSOs that reach U.S. waters via storm sewers; f) = (total loading by all urban runoff/storm water sources; g);

- (Total BOD loading in SSOs reaching U.S. waters via storm sewers; h [a subset of f]) ÷ (total BOD loading by all urban runoff/storm sewer sources; i [a subset of g]) = (SSO portion of all urban runoff/storm sewer source loadings of BOD; j) [The same procedure is followed for each of the pollutants.]

- [(SSO portion of all urban runoff/storm sewer source loadings of BOD; j) + (SSO portion of all urban runoff/storm sewer source loadings of total nutrients; k) + (SSO portion of all urban runoff/storm sewer source loadings of suspended solids; l) + (SSO portion of all urban runoff/storm sewer source loadings of fecal coliform; m)] ÷ 4 = (SSO loadings as weighted average

% of all urban runoff/storm sewer source loadings; ANSWER).

As noted above, the fraction of SSOs reaching U.S. waters via storm sewers is used for this calculation because it is believed that SSOs that flow into storm sewers are categorized by States in the urban runoff/storm sewer source category. Two different assumptions regarding the fraction of SSO that reaches U.S. waters via storm sewers are applied. These assumptions are consistent with, and are the flip side of, the Case 1 and Case 2 assumptions in Tables D-1 and D-2. The “Case 1" version of Table D-4 assumes that 50% of SSO pollutants reaching U.S. waters do so via storm sewers; the remaining 50% reach U.S. waters directly, and were counted in the “Case 1" versions of Tables D-1 and D-2. The “Case 2" version of Table D-4 assumes that 10% of SSO pollutants reaching U.S. waters do so via storm sewers; the remaining 90% reach U.S. waters directly, and were counted in the “Case 2" versions of Tables D-1 and D-2. After adding the total pollutants in SSOs reaching U.S. waters via storm sewers, and the total pollutants in stormwater, the SSO percentage of the total was calculated.

The SSO percentage contribution to total pollutant volume from the urban runoff/storm sewer source category was calculated by assigning an equal weight to the SSO portion of total BOD loadings, the SSO portion of total nutrient loadings, the SSO portion of suspended solids loadings, and the SSO portion of total pathogen loadings. As indicated in the two far-right columns in Table D-4, Case 1, the lower-estimate SSO percentage of total pollutant loadings from urban runoff/storm sewer sources is 15.21%, and the upper estimate is 21.12%. In Table D-4, Case 2, the lower-estimate SSO percentage of total pollutant loadings from municipal discharge sources is 5.13%, and the upper estimate is 8.72%. As shown in Table D-5, the lower estimate from Table D-4, Case 1 and the lower estimate from Table D-4, Case 2 are averaged to arrive at a final lower-estimate SSO percentage of total pollutant loadings from urban runoff/storm sewer sources [(15.21% + 5.13%) / 2 = **10.17%**], and the two upper estimates are averaged to arrive at a final upper estimate [(21.12% + 8.72%) / 2 = **14.92%**].

Table D-5 summarizes the results of Appendix D. The final lower and upper estimates of the SSO contribution to municipal discharge pollution, along with the final lower and upper estimates of the SSO contribution to urban runoff/storm sewer pollution, are applied throughout this report to calculate lower and upper estimates for the following benefits categories: freshwater recreational (Mitchell & Carson) benefits; reduced freshwater and marine swimming illnesses; enhanced commercial finfishing; enhanced commercial shellfishing; enhanced recreational fishing; and increased wildlife viewing along the coast.

INSERT Table D-3: Volume of pollutants reaching waters of the U.S. from storm water

INSERT Table D-4: Fraction of pollutants in urban runoff/storm sewers that derives from SSOs (Case 1)

INSERT Table D-4A: Fraction of pollutants in urban runoff/storm sewers that derives from SSOs (Case 2)

INSERT Table D-5: SSO contribution to municipal discharge and urban runoff/storm sewer impairment – Calculation of lower and upper estimates to be applied throughout the benefits analysis

APPENDIX E METHODOLOGY FOR ESTIMATING THE PERCENTAGE OF IMPAIRED WATERS THAT DO NOT SUPPORT BOATING

In section 2.1.2 of this report, Table 2-7 estimates the percentage of impaired waters that do not support the different use categories – swimming, fishing and boating. To determine the percentage not supporting swimming, Table 2-7 uses 1996 305b data on the number of river miles and lake acres partially and not supporting swimming use, and applies the assumption that waters surveyed for uses other than swimming show the same rate of impairment as waters surveyed for swimming. This approach is also used to calculate the percentage of impaired waters that do not support fishing use.

Certain factors particular to the boating category suggest the need for a different approach in calculating the percentage of impaired waters that do not support boating use. Considerably fewer waters are surveyed for boating than for fishing and swimming. Only 257,392 river miles were surveyed for boating use impairment in 1996 out of a total of 693,905 surveyed miles, compared with 379,261 miles surveyed for fish consumption, 434,421 surveyed for swimming, and 641,611 surveyed for aquatic life support. Given that there are many more miles <u>not</u> surveyed for boating use support than <u>are</u> surveyed for boating, the choice of an impairment rate for waters not surveyed for boating use determines, in large part, the final calculated percentage of impaired waters that do not support boating. This contrasts with the situation regarding swimming and fishing, for which: a) the fraction of waters not surveyed for these uses is much smaller than the fraction that is surveyed for these uses; and b) we can reasonably guess how to extrapolate from conditions in waters surveyed for these uses to conditions in waters not surveyed for these uses. It is particularly difficult to project what the rate of boating use impairment in waters not surveyed for boating use might be. As noted in Section 2.1.2, waters that are not designated for a given use are generally not surveyed for that use. However, in the case of boating, most if not all waters could potentially be designated for boating because , in general, most waters are thought to be boatable, even if some of them turn out not to support boating. It is therefore unclear what, if any, rationale is employed when States select waters to survey for boating use impairment. States may select waters that are thought to be impaired for boating; they may select waters in recreational areas that are also being surveyed for fishing and swimming; or they may select waters randomly. Since none of these scenarios can be ruled out with any confidence, another methodology which offers greater certainty was sought.

In order to get a more accurate estimate of the percentage of all impaired waters that do not support boating use, EPA used the National Water Pollution Control Assessment Model (NWPCAM). The model, developed by Research Triangle Institute, is a national-level water quality modeling system that can be used to simulate water quality changes associated with different pollution control policies (RTI, 2000). The model links place-specific pollutant loadings from both point and nonpoint sources across the nation to a network of surface waters, and simulates hydraulic transport, routing, and connectivity of surface waters in estimating water quality under different policy and loading scenarios. NWPCAM is capable of estimating the proportion of river miles (RF1) in the nation that fell below the "boatable" threshold on the Water Quality Index in 1997. According to the Water Quality Index graphic shown to respondents in the Carson and Mitchell's contingent valuation survey (Carson and Mitchell, 1993), the index value corresponding to the minimum level of "boatable" water is 25. Thus, waters that have an index value of 1-24 represent the waters that were understood by survey respondents to be "below-boatable". The NWPCAM contains data on the number of river miles for each of the 100 index increments, as well as the cumulative proportion of waters at or below a given index value. For 1997, the model estimates that approximately 5% of the nation's waters (RF1) were "below-boatable" in quality.

We adopt the 5% figure in the benefits analysis as the percentage of all waters in the country that do not support boating. We assume that this 5 % figure applies both for waters that have been surveyed and for waters that have not been surveyed.[52] Since Table 2-8 calculates the percentage of all <u>impaired</u> waters that do not support boating, we need to convert the 5% of surveyed waters figure to a percentage of impaired waters. Based on the model, if 5 % of the 693,905 surveyed river miles do not support boating, then 34,695 river miles are both surveyed and do not support boating. These 34,695 river miles are equivalent to 14% of all river miles that are surveyed and impaired [34,695 ÷ 248,028 river miles surveyed and impaired = 14%]. We use a similar approach to arrive at the percentage of impaired lake acres that do not support boating (13%).

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[52] This assumption that boating use non-support occurs equally frequently in non-surveyed and in surveyed waters is a simplification that results in underestimating the impact of eliminating SSOs. A more realistic assumption would be that boating use non-support occurs more frequently in surveyed waters than in non-surveyed waters. (In general, non-surveyed waters are likely to have better quality than surveyed waters.) It might be the case, for example, that 5 % of all river miles are impaired for boating use support, but that this consists of 15 % of surveyed river miles that are impaired for boating use support and 3.5 % of non-surveyed river miles that are impaired for boating. (This set of hypothetical figures is consistent with 19 % of all river miles being surveyed and 81 % being non-surveyed.) This pattern – where boating use non-support is likely higher in surveyed waters than in non-surveyed waters – would result in greater estimated benefits from SSO elimination under any calculation scenario (e.g., our "lower estimate" scenario) in which the fraction of waters assumed to "move up" with SSO elimination is greater for surveyed waters than for non-surveyed waters.

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