EPA 815-R-00-013

Proposed Arsenic in Drinking Water Rule
Regulatory Impact Analysis

Developed for:

Office of Ground Water and Drinking Water
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

John B. Bennett
Work Assignment Manager

Developed by:

Abt Associates Inc.
4800 Montgomery Lane
Bethesda, MD 20814

Gerald D. Stedge, Ph.D.
Principal Investigator

June 2000

EPA 815-R-00-013

Proposed Arsenic in Drinking Water Rule
Regulatory Impact Analysis

Developed for:

Office of Ground Water and Drinking Water
U.S. Environmental Protection Agency
401 M Street, S.W.
Washington, DC 20460

John B. Bennett
Work Assignment Manager

Developed by:

Abt Associates Inc.
4800 Montgomery Lane
Bethesda, MD 20814

Gerald D. Stedge, Ph.D.
Principal Investigator

June 2000

Contents

Exhibits

Chapter 1: Executive Summary

1.1 Regulatory Background

An enforceable standard of 50 µg/L currently exists for arsenic in community water systems under the National Interim Primary Drinking Water Regulations (NPDWR) (40 CFR 59566). In §1412(b)(12)(A) of the SDWA, as amended in 1996, Congress specifically directed EPA to issue a final regulation by January 1, 2001. At the same time, Congress directed EPA to develop a research plan to reduce the uncertainty in assessing health risks from low levels of arsenic by February 2, 1997, and conduct the research in consultation with the National Academy of Sciences, other Federal agencies, and interested public and private entities.

This document analyzes the impacts of the proposed rule which revises the current standard as follows:

1) reduces the current MCL for arsenic in community water systems from 50 µg/L to 5 µg/L;
2) requires nontransient non-community water systems (NTNC) to perform compliance monitoring; and
3) revises the current monitoring requirements to make them consistent with the Standard Monitoring Framework (40 CFR 141.23(c)).

1.2 Health Effects of Arsenic

Arsenic's carcinogenic role was noted over 100 years ago (NCI, 1999) and has been studied ever since. The Agency has classified arsenic as a Class A human carcinogen, "based on sufficient evidence from human data. An increased lung cancer mortality was observed in multiple human populations exposed primarily through inhalation. Also, increased mortality from multiple internal organ cancers (liver, kidney, lung, and bladder) and an increased incidence of skin cancer were observed in populations consuming drinking water high in inorganic arsenic."

A 1999 NRC report on arsenic states that "epidemiological studies ... clearly show associations of arsenic with several internal cancers at exposure concentrations of several hundred micrograms per liter of drinking water." Ten epidemiological studies covering eight organ systems have quantitative data for risk assessment (NRC, 1999, Table 4-1). The organ systems where cancers in humans have been identified include skin, bladder, lung, kidney, nasal, liver, and prostate.

Table 10-6 of the same NRC report provides risk parameters for three cancers: bladder, lung, and liver cancer. Considering all cancers in aggregate, the NRC states that "considering the data on bladder and lung cancer in both sexes noted in the studies ... a similar approach for all cancers could easily result in a combined cancer risk on the order of 1 in 100" (at the current MCL of 50 µg/L).

New data provide additional health effects information on both carcinogenic and noncarcinogenic effects of arsenic. A recent study by Tsai et al. (1999) of a population that has been studied over many years in Taiwan has provided standardized mortality ratios (SMRs) for 23 cancerous and non-cancerous causes of death in women and 27 causes of death in men at statistically significant levels in an area of Taiwan with elevated arsenic exposures (Tsai et al., 1999). SMRs are an expression of the ratio between deaths that were observed in an area with elevated arsenic levels and those that were expected to occur, based on the mortality experience of the populations in nearby areas without elevated arsenic levels. Drinking water (250-1,140 µg/L) and soil (5.3-11.2 mg/kg) in the Tsai et al. (1999) population study had very high arsenic content.

Tsai et al. (1999) identified "bronchitis, liver cirrhosis, nephropathy, intestinal cancer, rectal cancer, laryngeal cancer, and cerebrovascular disease" as possibly "related to chronic arsenic exposure via drinking water," which had not been reported before. In addition, the study area had upper respiratory tract cancers previously only related to occupational inhalation. High male mortality rate (SMR > 3) existed for bladder, kidney, skin, lung, and nasal cavity cancers and for vascular disease. However, the authors noted that the mortality range was marginal for leukemia, cerebrovascular disease, liver cirrhosis, nephropathy (kidney), and diabetes. Females also had high mortalities for laryngeal cancer. There are, of course, possible differences between the population and health care in Taiwan and the United States. For example, arsenic levels in the U.S. are not as high as they were in the study area of Taiwan. However, the study gives an indication of the types of health effects that may be associated with arsenic exposure via drinking water.

Arsenic interferes with a number of essential physiological activities, including the actions of enzymes, essential cations, and transcriptional events in cells (NRC, 1999). A wide variety of adverse health effects have been associated with chronic ingestion of arsenic in drinking water, occurring at various exposure levels. Exhibit 5-1 lists the effects on specific organ systems reported in humans exposed to arsenic and provides descriptive information on the specific diseases and/or symptoms associated with categories of diseases.

1.3. Regulatory Alternatives Considered

In regulating a contaminant, EPA first sets a maximum contaminant level goal (MCLG), which establishes the contaminant level at which no known or anticipated adverse health effects occur. MCLGs are non-enforceable health goals. For this rulemaking, EPA is proposing an MCLG of zero. EPA then sets an enforceable maximum contaminant level (MCL) as close as technologically possible to the MCLG. In addition, EPA may use its discretion in setting the MCL by choosing an MCL that is protective of public health while also insuring that the quantified and non-quantified costs are justified by the quantified and non-quantified benefits of the rule. For this rulemaking, EPA is proposing an MCL of 5 µg/L. Chapter 3 describes the process by which EPA determined both the MCLG and the MCL.

EPA considered a range of MCLs in developing the proposed Arsenic Rule, including MCLs of 3, 5, 10, and 20 μg/L. EPA evaluated the following five factors to determine the proposed Maximum Contaminant Level (MCL):

- the analytical capability and laboratory capacity,
- likelihood of water systems choosing various compliance technologies for several sizes of systems based on source water properties,
- the national occurrence of arsenic in water supplies.
- quantified and non-quantified costs and health risk reduction benefits likely to occur at the MCLs considered, and
- the effects on sensitive subpopulations.

After evaluating the above factors, EPA considered an MCL of 3 µg/L since this is the level that has been determined to be as close to the MCLG as is feasible. However, the Agency is using its discretionary authority in Section 1412(b)(6)(A) to consider setting MCL at a less stringent level. The statute requires that the alternative less stringent level be one which maximizes health risk reduction at a level where costs and benefits are balanced. As a result, EPA considered the alternative MCL options of 5, 10, and 20 µg/L. These alternative MCL options were considered because they also provide assurance that the residual risk for both bladder and lung cancer endpoints will be in the 10^{-4} range, but at lower anticipated national costs.

The Agency also considered two regulatory options related to the applicability of the proposed MCL. Specifically, EPA investigated applying both the monitoring and treatment requirements of the proposed rule to both community water systems (CWS) and non-transient non-community water systems (NTNC). A CWS is defined as a system that provides piped water to at least 25 people or with at least 15 service connections year-round. A NTNC is a public water systems that is not defined as a CWS and that regularly serves at least 25 of the same people for at least six months of the year. After considering the costs and benefits of the proposed rule with regard to both CWSs and NTNCs, EPA proposes to require CWS to comply with all facets of the proposed rule, while only requiring NTNCs to comply with the monitoring components of the rule. The benefit-cost analysis upon which this decision is based is provided in Chapters Five, Six, and Seven of this RIA. Transient non-community systems, which provide potable water to continuously changing populations, will not be subject to the proposed rule.

The proposed rule also includes modifications to the current monitoring requirements, including the availability of monitoring waivers. A detailed discussion of these changes can be found in Chapter 3.

1.4 Benefits and Costs of the Proposed Rule

Quantitative risk metrics (e.g., slope factors or reference doses) are necessary to evaluate cancer or non-cancer risks. Although arsenic causes numerous health effects, bladder cancer is the only endpoint for which an Agency-approved metric for evaluating arsenic related risk currently exists.

This cancer slope factor (SF) for bladder cancer is used to calculate cases potentially avoided due to EPA's proposed drinking water standards. Benefits estimates for avoided cases of bladder cancer were calculated using mean population risk estimates at various MCL levels. Lifetime risk estimates were converted to annual risk factors, and applied to the exposed population to determine the number of cases avoided. These cases were divided into fatalities and non-fatal cases avoided, based on survival information. The avoided premature fatalities were valued based on the VSL estimates discussed earlier, as recommended by EPA current guidance for cost/benefit analysis. The avoided non-fatal cases were valued based on the willingness to pay estimates for the avoidance of chronic bronchitis. The upper bound estimates include the possibility of the incidence rate being understated, depending on the survival rate for bladder cancer in the study area of Taiwan during the Chen study.

The "What if?" scenario for lung cancer benefits was used to estimate benefits for avoided cases of lung cancer. This scenario is based on the statement in the NRC report "Arsenic in Drinking Water," which states that "some studies have shown that excess lung cancer deaths attributed to arsenic are 2-5 fold greater than the excess bladder cancer deaths (NRC, 1999, pg. 8)." Two-to-five fold greater would be 3.5 fold greater on average. Also in the U.S. the mortality rate from bladder cancer is 26% and the mortality rate of lung cancer is 88%. This suggests that if the risk of contracting lung cancer were identical to the risk of contracting bladder cancer, one would expect 3.4 times the number of deaths from lung cancer as from bladder cancer. Since these numbers are essentially the same, it seems reasonable to assume that the risk of contracting lung cancer is essentially the same as the rate of contracting bladder cancer,[1] in the context of this "what-if" scenario. If the risk of contracting lung cancer from arsenic in drinking water is approximately equal to the risk of contracting bladder cancer, then the combined risk estimates of contracting either bladder or lung cancer would be approximately double the risk estimates of bladder cancer alone.

Numerous other health effects that are likely to be avoided as a result of this rule may generate significant benefits, and should not be discounted based on the fact that they can't be quantified at this time. The estimated total national monetized benefits of the proposed rule and the other rule options considered are provided in Exhibit 1-1.

---

[1]If "X" is the probability of contracting bladder cancer, then 0.26X is the probability of mortality from bladder cancer. If lung cancer deaths are 2 to 5 times as high as bladder cancer, then they are, on average, 3.5 times as high and the average probability of mortality from lung cancer would be 3.5 times 0.26X, or 0.91X. Since we also know that there is a 88% mortality rate from lung cancer, then if the probability of contracting lung cancer is "Y," the probability of mortality from lung cancer can also be represented as 0.88Y. Setting the two ways of deriving the probability of mortality from lung cancer equal, or 0.91X = 0.88Y, one can solve for Y (Y= (0.91/0.88) X). Thus Y is approximately equal to X, and the rate of contracting lung cancer is approximately the same as the rate of contracting bladder cancer.

Exhibit 1-1
Estimated Monetized Total Cancer Health Benefits and Non-Quantifiable Health Benefits from Reducing Arsenic in CWSs

Arsenic Level (µg/L)	Annual Bladder Cancer Health Benefits ($millions)[1,2]	"What-if" Scenario and Potential Non-Quantifiable Health Benefits	
		"What-if" Scenario Annual Lung Cancer Health Benefits ($millions)[1,3]	Potential Non-Quantifiable Health Benefits
3	$43.6 - $104.2	$47.2 - $448.0	• Skin Cancer • Kidney Cancer • Cancer of the Nasal Passages • Liver Cancer • Prostate Cancer • Cardiovascular Effects • Pulmonary Effects • Immunological Effects • Neurological Effects • Endocrine Effects • Reproductive and Developmental Effects
5	$31.7 - $89.9	$35.0 - $384.0	
10	$17.9 - $52.1	$19.6 - $224.0	
20	$7.9 - $29.8	$8.8 - $128.0	

1. May 1999 dollars.
2. The lower-end estimate is calculated using the lower-end number of bladder cancer cases avoided (see Exhibit 5-12) and assumes that the conditional probability of mortality among the Taiwanese study group was 100 percent. The upper-end estimate is calculated using the upper-end number of cancer cases avoided (see Exhibit 5-12) and assumes that the conditional probability of mortality among the Taiwanese study group was 80 percent.
3. These estimates are based on the "what if" scenario for lung cancer, where the risks of a fatal lung cancer case associated with arsenic are assumed to be 2-5 times that of a fatal bladder cancer case.

For the proposed MCL of 5 µg/L, the estimated monetized bladder cancer health benefits range from $31.7 million to $89.9 million. Potential lung cancer health benefits, based on the "What-if" scenario, range from $35.0 million to $384.0 million. More detail about these benefit estimates are found in Chapter 5. Exhibit 1-2 shows the estimated national cost of compliance of the proposed rule and the other rule options that were considered. At the proposed MCL of 5 µg/L, the estimated national cost of compliance is $379 million at a discount rate of 3 percent, and $442 million at a discount rate of 7 percent.

Exhibit 1-2
Total National Cost of Compliance ($ millions)

	CWS		NTNC*		TOTAL	
Discount Rate	**3%**	**7%**	**3%**	**7%**	**3%**	**7%**
MCL = 3 μg/L						
System Costs						
Treatment	$639.2	$746.4	--	--	$639.2	$746.4
Monitoring/ Administrative	$2.2	$3.0	$0.9	$1.1	$3.1	$4.1
State Costs	$1.6	$1.9	$0.6	$0.7	$2.2	$2.6
TOTAL COST	$643.1	$751.4	$1.5	$1.8	$644.6	$753.2
MCL =5 μg/L						
System Costs						
Treatment	$374.0	$436.0	--	--	$374.0	$436.0
Monitoring/ Administrative	$2.0	$2.8	$0.9	$1.1	$2.9	$3.9
State Costs	$1.3	$1.6	$0.6	$0.7	$2.0	$2.3
TOTAL COST	$377.3	$440.4	$1.6	$1.8	$378.9	$442.2
MCL = 10 μg/L						
System Costs						
Treatment	$160.4	$186.7	--	--	$160.4	$186.7
Monitoring/ Administrative	$1.8	$2.5	$1.0	$1.1	$2.8	$3.7
State Costs	$1.1	$1.3	$0.6	$0.7	$1.7	$2.1
TOTAL COST	$163.3	$190.5	$1.6	$1.9	$164.9	$192.4
MCL =20 μg/L						
System Costs						
Treatment	$58.9	$68.3	--	--	$58.9	$68.3
Monitoring/ Administrative	$1.7	$2.4	$1.0	$1.1	$2.7	$3.5
State Costs	$1.0	$1.2	$0.7	$0.7	$1.6	$1.9
TOTAL COST	$61.6	$71.8	$1.6	$1.9	$63.2	$73.7

*Costs include treatment, O&M, monitoring, and administrative costs to CWSs, monitoring and administrative costs to NTNCWSs, and State costs for administration of water programs.

The net benefits and benefit-cost ratios of each regulatory option are provided in Exhibit 1-3, when only health benefits for bladder cancer cases avoided are quantified. At the proposed MCL of 5 μg/L, the net benefits range from a high of -$287.4 million to a low of -$345.6 million, at a discount rate of 3 percent. These net benefits correspond to benefit-cost ratio of 0.24 and 0.08 (also at a 3 percent rate of discount). At a 7 percent discount rate the net benefits range from a high of -$350.5 million to a low of -$408.7 million. These net benefits correspond to benefit-cost ratio ranging from 0.20 to 0.07 (also at a seven percent rate of discount).

Exhibit 1-3
Net Benefits and Benefit-Cost Ratios of Each Regulatory Option (Bladder Cancer Cases Only, in $ millions)

	MCL (μg/L)	3	5	10	20
3% Discount Rate					
lower bound	Net Benefits	$ (599.5)	$ (345.6)	$ (145.4)	$ (53.7)
	Benefit/Cost Ratio	0.07	0.08	0.11	0.13
upper bound	Net Benefits	$ (538.9)	$ (287.4)	$ (111.2)	$ (31.8)
	Benefit/Cost Ratio	0.16	0.24	0.32	0.48
7% Discount Rate					
lower bound	Net Benefits	$ (707.8)	$ (408.7)	$ (172.6)	$ (63.9)
	Benefit/Cost Ratio	0.06	0.07	0.09	0.11
upper bound	Net Benefits	$ (647.2)	$ (350.5)	$ (138.4)	$ (42.0)
	Benefit/Cost Ratio	0.14	0.20	0.27	0.42

*Costs include treatment, O&M, monitoring, and administrative costs to CWSs, monitoring and administrative costs to NTNCWSs, and State costs for administration of water programs.
The lower-end estimate of bladder cancer cases avoided is calculated using the lower-end risk estimate (see Exhibit 5-9) and assumes that the conditional probability of mortality among the Taiwanese study group was 100 percent. The upper-end estimate of bladder cancer cases is calculated using the upper-end risk estimate (see Exhibit 5-9) and assumes that the conditional probability of mortality among the Taiwanese study group was 80 percent.

As mentioned above, there are a number of important non-monetized benefits of reducing arsenic exposure that are not include in the net benefit and benefit-cost calculations. Chief among these are certain health impacts known to be caused by arsenic (such as skin cancer). In 1988 EPA published a risk estimate which used the skin cancer data from Taiwan. EPA calculated a Maximum Likelihood Estimate (MLE) for skin cancer of 3×10^{-5} for females and 7×10^{-5} for males drinking 2 liters a day contaminated with 1 µg/L of arsenic. At the current MCL of 50 µg/L and two liters per day, the risk would be 5×10^{-3}. A number of epidemiologic studies conducted in several countries (e.g., Taiwan, Japan, England, Hungary, Mexico, Chile, and Argentina) report an association between arsenic in drinking water and skin cancer in exposed populations. Studies conducted in the U.S. have not demonstrated an association between inorganic arsenic in drinking water and skin cancer. However, these studies may not have included enough people in their design to detect these types of effects.

The potential monetized benefits associated with skin cancer reduction would not change the total benefits of the rule to an appreciable degree, even if the assumption were made that the risk of skin cancer were equivalent to that of bladder cancer, using EPA's 1988 risk assessment. Skin cancer is highly treatable (at a cost of illness of less than $3,500 for basal and squamous cell carcinomas vs. a cost-of-illness of $178,000 for non-fatal bronchitis) in the U.S., with few fatalities (less than one percent).

In addition to potentially reducing the risk of skin and lung cancer, there are also a large number of other health effects associated with arsenic, as presented in Exhibit 1-1, which are not monetized in this analysis, due to lack of appropriate data.

Other benefits not monetized in this analysis include customer peace of mind from knowing drinking water has been treated for arsenic and reduced treatment costs for currently unregulated contaminants that may be co-treated with arsenic. To the extent that reverse osmosis is used for arsenic removal, these benefits could be substantial. Reverse osmosis is the primary point of use treatment, and it is expected that very small systems will use this treatment to a significant extent. (These benefits of avoided treatment cannot currently be monetized; however, they can be readily monetized in the future, as decisions are made about which currently unregulated contaminants to regulate.)

Chapter 2: Need for the Proposal

2.1 Introduction

The Safe Drinking Water Act (SDWA), as amended in 1996, requires the EPA to identify and regulate substances in drinking water that may have an adverse effect on public health and that are known or anticipated to occur in public water supplies. National Primary Drinking Water Regulations (NPDWRs) address risks to public health, and secondary regulations address aesthetic qualities (such as taste, odor, or color) that relate to public acceptance of drinking water. For NPDWRs, EPA must either establish a Maximum Contaminant Level (MCL) or, if it is not economically or technically feasible to monitor the contaminant in drinking water, specify a treatment technique to remove the contaminant or reduce its concentration in the water supply.

An enforceable standard of 50 µg/L currently exists for arsenic in community water systems under the National Interim Primary Drinking Water Regulations (40 CFR 59566). In §1412(b)(12)(A) of the SDWA, as amended in 1996, Congress specifically directed EPA to propose a NPDWR for arsenic by January 1, 2000 and issue the final regulation by January 1, 2001. At the same time, Congress directed EPA to develop a research plan to reduce the uncertainty in assessing health risks from low levels of arsenic by February 2, 1997 and conduct the research in consultation with the National Academy of Sciences, other Federal agencies, and interested public and private entities.

This document analyzes the impacts of the proposed rule which revises the current standard as follows:

1) reduces the current MCL for arsenic in community water systems from 50 µg/L to 5 µg/L;
2) requires nontransient non-community water systems (NTNC) to perform compliance monitoring; and
3) revises the current monitoring requirements to make them consistent with the Standard Monitoring Framework (40 CFR 141.23(c)).

Executive Order 12866, *Regulatory Planning And Review*, requires EPA to estimate the costs and benefits of the Arsenic Rule in a *regulatory impact analysis* (RIA). This chapter of the RIA discusses the public health concerns being addressed by the rule, describes the history of regulatory efforts concerning arsenic, and discusses the economic rationale for the rule. Subsequent chapters will accomplish the following:

- discuss the regulatory options considered by EPA (Chapter 3),
- present the results of the baseline analysis (Chapter 4),
- examine the benefits of the proposed rule (Chapter 5),
- present the results of the cost analysis (Chapter 6),
- compare the costs and benefits of the proposed rule and the regulatory options considered by EPA (Chapter 7), and
- discuss the potential economic impacts of the rule (Chapter 8).

2.2 Public Health Concerns to be Addressed

This section describes the public health concerns addressed by the proposed Arsenic Rule. A description of potential health effects associated with arsenic, including effects in sensitive subpopulations, along with the sources of human exposure to arsenic is presented. In addition, the section describes current controls that address exposure to arsenic.

2.2.1 Health Effects of Arsenic

Arsenic is a naturally occurring element present in the environment in both organic and inorganic forms. Inorganic arsenic, the more toxic form, is found in ground water, surface water and many foods. Chronic exposure to arsenic has been found to result in a variety of adverse health effects, including skin and internal cancers and cardiovascular and neurological effects. The available evidence on the health effects of arsenic has recently been reviewed in a report by the National Research Council (NRC) of the National Academy of Sciences (NAS). The health effects of inorganic arsenic are summarized here and are described in more detail in Chapter 5. Exposures to organic forms of arsenic also occur through ingestion of food and metabolism of ingested inorganic arsenic. Experimental data on the effects of organic forms of arsenic are not as well characterized as those for inorganic arsenic, and thus are the subject for future research. Limited data in animals suggest that some organic forms of arsenic also produce cancer and non-cancer health effects.

Cancer

EPA has identified arsenic as a group A “known” human carcinogen, based on increased risks of lung cancer in workers exposed to airborne arsenic and dose-dependent increases in skin cancer risk in Taiwan. Using data from Taiwan, EPA calculated a Maximum Likelihood Estimate (MLE) of 3×10^{-5} for females and 7×10^{-5} for males drinking 2 liters a day contaminated with 1 µg/L of arsenic. The values were combined to give an overall risk of 5×10^{-5} /(µg/L) or 2 µg/L = 1×10^{-4} risk level. The International Agency for Research on Cancer (IARC) has also classified arsenic as a human carcinogen. Epidemiological studies have shown evidence of carcinogenic risk by both inhalation and ingestion.

Unlike most environmental contaminants, there is a large human database available for inorganic arsenic. However, there is substantial debate among the scientific community over the interpretation of these data and their application in risk assessment. A number of epidemiologic studies conducted in several countries (e.g., Taiwan, Japan, England, Hungary, Mexico, Chile, and Argentina) report an association between arsenic in drinking water and skin cancer in exposed populations. Increased mortality from internal cancers of liver, bladder, kidney, and lung have also been reported.

In 1996, EPA requested that the National Research Council (NRC) of NAS conduct an independent review of the arsenic toxicity data. NRC was asked to review EPA’s current criteria (50 µg/L and 0.018 µg/L), evaluate use of recent Taiwan data and other studies to assess the carcinogenic and non-carcinogenic health effects of arsenic, and recommend changes to EPA’s risk characterization for arsenic. NRC issued its report on March 23, 1999. A summary of the

NRC's results are provided below.

Non-Cancer Health Effects

In addition to cancer, arsenic exposures have been reported to result in other adverse health effects. These include thickening of the skin, effects on the nervous system such as tingling and loss of feeling in limbs, hearing impairment, effects on the heart and circulatory system, diabetes, developmental effects, and effects on the gastrointestinal system and liver. Many of these effects are observed at concentrations where cancer effects were observed in the epidemiology studies.

Sensitive Subpopulations

Certain sensitive individuals may be at a greater risk of serious illness from exposure to arsenic than the general population. The NRC report noted that human sensitivity to the toxic effects of inorganic arsenic exposure is likely to vary based on genetics, metabolism, diet, health status, sex, and other possible factors. For example, reduced ability to methylate arsenic (converting inorganic arsenic into less acutely toxic and more readily excreted forms) may result in retention of more arsenic in the body and increased risk of toxic effects.

The following groups are cited in various studies as being particularly susceptible to arsenic:

- **Children** are identified as especially susceptible to health effects from arsenic because their dose of arsenic will be, on average, higher than that of adults exposed to similar concentrations due to their higher fluid and food intake relative to body weight. The NRC report cited one study that suggests that children may have a lower arsenic-methylation efficiency than adults.

- **Pregnant and lactating women** are especially vulnerable because of the adverse reproductive and developmental effects of arsenic.

- **People with poor nutritional status** may have a reduced ability to methylate arsenic.

- **Individuals with pre-existing diseases that affect specific organs –** in particular, kidney and liver problems – may be more susceptible to the effects of arsenic, because these organs act to detoxify arsenic in the body. In addition, arsenic can directly damage these and other organ systems, as described above. Individuals with pre-existing damage or congenital defects in these systems are more susceptible to health effects from exposure to arsenic. The elderly are more likely as a group to have pre-existing conditions in the susceptible organ systems.

Section 5.2.4 discusses the susceptibility of these subgroups in more detail. Due to a lack of available data, no quantitative analysis of the specific risks to sensitive populations was performed as part of this RIA.

2.2.2 Sources and Mechanisms of Exposure

Arsenic is an element that occurs in the earth's crust. Accordingly, there are natural sources of exposure. Erosion and weathering of rocks deposit arsenic in water bodies and lead to the uptake of arsenic by animals and plants. Consumption of food and water are the major sources of arsenic exposure for the majority of U.S. citizens. People may also be exposed from industrial sources, as arsenic is used in semiconductor manufacturing, petroleum refining, wood preservatives, animal feed additives and herbicides.

Arsenic can combine with other elements to form inorganic and organic arsenicals. In general, inorganic derivatives are regarded as more toxic than the organic forms. While food contains both inorganic and organic arsenicals, primarily inorganic forms are present in water.

Recently, EPA developed estimates of human exposure to arsenic in drinking water, food, and air using data from numerous Federal sampling surveys analyzing the occurrence of arsenic in public water supplies, dietary foods, and ambient air. EPA's national air sampling data bases indicate very low concentrations of arsenic in both urban and non-urban locations, at levels typically ranging from about 0.003-0.03 $\mu g/m^3$. Air is therefore an insignificant source of arsenic intake, representing typically less than one percent of overall exposure.

EPA reviewed several local and regional studies for comparison purposes. Using the Food and Drug Administration's (FDA) Total Diet Study, recent dietary analyses indicate that the average adult's total arsenic intake is about 53 µg/day. However, the FDA analytical methodology does not differentiate between the organic and inorganic forms of arsenic. For most people living in the U.S., inorganic arsenic exposure is primarily from food and water sources. Since the inorganic forms are considered to be more toxic, it is important to estimate the amount of inorganic arsenic in the diet. To accomplish this estimation, EPA used the FDA data along with a separate study that characterized arsenic species in foods. This separate characterization indicated that about 20 percent of daily intake of dietary arsenic is in the inorganic form. Conversely, most arsenic present in drinking water is in the form of inorganic arsenic species.

Accounting for the organic forms of arsenic in food, the dietary intake of inorganic arsenic was estimated to be approximately 14 µg/day. An adult drinking 2 L/day of water containing 10 µg/L of arsenic, would obtain 20 µg/day from drinking water, so that drinking water would contribute about 60 percent of total intake of inorganic arsenic. On the other hand, an adult drinking water containing 2 µg/L of arsenic would obtain almost 80 percent of the daily inorganic arsenic from food.

2.3 Regulatory History

This section provides a chronology and overview of regulatory actions affecting arsenic in drinking water and recent efforts that have led to this proposed rule-making. The major studies and data collection efforts that have highlighted the need for new regulation are also summarized.

Current MCL: In 1975, EPA set the National Interim Primary Drinking Water Regulation at 50

μg/L (40 FR 59566 December 24, 1975.) This standard was equal to the standard set in 1943 by the U.S. Public Health Service (US PHS) for interstate water carriers which was not based on a risk assessment. The MCL was based on EPA's assertion that daily consumption of two liters of water provides approximately 10 percent of total ingested arsenic of 900 µg/day. Commenters recommended an MCL of 100 µg/L based on no observed adverse health effects. EPA noted long-term chronic effects at 300 to 2,750 µg/L, but no chronic effects at 120 µg/L (NIPDWRs, EPA-570/9-76-003).

Water Quality Criteria: In 1980, EPA announced the availability of Water Quality Criteria Documents to protect surface water bodies of water from pollutants under the Clean Water Act (45 FR 79318, November 28, 1980). These criteria are used as guidance to the States in establishing surface water quality standards and discharge limits for effluents. The criteria for protection of human health from ingestion of arsenic in contaminated water and aquatic organisms was 2.2 mg/L, or 0.0022 µg/L. In 1992, the Clean Water Act criteria were recalculated with updated cancer slope factor data to yield 0.018 µg/L for arsenic (57 FR 60848, December 22, 1992.).

1985 Proposed MCL: In an Advanced Notice of Proposed Rulemaking (ANPR) published October 5, 1983 (48 FR 45502), EPA requested comment on whether the arsenic MCL should consider carcinogenicity, other health effects, and nutritional requirements; and whether MCLs are necessary for separate valence states. In 1985, EPA then proposed a non-enforceable Maximum Contaminant Level Goal (MCLG) of 50 µg/L based on a NAS conclusion that 50 µg/L balanced toxicity and possible essentiality. EPA also requested comment on alternate MCLGs of 100 µg/L based on non-carcinogenic effects and 0 µg/L based on carcinogenicity (50 FR 46936, November 13, 1985).

1986 SWDA Amendments: The 1986 SDWA Amendments converted the 1975 interim arsenic standard to a NPDWR, subject to revision by 1989.

1988 Risk Assessment Forum Report: EPA's Risk Assessment Forum wrote the Special Report on Ingested Inorganic Arsenic: Skin Cancer; Nutritional Essentiality (EPA/625/3-87/013), in part, to evaluate the validity of applying the Taiwan 1968/1977 data to dose-response assessments in the U.S. At the 50 µg/L standard, the calculated U.S. lifetime risk ranged from 1×10^{-3} to 3×10^{-3}.

1989: After reviewing EPA's arsenic health effects studies in June 1988, the Science Advisory Board (SAB) stated in its August 14, 1989, report the following:

- The essentiality of arsenic is suggestive but not definitive;
- Hyperkeratosis may not be a precursor of skin cancer;
- The Taiwan data are adequate to conclude that high doses of ingested arsenic can cause skin cancer;
- The Taiwan study is inconclusive to determine cancer risk at levels ingested in the U.S.; and
- As (III) levels below 200 to 250 µg per day may be detoxified.

SAB concluded that the dose-response is nonlinear and reported that the 1988 Forum Report did not apply nonlinearity in its risk assessment.

1989: Uncertainty about arsenic risk assessment issues caused the Agency to miss the 1989 deadline for proposing a revised NPDWR, and a citizen suit was filed against EPA. A consent decree was entered by the court in June, 1990, and was amended several times thereafter before being dismissed after passage of the 1996 SDWA Amendments.

1994: EPA thoroughly reviewed the available information and determined that:

- There is evidence of an association between internal cancer and arsenic;
- The risk of internal cancer cannot be quantified using the available epidemiological data; and
- The risk assessment will be based on the existing quantified skin cancer risk with a hazard identification for internal cancer.

The Safe Drinking Water Act Amendments of 1996, in Section 1412(b)(12)(A) pertaining to arsenic, directed EPA to take the following actions:

- Develop an arsenic research strategy within 180 days of enactment;
- Propose a revised MCL by January 1, 2000;
- Issue a final regulation by January 1, 2001;
- Assess health effects for sensitive populations;
- List both compliance and variance treatment technologies for small systems;
- Evaluate the incremental costs and benefits of different regulatory options, accounting for the changes that may result from implementation of other rules;
- Issue an MCL that maximizes health benefits at a cost that is justified by the benefits;
- Review MCLs every six years or sooner.

The 1996 amendments also made the following changes:

- The effective date of MCLs is three-to-five years after promulgation of the final rule.
- Compliance can be achieved by use of point-of-use (POU) or point-of-entry (POE) devices that are maintained by the public water system;

Congress authorized $2.5 million per year from 1997-2000 for the studies. In 1996 and 1997, Congress appropriated $1 million each year for arsenic research.

EPA is proposing this rule to meet the deadlines specified in the 1996 Amendments. At the same time, EPA is proceeding with its Arsenic Research Plan, which will address a variety of issues related to exposure, treatment, and health effects.[1]

NRC Report: As mentioned above, In 1996, EPA requested that the National Research Council (NRC) of NAS conduct an independent review of the arsenic toxicity data and evaluate the scientific validity of EPA's 1988 risk assessment for arsenic in drinking water. In addition, NRC was asked to review EPA's current criteria (50 µg/L and 0.018 µg/L), evaluate use of recent Taiwan data and other studies to assess the carcinogenic and non-carcinogenic health effects of arsenic, and recommend changes to EPA's risk characterization for arsenic. NRC issued its

---

[1]The Arsenic Research Plan is published at http://www.epa.gov/ORD/WebPubs/final/arsenic.pdf.

report on March 23, 1999. The report had four conclusions:

- The Taiwan studies provide the best available evidence on the human health effects of arsenic, and are supported by studies in Chile and Argentina which report similar results. These studies show that chronic ingestion of inorganic arsenic at high doses causes bladder and lung cancer, as well as skin cancer.
- Noncancer effects from chronic ingestion of arsenic have been detected at doses of 0.01 mg/kg per day and higher.
- There is a need for more research to characterize the dose-response relationship for both cancer and non-cancer endpoints, especially at low doses.
- The current 50 µg/L MCL is not adequately protective of human health, and therefore requires downward revision as promptly as possible.[2]

2.4 Rationale for the Regulation

This section discusses the economic rationale for choosing a regulatory approach to address the public health consequences of drinking water contamination. EPA proves the economic rationale in response to Executive Order Number 12866, *Regulatory Planning and Review*, which states:

> [E]ach agency shall identify the problem that it intends to address (including, where applicable, the failures of the private markets or public institutions that warrant new agency action) as well as assess the significance of that problem (Section 1, b(1)).

In addition, OMB guidance dated January 11, 1996, states that “in order to establish the need for the proposed action, the analysis should discuss whether the problem constitutes a significant market failure” (p.3). Therefore, the economic rationale presented in this section should not be interpreted as the agency’s approach to implementing the Safe Drinking Water Act (SDWA). Instead, it is the agency’s justification, as required by the Executive Order, for a *regulatory approach* to this public health issue.

2.4.1 Statutory Authority

Section 1412(b)(1)(A) of the Safe Drinking Water Act requires EPA to establish National Primary Drinking Water Regulations for contaminants that may have an adverse public health effect, that are known to occur, or present a substantial likelihood of occurring once in public water systems (PWSs), at a frequency and level of public health concern and that present a meaningful opportunity for health risk reduction for persons served by PWSs. This general provision is supplemented with an additional requirement under Section 1412(b)(12)(A) that EPA propose a revised MCL for arsenic by January 1, 2000, and issue a final regulation by January 1, 2001.

[2] The NRC report is available at http://www.nap.edu/readingroom/enter2.cgi?0309063337.html

2.4.2 Economic Rationale for Regulation

In addition to the statutory directive to regulate arsenic, there is also economic rationale for government regulation. In a perfectly competitive market, market forces guide buyers and sellers to attain the best possible social outcome. A perfectly competitive market occurs when there are many producers of a product selling to many buyers, and both producers and buyers have complete knowledge regarding the products of each firm. There must also be no barriers to entry in the industry, and producers in the industry must not have any advantage over potential new producers. Several factors in the public water supply industry do not satisfy the requirements for a perfect market and lead to market failures that may require regulation.

First, water utilities are natural monopolies. A natural monopoly exists because it is not economically efficient to have multiple suppliers competing to build multiple systems of pipelines, reservoirs, wells, and other facilities.[3] Instead, a single firm or government entity performs these functions generally under public control. Under monopoly conditions, consumers are provided only one level of service with respect to the quality of the product, in this case drinking water quality. If consumers do not believe the margin of safety in public health protection is adequate, they cannot simply switch to another water utility or perceived higher quality source of supply (e.g., bottled water) without incurring additional cost.

Second, there are high information and transaction costs that impede public understanding of the health and safety issues concerning drinking water quality. The type of health risks potentially posed by trace quantities of drinking water contaminants involve analysis and distillation of complex toxicological data and health sciences. EPA recently developed the Consumer Confidence Report rule to make water quality information more easily available to consumers. The Consumer Confidence Report rule requires community water systems to mail their customers an annual report on local drinking water quality. However, consumers will still have to analyze this information for its health risk implications. Even if informed consumers are able to engage utilities regarding these health issues, the costs of such engagement, known as "transaction costs," (in this case measured in personal time and commitment) present another significant impediment to consumer expression of risk preference.

SDWA regulations are intended to provide a level of protection from exposure to drinking water contaminants that would not otherwise occur in the existing market environment of public water supply. The regulations set minimum performance requirements for all public water supplies in order to reduce the risk confronted by all consumers from exposure to drinking water contaminants. SDWA regulations are not intended to restructure market mechanisms or to establish competition in supply. Rather, SDWA standards establish the level of service to be

---

[3]Mansfield (1975) states that natural monopolies exists because the average cost of producing the product reaches a minimum at an output rate that is enough to satisfy the entire market at a price that is profitable. Multiple producers competing would produce the product at higher than minimum long-run average cost. competition to achieve lower average costs would drive prices down until a single supplier is victorious.

provided in order to better reflect public preference for safety. The Federal regulations remove the high information and transaction costs by acting on behalf of all consumers in balancing the risk reduction and the social costs of achieving this reduction.

Chapter 3: Consideration of Regulatory Alternatives

3.1 Regulatory Approaches

The Safe Drinking Water Act (SDWA) establishes EPA's responsibility for ensuring the quality of drinking water, and defines the mechanisms available to the Agency to protect public health. Specifically, the SDWA requires EPA to set enforceable MCLs when technically or economically feasible or otherwise establish treatment technique requirements for specific contaminants in drinking water. In meeting this mandate, EPA sets water quality standards by identifying which contaminants should be regulated and establishing the levels of the contaminant water systems must attain. This section discusses the approach EPA used in determining the regulatory alternatives that have been considered.

3.1.1 Determining the Standard

In regulating a contaminant, EPA first sets a maximum contaminant level goal (MCLG), which establishes the contaminant level at which no known or anticipated adverse health effects occur. MCLGs are non-enforceable health goals. For this rulemaking, EPA is proposing an MCLG of zero. EPA then sets an enforceable maximum contaminant level (MCL) as close as technologically possible to the MCLG. In addition, EPA may use its discretion in setting the MCL by choosing an MCL that is protective of public health while also insuring that the quantified and non-quantified costs are justified by the quantified and non-quantified benefits of the rule. For this rulemaking, EPA is proposing an MCL of 5 µg/L. The following sections describe the process by which EPA determined both the MCLG and the MCL.

3.1.2 Determining the MCLG

Carcinogens: For many years, Congress supported a goal of zero tolerance for carcinogens in food and water, and that goal was incorporated into the SDWA of 1974. Under this policy, contaminants that are classified as probable human carcinogens have had MCLGs set at zero. EPA's Office of Science and Technology (OST) (in the Office of Water) develops a cancer risk range that quantifies the probability that a person will develop cancer during a lifetime of ingesting water containing the regulated contaminant. Mathematical models have been used to calculate the drinking water concentration that would lead to excess cancer risks of 10^{-5} to 10^{-6} from exposure to the carcinogen.

Data used in risk estimates usually come from lifetime exposure studies in animals. To predict the risk for humans, the oral doses used in animal studies are corrected for differences in animal and human size and surface area.

In 1986, EPA published <u>Guidelines for Carcinogen Risk Assessment</u> in the Federal Register (51 FR 33992). At that time EPA's default assumptions included low-dose linearity to extrapolate the cancer risk range, which assumes that carcinogenic effects do not exhibit a threshold and that carcinogens pose risks to humans at any concentration. EPA proposed revised Guidelines for Carcinogen Risk Assessment in 1996 (61 FR 17960).

Noncarcinogens: MCLGs for noncarcinogens are based on Reference Doses (RfDs) and their Drinking Water Equivalent Levels (DWELs).

The Reference Dose (RfD, formerly the Acceptable Daily Intake, or ADI), estimates the daily amount of chemical a person, including sensitive humans, can ingest over a lifetime with little risk of causing adverse health effects. RfDs are usually expressed in milligrams of chemical per kilogram of body weight per day (mg/kg/day). Data from chronic (usually two years) or sub-chronic (usually 90 days) studies of humans or animals provide estimates of the No- or- Lowest-Observed-Adverse-Effect Level (NOAEL or LOAEL). The NOAEL (or LOAEL) is divided by a total uncertainty factor (UF) of 1 to 10,000 to obtain the RfD. In the final National Primary Drinking Water Regulations published on January 30, 1991 (56 FR 3532), EPA applies a UF of 1, 3, or 10 when a NOAEL from a human study is used to account for intraspecies variation and an uncertainty factor of 100 to a human LOAEL to account for lack of a NOAEL and for species variation. The UFs provide a margin for variations in species responses, data gaps, and less than lifetime exposures. Scientific judgement is used to select the total UF factor for specific risk assessments.

The Drinking Water Equivalent Level (DWEL) is calculated by multiplying the RfD by an assumed adult body weight of 70 kg (approx. 154 pounds) and dividing by an average adult water consumption of 2 liters per day (L/day). The DWEL assumes that 100 percent of the exposure comes from drinking water. The MCLG is then determined by multiplying the DWEL by the percentage of the total daily exposure contributed by drinking water (relative source contribution), set at 20% by default when adequate data are not available, but set between 20 and 80 percent when adequate data are available to estimate exposure. Based on the 1993 RfD (1993 Draft Criteria) for arsenic (0.3 µg/kg/day), the calculated DWEL would be 0.3 µg/kg/day times 70 kg divided by 2 L/day, or 10 µg/L. Due to the three-fold uncertainties noted in the IRIS file on arsenic, the DWEL could be 3 to 30 µg/L. It should be noted that the toxicological studies used to determine the effect level and the derivation of the RfD are different from the analysis conducted in 1975. Additionally, the current policy on relative source contribution, including the default policy are also different from those used in 1975.

3.1.3 Determining an MCL

Once an MCLG is established, EPA sets an enforceable standard – in most cases, a Maximum Contaminant Level (MCL). The MCL is the maximum permissible level of a contaminant in water that is delivered to any user of a public water system. EPA must set the MCL as close to the MCLG as feasible. The SWDA defines feasible as the level that may be achieved with the use of the best available technology, treatment techniques, and other means which EPA finds are available (after examination for efficacy under field conditions), taking cost to large systems into consideration.

After determining an MCL based on affordable technology for large systems, EPA must complete an economic analysis to determine whether the benefits of the standard justify the costs. If not, EPA may adjust the MCL for a particular class or group of systems to a level that "maximizes health risk reduction benefits at a cost that is justified by the benefits" (§1412(b)(6)).

3.1.4 Variances and Exemptions

The 1996 SDWA identifies two classes of technologies for small systems: compliance and variance technologies. A compliance technology is one that achieves compliance with the MCL or treatment technique requirement. The 1996 Amendments require EPA to list affordable compliance technologies for three categories of small systems: those serving 25 to 500 people, those serving 501 to 3,300 people, and those serving 3,301 to 10,000 people. If EPA cannot identify an affordable compliance technology for a particular system category, it must then identify a variance technology instead. The variance technology must achieve the maximum reduction that is affordable, considering the size of the system and the quality of the source water, and must be protective of public health. If EPA lists such a variance technology, small systems will be eligible to apply to the States for a small system variance. States are authorized to grant variances from standards for systems serving up to 3,300 people if the system cannot afford to comply with a rule and the system installs the EPA-approved variance technology. States can grant exemptions to systems serving 3,301 - 10,000 people with EPA approval.

The Agency published draft national-level affordability criteria in the August 6, 1998, *Federal Register* (63 FR 42302). The draft criteria discuss affordable treatment technology determinations for contaminants regulated before 1996. An average expenditure level of up to $500 per year was considered affordable for those contaminants. Since EPA identified treatment technologies for all pre-1996 contaminants with average per household costs below $500 per year, the Agency did not list any small system variance technologies.

EPA expects the national-level affordability criteria to be lower than $500 per household per year for the arsenic rule because water rates are currently increasing faster than median household income, and because the baseline for annual water bills will rise as treatment is installed to comply with regulations promulgated after 1996. As part of this RIA, a household level cost analysis was done to determine if EPA needs to list variance technologies (Chapters 6 and 8).

3.1.5 Analytic Methods

Determination of an MCL depends on the ability of laboratories to reliably measure the contaminant at the MCL. The SDWA directs EPA to set an MCL "if in the judgement of the Administrator, it is economically and technologically feasible to ascertain the level of such contaminant in water in public water systems (Section 1401 (1)(c)(ii))." EPA must therefore evaluate the available analytical methods to determine a Practical Quantification Level (PQL), which is the minimum reliable quantification level that most laboratories can be expected to meet during day-to-day operations.

EPA has approved several analytical methods to support compliance monitoring of arsenic at the current MCL (40 CFR 141.23). In 1994, EPA evaluated available data and determined the PQL for arsenic to be 2.0 μg/L at an acceptable limit of ± 40%. In its July 1995 report, EPA's Science Advisory Board recommended that EPA set the PQL for arsenic using acceptance limits similar to those applied for other inorganics (± 20% or ± 30 %). Based on more recent information and these acceptance limits, EPA has established a 1999 PQL for arsenic of 3 μg/L (EPA, MOM 1999) with an acceptance limit of ± 30 percent. While the PQL represents a stringent target for laboratory performance, the Agency believes most laboratories, using appropriate quality assurance and quality control procedures, have the capacity to achieve this level on a routine basis. Available data suggest that 75 percent of EPA Regional and State laboratories and 62 percent of non-EPA laboratories were capable of achieving acceptable results at 3 μg/L.

3.2 Regulatory Alternatives Considered and Proposed Rule

This section describes the components of the proposed rule and the alternatives that were considered by the Agency.

3.2.1 Applicability

The Agency investigated applying both the monitoring and treatment requirements of the proposed rule to both community water systems (CWS) and non-transient non-community water systems (NTNC). A CWS is defined as a system that provides piped water to at least 25 people or with at least 15 service connections year-round. A NTNC is a public water systems that is not defined as a CWS and that regularly serves at least 25 of the same people for at least six months of the year. After considering the costs and benefits of the proposed rule with regard to both CWSs and NTNCs, EPA proposes to require CWS to comply with all facets of the proposed rule, while only requiring NTNCs to comply with the monitoring components of the rule. The benefit-cost analysis upon which this decision is based is provided in Chapters Five, Six, and Seven of this RIA. Transient non-community systems, which provide potable water to continuously changing populations, will not be subject to the proposed rule. The rule applies to CWSs and NTNCs that produce water from either primarily ground or surface water sources.

3.2.2 MCL

EPA considered a range of MCLs in developing the proposed Arsenic Rule, including MCLs of 3, 5, 10, and 20 μg/L. EPA evaluated the following five factors to determine the proposed Maximum Contaminant Level (MCL):

- the analytical capability and laboratory capacity,
- likelihood of water systems choosing various compliance technologies for several sizes of systems based on source water properties,
- the national occurrence of arsenic in water supplies.
- quantified and non-quantified costs and health risk reduction benefits likely to occur at the MCLs considered, and
- the effects on sensitive subpopulations.

An MCL of 3 μg/L was considered since this is the level that has been determined to be as close to the MCLG as is feasible. However, the Agency is using its discretionary authority in Section 1412(b)(6)(A) to consider setting MCL at a less stringent level. The statute requires that the alternative less stringent level be one which maximizes health risk reduction at a level where costs and benefits are balanced. As a result, EPA considered the alternative MCL options of 5, 10, and 20 μg/L. These alternative MCL options were considered because they also provide assurance that the residual risk for both bladder and lung cancer endpoints will be in the 10^{-4} range, but at lower anticipated national costs.

3.2.3 Monitoring

The current monitoring requirements for arsenic (40 CFR 141.23(l)) apply to community water systems only. EPA is proposing to change the current monitoring requirements and require systems to monitor for arsenic in accordance with the provisions of 40 CFR 141.23(c), the Standard Monitoring Framework (SMF). This change will make the arsenic requirements consistent with the requirements for inorganic contaminants (IOCs) regulated under the Phase II/V regulations. The proposal would make the following changes to the monitoring requirements for arsenic:

- NTNC systems will be required to monitor for arsenic for the first time.
- MCL exceedances will trigger quarterly monitoring, as opposed to the current requirements for three additional samples within one month when exceedances occur.
- The State will determine when the system is "reliably and consistently" below the MCL, after a minimum number of samples following an exceedance (two sample for ground water systems and four for surface water systems), and can return to the default sampling frequency. (Currently, the system automatically returns to the default monitoring frequency when a minimum of two consecutive samples are below the MCL).
- States may grant a nine year monitoring waiver to a system, if it finds that arsenic detections are the result of natural occurrence and not from human activity. (Currently, no monitoring waivers are permitted).

3.2.4 Compliance Technologies and Variances

EPA reviewed several technologies as BAT candidates for arsenic removal. Those technologies capable of removing arsenic from source water that fulfill the SDWA requirements for BAT determinations for arsenic are as follows:

- ion exchange;
- activated alumina;
- reverse osmosis ;
- coagulation assisted microfiltration;
- modified coagulation/filtration;
- modified lime softening;
- point-of-use RO/AA; point-of-entry AA ; and
- oxidation/filtration (including greensand filtration).

EPA has further determined that these technologies are affordable for all system size categories and has therefore not identified a variance technology for any system size or source water combination at the proposed MCL.

3.2.5 Monitoring Waivers

Under the proposed Arsenic Rule (§141.23(c)(3)), States may grant a nine year monitoring waiver from sampling requirements to water systems based on the analytical results from previous sampling and a vulnerability assessment or the assessment from an approved source water assessment program (provided that the assessments were designed to collect all of the necessary information needed to complete a vulnerability assessment for a waiver). States issuing waivers must consider the requirements in 40 CFR 141.23(c)(2)-(6). In order to qualify for a waiver, there must be three previous samples from a sampling point (annual for surface water and three rounds for ground water) with analytical results reported below the proposed MCL (i.e., the reporting limit must be < 0.005 mg/L). The use of grandfathered data collected after January 1, 1990, that is consistent with the analytical methodology and detection limits of the proposed regulation may be used for issuing sampling point waivers.

The current arsenic regulations §141.23(l)-(q) do not permit the use of monitoring waivers. However, a State could now use the analytical results from the three previous compliance periods (1993 to 1995, 1996 to1998, and 1999 to 2001) to issue ground water sampling point waivers. Surface water systems must collect annual samples so a State could use the previous three years sampling data (1999, 2000, and 2001) to issue sampling point waivers. One sample must be collected during the nine-year compliance cycle that the waiver is effective, and the waiver must be renewed every nine years. Vulnerability assessments must be based on a determination that the water system is not susceptible to contamination and arsenic is not a result of human activity (i.e., it is naturally occurring).

Although the approved analytical methods can measure to 0.005 mg/L, not all States have required systems to report arsenic results below 50 µg/L. In this case, the States would not have adequate data to grant waivers until enough data is available to make the determinations.

EPA believes that some States may have been regulating arsenic under the proposed standardized inorganic framework. If so, those States will have to ensure that existing monitoring waivers have been granted using data reported below the new proposed MCL. Otherwise States will have to notify the systems of the new lower reporting requirements that need to be met to qualify for a waiver for the proposed MCL.

3.2.6 Implementation

The following schedule is proposed for implementation of the proposed rule:

- States must submit applications for primacy revisions within two years after promulgation, unless the State requests and is granted a two year extension.
- The rule will be effective three years after promulgation (January 1, 2004).
- All systems must complete initial sampling by December 31, 2004.
- If capital improvements are needed to achieve compliance, systems may apply to the State for a two year extension.

If EPA makes a national finding that capital improvements are necessary at the majority of systems, then the rule will become effective five years after promulgation (January 1, 2006). In this case, systems will have to complete the initial round of monitoring by December 31, 2007 (for ground water systems), or December 31, 2006 (for surface water systems.)

Chapter 4: Baseline Analysis

4.1 Introduction

This chapter presents baseline information to describe the operational and financial characteristics of water systems in the absence of the proposed Arsenic Rule. The baseline information provides a basis for EPA's analysis of the costs, benefits and economic impacts of the regulatory options considered. This chapter includes data on the number of water systems regulated, the population affected, current treatment practices, raw and treated water quality, and socio-economic impacts. In addition, this chapter provides information to support the Agency's national-level affordability determination.

The baseline is assumed to be current conditions, as reflected in the most recent available data. In some cases, changes in the industry have occurred or will occur that are not reflected in the available data; for example, changes in operations induced by a regulation that will take effect prior to the Arsenic Rule.

4.2 Industry Profile

4.2.1 Definitions

According to EPA's definition, public water systems (PWSs) include community water systems (CWSs) and non-community water systems (NCWSs). NCWSs are further classified as either transient or non-transient. The proposed rule will affect all public water systems except for transient non-community water systems. The following definitions will help the reader follow the discussion in this chapter:

- **Public water systems (PWS)** serve 25 or more people or has 15 or more service connections and operates at least 60 days per year. A PWS can be publicly-owned or privately-owned.
- **Community water systems (CWS)** serve at least 15 service connections used by year-round residents, or regularly serve at least 25 year-round residents.
- **Non-community water systems (NCWS)** do not have year-round residents, but serve at least 15 service connections used by travelers or intermittent users for at least 60 days each year, or serve an average of 25 individuals for at least 60 days a year.
- **Non-transient non-community water systems (NTNC)** serve at least 25 of the same persons over six months per year (e.g., factories, schools, office buildings, and hospitals).
- **Transient non-community water systems (TNC)** serve fewer than 25 of the same persons over six months per year (e.g., many restaurants, rest stops, parks).

Public water systems are also classified by their water source as being surface water (e.g., drawn from lakes, streams, rivers, etc.) or ground water (e.g., drawn from wells or springs).

4.2.2 Sources of Industry Profile Data

EPA uses two primary sources of data to characterize the universe of ground water systems: the Safe Drinking Water Information System (SDWIS) and the Community Water System Survey (CWSS).

EPA's SDWIS contains data on all PWSs as reported by States and EPA regions. This source reflects both mandatory and optional reporting components. States must report the system location, system type (CWS, NTNC, or TNC), primary raw water source (ground water or surface water), and violations. Optional reporting fields include type of treatment and ownership type. Because providing some data is discretionary, EPA does not have complete data on every system for these parameters. This is particularly common for non-community systems.

The second source of information, the CWSS, is a detailed survey of surface and ground water CWSs conducted by EPA in 1995 and published in 1997 (EPA, 1997). The CWSS is stratified to represent the complete population of CWSs across the U.S. The CWSS includes information such as revenues, expenses, treatment practices, source water protection measures, and plant capacity. There is no equivalent survey such as the CWSS to define treatment practices in non-community water systems.

4.2.3 Number and Size of Public Water Systems

Exhibit 4-1 shows the number of systems in the U.S. by source water (ground or surface) and system size (measured by the number of people served), based on the December 1998 SDWIS data. In the U.S. there are a total of 63,984 ground water systems and 11,843 surface water systems, including CWSs and NTNCs. All are potentially affected by the proposed Arsenic Rule.

Some ground water sources (e.g., riverbank infiltration/galleries) are directly impacted by adjacent source water bodies and are separately identified in SDWIS as ground water under the direct influence of surface water (GWUDI). Since these systems would have similar occurrence as surface water systems, GWUDI systems are considered surface water systems in this analysis. SDWIS also provides system data by ownership. As previously described, PWSs include both publicly-owned and privately-owned systems. This detail is also provided in Exhibit 4-1, where any systems referred to as "other" in the SDWIS database has been presented as a privately-owned system.

The majority (95%) of PWSs are small systems that serve fewer than 10,000 people. 89 percent of PWSs serve 3,300 people or fewer; 77 percent serve fewer than 1,000 people; 67 percent serve fewer than 500 people; and 34 percent serve fewer than 100 people.

Exhibit 4-1
Total Number of Systems by Size, Type, and Ownership

SOURCE	<100	101-500	501-1,000	1,001-3,300	3,301-10,000	10,001-50,000	50,001-100,000	100,001-1,000,000	TOTAL
CWS									
Ground Water									
Public	1,335	4,678	2,868	4,167	1,993	1,011	105	50	16,207
Private	12,942	10,380	1,821	1,547	466	205	26	11	28,303
Total	14,277	15,058	4,689	5,714	2,459	1,216	131	61	44,510
Surface Water									
Public	394	1,117	917	2,012	1,656	1,436	260	217	8,009
Private	698	886	303	408	188	171	40	44	3,053
Total	1,092	2,003	1,220	2,420	1,844	1,607	300	261	11,062
Total	15,369	17,061	5,909	8,134	4,303	2,823	431	322	54,352
NTNCWS									
Ground Water									
Public	1,725	3,108	1,163	337	23	9	0	0	6,365
Private	7,965	3,930	815	355	39	5	0	0	13,109
Total	9,690	7,038	1,978	692	62	14	0	0	19,474
Surface Water									
Public	58	63	19	24	6	3	1	1	175
Private	213	232	87	56	17	1	0	0	606
Total	271	295	106	80	23	4	1	1	781
Total	9,961	7,333	2,084	772	85	18	1	1	20,255

Source: Safe Drinking Water Information System (SDWIS), December 1998 freeze.

4.2.4 System Size and Population Served

All PWSs are potentially subject to the proposed requirements of the Arsenic Rule, with the exception of TNCs. The majority of systems to be regulated are community water systems, which also serve, on average, more people than NTNCs. Exhibit 4-2 provides information on the average populations served by CWSs for each system size category.

Exhibit 4–2
Total Population Served of Water Systems by
Source Water, System Type, and Service Population Category

Service Population Category	Community		Non-Transient Non-Community
	Ground water	Surface Water	
< 100	859,777	61,450	-
101–500	3,741,017	570,448	-
501–1,000	3,457,163	921,449	-
1,001–3,300	10,631,422	4,797,855	-
3,301–10,000	14,095,015	10,995,980	-
10,001–50,000	25,004,779	36,819,575	-
50,001–100,000	8,609,455	20,500,370	-
100,001-1,000,000	14,575,556	65,375,183	-
> 1,000,000	2,855,494	28,658,586	-
Total	**83,829,678**	**168,700,896**	**31,968,181**

Source: Safe Drinking Water Information System (SDWIS), December 1998 freeze.

Those NTNCs determined to be affected by the Arsenic Rule are presented in Exhibit 4-3 by type of system. The NCWSs are much smaller than CWSs on average and vary substantially in their characteristics. Schools account for more than half of the affected NCWSs (8,414 of 16,410), followed by office parks (950), daycare centers (809) and food manufacturing facilities (768). Prisons serve the largest number of people on average (1,820). All other system types serve an average of 500 people or fewer.

Exhibit 4-3
Characteristics of NCWSs Affected by the Arsenic Rule

Service Area Type	# of Systems	Avg. Pop.	Design Flow/System (mpd)	Avg. Flow/System (mpd)
Daycare Centers	809	76	0.005114	0.001068
Highway Rest Areas	15	407	0.008895	0.001970
Hotels/Models	351	133	0.01892	0.004540
Interstate Carriers	287	123	0.002853	0.00056
Medical Facilities	367	393	0.116623	0.033945
Mobile Home Parks	104	185	0.026164	0.006498
Restaurants	418	370	0.003907	0.000793
Schools	8,414	358	0.033269	0.008476
Service Stations	53	230	0.00511	0.001067
Summer Camps	46	146	0.021758	0.005299
Water Wholesalers	266	173	0.163659	0.049381
Agricultural Products/Services	368	76	0.019882	0.004796
Airparks	101	60	0.002608	0.000507
Construction	99	53	0.000914	0.000159
Churches	230	50	0.005287	0.001108
Campgrounds/RV Parks	123	160	0.021428	0.00521
Fire Departments	41	98	0.018623	0.004461
Federal Parks	20	39	0.006528	0.001399
Forest Service	107	42	0.001351	0.000245
Golf and Country Clubs	116	101	0.011796	0.002692
Landfills	78	44	0.005253	0.0011
Mining	119	113	0.012322	0.002825
Amusement Parks	159	418	0.017084	0.004055
Military Bases	95	395	0.069538	0.019159
Migrant Labor Camps	33	63	0.010212	0.002295
Misc. Recreation Services	259	87	0.002468	0.000477
Nursing Homes	130	107	0.04107	0.0107
Office Parks	950	136	0.00769	0.001677
Prisons	67	1,820	0.532196	0.182
Retailers (Non-food related)	695	174	0.003787	0.000766
Retailers (Food related)	142	322	0.005789	0.001225
State Parks	83	165	0.004828	0.001002
Non-Water Utilities	497	170	0.013288	0.003071
Manufacturing: Food	768	372	0.045384	0.01195
Manufacturing: Non-Food	0	0	0.015723	0.003785
Sum	**16,410**			
Weighted Average		**981**	**0.028**	**0.007**

Source: EPA, 1999a*. Geometries and Characteristics of Public Water Systems*, Table 7.5 and Table 7.6.

4.2.5 Number of Entry Points

If water systems employ more than one water supply source, they may have more than one treatment facility. For estimation purposes this analysis assumes a treatment facility at every entry point to the distribution system. As a result, the total number of entry points is an important determinant of compliance costs. Exhibit 4–4 presents the distribution of entry points per ground water CWS by system service population category.

Exhibit 4-4
Average Number of Entry Points per Ground Water System

Upper Bound 95% Confidence	**Service Population Category**							
	< 100	**101-500**	**501-1,000**	**1,001 - 3,300**	**3,301 - 10,000**	**10,001 - 50,000**	**50,001 - 100,000**	**> 100,000**
Percentile								
Mean	1	1	2	2	2	4	6	9
5th	1	1	1	1	1	1	1	1
50th (median)	1	1	1	1	2	3	4	5
95th	2	3	3	5	5	12	22	28

Source: EPA, 1999a. *Geometries and Characteristics of Public Water Systems*, Table 5.2.

In this respect, surface water systems are unlike ground water systems in that little variation in the number of entry points was reported among surface water systems. Even for large population categories, the majority of surface water systems reported only one or two entry points. (EPA, 1999a). This finding was supported by data recently collected from the Information Collection Request for large surface water systems.

4.2.6 Number of Households

Another method for estimating the effect of regulations on customers is to determine the cost per household. This measure is often used instead of per capita cost because it is a more accurate representation of how customers are billed, per household, not per person. Exhibit 4-5 shows the average number of connections for CWSs by size, water source, and ownership. The number of connections, or households, ranges from an average of 30 residential service connections for CWSs serving fewer than 100 people to an average of more than 56,000 residential connections for CWSs serving more than 100,000 people (EPA, 1999b. *Drinking Water Baseline Handbook*, B4.2.2(b)).

Household consumption does not vary substantially across size category or ownership type. The mean water consumption ranges from 81,000 gallons per year to 127,000 gallons per year per household.

Exhibit 4-5
Water Consumption per Residential Connection and Number of Residential Connections per System

Population	System Type	Mean Water Consumption* (kgal/yr)	Connections per System by Source**	
			Ground	Surface
< 100	Public	81	46	24
	Private	92	29	37
101-500	Public	93	128	192
	Private	110	99	105
501-1,000	Public	97	314	315
	Private	88	321	321
1,001-3,300	Public	82	663	774
	Private	102	601	565
3,301-10,000	Public	87	2,130	2,304
	Private	124	1,572	2,120
10,001-50,000	Public	108	6,075	6,737
	Private	110	7,432	6,862
50,001-100,000	Public	122	20,278	19,427
	Private	96	27,423	24,432
100,001-1,000,000	Public	127	59,969	69,985
	Private	114	55,047	76,833

Source: *EPA, 1997. *CWSS, Vol. II: Detailed Summary Result Tables and Methodology Report,* Table 1-14;
** EPA, 1995. CWSS: mean residential connections exclude purchased systems.

4.2.7 Production Profile

Exhibit 4-6 shows the average design capacity (in thousands of gallons) of CWS plants by source, ownership, and system size categories. Design capacity is the maximum amount of water a plant can deliver. Exhibit 4-7 provides the daily production of CWSs (in thousands of gallons) for the same categories. Daily production is the average amount of water a plant delivers in a day.

Exhibit 4-6
Design Capacity of CWS Plants
by Source, Ownership, and System Size
(Thousands of Gallons)

Primary Source/ Ownership Type	Service Population Category									
	<25	25-100	101-500	501-1,000	1,001-3,300	3,301-10,000	10,001-50,000	50,001-100,000	100,001-1,000,000	>1,000,000
Ground water	6.27	21.86	86.86	251.0	619.5	1864	6673	20785	67379	392939
Public	4.84	29.46	123.67	305.0	740.3	2152	7365	22614	67994	401175
Private	6.50	21.34	77.30	232.1	560.6	1683	6347	18234	75629	-
Purchased-Public	-	5.71	27.37	81.4	223.0	801	3380	19796	26765	-
Purchased-Private	0.89	4.99	24.78	79.5	200.6	824	2748	8690	-	-
Surface Water	1.30	20.32	92.60	239.3	617.9	1818	6682	19707	69224	554759
Public	1.14	25.79	130.90	318.2	807.8	2218	7887	22337	77298	584889
Private	3.19	18.13	75.69	214.2	527.3	1582	6165	15869	61381	296609
Purchased-Public	0.04	5.71	29.01	81.8	241.1	854	3698	13206	43650	-
Purchased-Private	1.12	4.99	24.65	73.6	213.8	719	2933	12788	29270	-
GW under influence	-	22.16	87.20	247.5	631.6	1779	7499	18482	-	-
Public	-	33.29	111.32	291.2	760.0	2077	8992	20195	-	-
Private	-	21.53	81.77	227.4	618.5	1802	-	-	-	-
Purchased-Public	-	-	30.21	97.1	209.3	461	2319	-	-	-
Purchased-Private	-	2.54	29.83	94.3	-	905	-	-	-	-

Source: *Drinking Water Baseline Handbook, Table B1.5.3*.

Exhibit 4-7
Daily Production of CWS Plants
by Source, Ownership, and System Size
(Thousands of Gallons)

Primary Source/ Ownership Type	Service Population Category									
	<25	25-100	101-500	501-1,000	1,001-3,300	3,301-10,000	10,001-50,000	50,001-100,000	100,001-1,000,000	>1,000,000
Ground water	1.35	5.33	24.40	78.50	212	715	2,914	10,187	37,224	259,751
Public	0.96	6.72	33.20	90.50	243	796	3,129	10,900	37,095	267,256
Private	1.39	4.80	20.30	69.30	18	635	2,802	9,121	44,760	-
Purchased-Public	-	5.11	23.50	68.20	182	634	2,585	14,496	19,455	-
Purchased-Private	0.85	4.54	21.60	67.30	166	656	2,119	6,502	-	-
Surface Water	0.39	6.91	33.70	90.70	244	753	2,932	9,069	33,667	295,680
Public	0.28	7.51	41.60	106.20	284	823	3,133	9,387	34,749	293,439
Private	0.95	6.15	28.60	87.30	230	748	3,225	8,907	38,094	206,950
Purchased-Public	0.04	5.11	24.90	68.50	197	675	2,821	9,766	31,351	-
Purchased-Private	1.06	4.54	21.50	62.40	176	575	2,258	9,472	21,215	-
GW under influence	-	5.41	24.50	77.30	217	679	3,313	8,951	-	-
Public	-	7.70	29.50	86.00	250	765	3,907	9,611	-	-
Private	-	4.85	21.30	67.70	207	686	-	-	-	-
Purchased-Public	-	-	25.90	80.90	171	370	1,789	-	-	-
Purchased-Private	-	2.36	25.9	79.4	-	719	-	-	-	-

Source: EPA, 1999b. *Drinking Water Baseline Handbook, Table B1.5.1*.

4.2.8 Treatment Profile

Exhibit 4-8 below presents information regarding in-place treatment technologies that affect arsenic concentrations in delivered water. The current treatment in place will determine the likely remedy that systems will select in order to come into compliance with the new MCL.

Exhibit 4-8
Percentage of CWSs with Various Treatments In-Place

Primary Source/ Type of Treatments	Service Population Category								
	< 100	101-500	501-1,000	1,001-3,300	3,301-10,000	10,001-50,000	50,001-100,000	100,001-1,000,000	> 1,000,000
Ground Water Systems									
Ion Exchange	0.7%	1.6%	3.8%	1.9%	4.6%	3.3%	1.2%	0.0%	-
Reverse Osmosis	0.0%	1.2%	0.0%	0.9%	1.2%	0.7%	1.2%	0.0%	-
Coagulation/ Flocc.	1.5%	5.4%	4.2%	3.4%	8.1%	15.1%	24.2%	25.2%	-
Lime/Soda Ash Softening	2.1%	3.7%	4.1%	5.2%	7.0%	12.2%	17.4%	32.4%	-
Surface Water Systems									
Ion Exchange	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-
Reverse Osmosis	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-
Coagulation/ Flocc.	27.5%	52.6%	70.2%	78.5%	95.4%	94.5%	93.7%	99.5%	-
Lime/Soda Ash Softening	3.9%	8.1%	20.5%	17.5%	10.8%	6.9%	5.7%	5.1%	-

Source: EPA, 1999a. *Geometries and Characteristics of Public Water Systems*, Tables 6-1and 6-2.

4.2.9 Financial Profile

EPA developed a baseline financial profile of all CWSs based on CWSS data. Exhibit 4-9 shows revenues, expenses, and net revenues by size and ownership. Revenues and expenses are reported in thousands of dollars and are based on 1995 data. The smallest systems, i.e., those serving 100 people or fewer, have an average revenue of less than $10,000 per year, while the largest systems, i.e., those serving more than 100,000 people, have an average annual revenue of over $35 million.

Exhibit 4–9 presents the mean total expenses for all community water systems by service population category. Annual expenses range from a mean of approximately $7,000 per year for the smallest systems to over $28 million for the largest systems. In general, revenues exceed expenses; however, for systems that serve fewer than 500 people, expenses frequently exceed revenues.

Exhibit 4-9
Baseline Revenues and Expenses for CWSs

	System Size Category							
	<100	101-500	501-1,000	1,001-3,300	3,301-10,000	10,001-50,000	50,001-100,000	100,001-1,000,000
Publicly-Owned								
Revenues	$9,677	$39,023	$103,981	$238,163	$714,414	$2,701,280	$8,933,319	$35,439,984
Expenses	$14,747	$38,781	$96,015	$217,900	$626,242	$2,188,092	$8,010,010	$31,492,090
Net Revenues	($5,070)	$242	$7,966	$20,263	$88,172	$513,188	$923,309	$3,947,895
Privately-Owned								
Revenues	$7,009	$36,206	$110,375	$234,610	$702,382	$3,728,501	$10,188,865	$38,755,625
Expenses	$7,366	$37,681	$101,612	$226,307	$621,296	$2,973,931	$8,188,989	$33,333,252
Net Revenues	($356)	($1,476)	$8,764	$8,304	$81,086	$754,570	$1,999,877	$5,422,372
All Systems								
Revenues	$7,486	$37,644	$105,999	$237,326	$711,788	$2,829,324	$9,075,183	$35,750,697
Expenses	$8,683	$38,243	$97,782	$219,879	$625,162	$2,286,048	$8,030,233	$31,664,628
Net Revenues	($1,198)	($599)	$8,218	$17,447	$86,626	$543,277	$1,044,950	$4,086,070

Source: EPA, 1995. CWSS.
Expense data include operating costs, interest payments, and "other" expenses from systems reporting non-zero values.
Revenue data include total revenues from systems reporting zero values.

Unfortunately, there is no available information characterizing non-transient non-community water system revenues. This is primarily due to the fact that these systems generally do not operate water systems to generate revenue, but to support their primary business. It should also be noted that there are potential limitations with using the revenue and expense data from the CWSS since the data are based on only one year of information during which time all systems may not have accounted for all water-related revenues.

4.3 Occurrences of Arsenic

EPA has relied on a variety of data sources to evaluate the occurrence of arsenic in community water systems and non-transient non-community systems. This information supports EPA's assessment of baseline conditions, including (1) the number of systems expected to exceed various MCL options, and (2) the population exposed to different levels of arsenic.

In 1992, EPA conducted an analysis of the number of systems that would be impacted by various arsenic MCL options, ranging 0.5 μµg/L to > 50 μµg/L. These projections were based on the following national surveys:

- 1984-1986 National Inorganic and Radionuclide Survey (NIRS) for ground water systems;
- 1976-1977 National Organic Monitoring Survey for surface water systems;

- 1978-1980 Rural Water Survey for surface water systems; and
- 1978 Community Water Supply Survey for surface water systems.

EPA estimated that approximately 150 CWSs and NTNCs with ground water sources and five CWSs and NTNCs with surface water sources would exceed 50 μg/L, and that approximately 4,500 CWSs and NTNCs with ground water sources and 350 CWSs and NTNCs with surface water sources would exceed 5 μg/L.

These data sources have several limitations. First, the surveys used for surface water systems were conducted primarily before 1980. It is likely that arsenic occurrence has changed in the past two decades due to changes in raw water sources or the addition of filtration treatment to comply with the Surface Water Treatment Rule (SWTR). In addition, many of the survey responses had relatively high minimum reporting limits (5 μg/L). Therefore, it is statistically difficult to extrapolate low-level arsenic occurrence.

EPA has subsequently received new data from EPA offices, States, public water utilities, and associations supporting a new evaluation of baseline occurrences. These data, based on recent samples, benefit from improved analytical techniques with lower detection limits and lower reporting limits. The new data include the following:

- Arsenic MCL compliance monitoring data for ground and surface water community water systems in 25 states;
- A 1992-1993 national survey of 140 large ground and surface water systems (greater than 10,000 people), which was performed by the Metropolitan Water District of Southern California (MWDSC);
- A 1993 survey examining low levels of arsenic occurrence in surface water and ground water in the State of California (Association of California Water Agencies; ACWA); and
- A 1996 national survey of approximately 500 ground and surface water systems serving more than 1,000 people performed by American Water Works Association (AWWA).

In addition, the US Geological Survey (USGS) worked extensively with EPA to share arsenic ambient ground water occurrence data through an Interagency Agreement.

EPA (1999c) used the MCL compliance monitoring data from 25 states to develop an improved estimate of national baseline arsenic occurrence. The estimates based on this data are comparable to those based on the other sources listed above.

Exhibit 4-10
Arsenic Occurrence in CWSs at Various Concentration Levels (µg/L)

Source	% of systems greater than (µg/L)									
	2	3	5	10	15	20	25	30	40	50
GW	27.20	19.90	12.10	5.43	3.13	2.06	1.45	1.08	0.66	0.44
SW	9.93	6.01	2.90	0.75	0.40	0.26	0.19	0.14	0.09	0.07

Source: EPA, 1999c. *Arsenic Occurrence in Public Drinking Water Supplies.*

EPA used statistical techniques to assess

(1) the national distribution of mean arsenic concentrations in water systems,
(2) the distribution of source means within systems, and
(3) the number of systems with at least one source above various MCLs.

Exhibit 4-10 shows the percentage of systems with an arsenic occurrence in excess of ten different concentration levels, ranging from 2 µg/L to 50 µg/L. Less than one percent of ground water and surface water systems have a concentration level of arsenic greater than 50 µg/L. In contrast, 27 percent of ground water systems and 10 percent of surface water systems have an arsenic concentration greater than 2 µg/L.

Exhibit 4-11 provides a summary of the number of systems expected to exceed various MCLs, based on the results of EPA's revised occurrence estimates.

Exhibit 4-11
Number of CWSs Exceeding Various Arsenic MCL Concentrations (µg/L)

	<100	101-500	501-1,000	1,001-3,300	3,301-10,000	10,001-50,000	50,001-100,000	100,001-1,000,000
MCL 3								
GW	3,024	3,256	1,058	1,406	696	434	53	33
SW	62	109	67	137	94	76	16	16
MCL 5								
GW	1,898	2,048	671	893	444	286	35	21
SW	32	57	34	70	50	41	8	8
MCL 10								
GW	874	934	312	424	218	144	19	11
SW	10	18	11	23	16	13	3	4
MCL 20								
GW	343	377	126	177	91	61	8	5
SW	3	5	3	5	5	3	1	1

Chapter 5: Benefits Analysis

5.1 Nature of Regulatory Benefits

The benefits associated with reductions of arsenic in drinking water arise from a reduction in adverse human health effects. To a lesser degree benefits may also accrue from positive ecological effects and an avoidance of costly consumers behaviors aimed at avoiding exposure, such as the cost of bottled water.

The value to consumers of a reduction in the risk of adverse health effects includes the following components:

- The avoidance of medical costs and productivity losses associated with illness;
- The avoidance of the pain and suffering associated with illness;
- The losses associated with risk and uncertainty, also called the "risk premium;" and
- The reduction in risk of premature mortality.

This conceptual valuation framework goes beyond valuing out-of-pocket medical costs and lost time to include the value consumers place on avoiding pain and suffering and the risk premium. The risk premium represents the damages associated with risk and uncertainty, captured in the expression of consumer's "willingness-to-pay" for the reduction in risk of illness (Freeman, 1979).

This chapter first presents information on the multiple adverse health effects associated with arsenic, followed by a quantitative risk analysis of a single arsenic related endpoint, bladder cancer. Due to the large number of potential health effects can't be quantified, it is likely that the estimated benefits associated with avoidance of bladder cancer considerably underestimate the total benefits of a reduction of arsenic in drinking water.

5.2 Health Effects

5.2.1 Overview

Exposure to arsenic has many potential health effects which have been described in two recent publications: *Arsenic in Drinking Water* by the National Research Council (NRC, 1999), and the Agency for Toxic Substances and Disease Registry's *Draft Toxicological Profile for Arsenic* (ATSDR, 1998). These two sources provide descriptions of health effects which are summarized in this section, along with additional information provided from the recent literature.

Ingestion of inorganic arsenic can result in both cancer and non-cancer health effects (NRC, 1999). Exposure may also occur via other routes of exposure including inhalation and dermal exposure. There is a large human effects database available for inorganic arsenic. However, the effects of organic forms of arsenic are not as well characterized as those for inorganic arsenic. The proposed rule addresses both organic and inorganic forms of arsenic.

The nature of the health effects avoided by reducing arsenic levels in drinking water is a function of characteristics unique to each individual and the level and timing of exposure. Therefore, the relationship between exposure and response is quite complex. This section describes potential health effects, but does not reach conclusions about specific effects that might occur due to the current levels of arsenic in our country's drinking water.

5.2.2 Carcinogenic Effects

Arsenic's carcinogenic role was noted over 100 years ago (NCI, 1999) and has been studied since that time. The Agency has classified arsenic as a Class A human carcinogen, "based on sufficient evidence from human data. An increased lung cancer mortality was observed in multiple human populations exposed primarily through inhalation. Also, increased mortality from multiple internal organ cancers (liver, kidney, lung, and bladder) and an increased incidence of skin cancer were observed in populations consuming drinking water high in inorganic arsenic." (EPA, IRIS web site extracted 8/99).

The International Agency for Research on Cancer (IARC) concluded that inhalation of inorganic arsenic caused skin and lung cancer in humans. The 1999 NRC report on arsenic states that "epidemiological studies ... clearly show associations of arsenic with several internal cancers at exposure concentrations of several hundred micrograms per liter of drinking water" (NRC, 1999). Ten epidemiological studies, covering eight organ systems, present quantitative data useful for risk assessment (NRC, 1999, Table 4-1). The organ systems where cancers in humans have been identified include skin, bladder, lung, kidney, nasal, liver, and prostate.

Table 10-6 of the NRC report provides risk parameters for three cancers: bladder, lung, and liver cancer. Considering all cancers in aggregate, the NRC states in their Risk Characterization section that "considering the data on bladder and lung cancer in both sexes noted in the studies in chapter 4, a similar approach for all cancers could easily result in a combined cancer risk on the order of 1 in 100" (at the current MCL of 50 µg/L).

New data provide additional health effects information on both carcinogenic and noncarcinogenic effects of arsenic. A recently study by Tsai et al. (1999) of a population that has been studied over many years in Taiwan has provided statistically significant standardized mortality ratios (SMRs) for 23 cancerous and non-cancerous causes of death in women and 27 causes of death in men. SMRs are an expression of the ratio between deaths that were observed in an area with elevated arsenic levels and those that were expected to occur, based on the mortality experience of the populations in nearby areas without elevated arsenic levels. Drinking water (250-1,140 µg/L) and soil (5.3-11.2 mg/kg) in the Tsai et al. (1999) population study had very high arsenic content.

Tsai et al. (1999) identified "bronchitis, liver cirrhosis, nephropathy, intestinal cancer, rectal cancer, laryngeal cancer, and cerebrovascular disease" as possibly "related to chronic arsenic exposure via drinking water." In addition, the study area had upper respiratory tract cancers previously only related to occupational inhalation. High male mortality rate (SMR > 3) existed for bladder, kidney, skin, lung, and nasal cavity cancers and for vascular disease. However, the authors noted that the mortality range was marginal for leukemia, cerebrovascular disease, liver cirrhosis, nephropathy (kidney), and diabetes. Females also had high mortalities for laryngeal cancer. The SMRs calculated by Tsai et al. (1999) used the one cause of death noted on the death certificates. Many chronic diseases, including some cancers, do not result in mortality. Consequently, the impact indicated by the SMR will underestimate the total impact of these diseases.

There are, of course, possible differences between the population and health care in Taiwan and the United States. For example, arsenic levels in the U.S. are not nearly as high as they were in the study area of Taiwan. However, the study gives an indication of the types of health effects that may be associated with arsenic exposure via drinking water.

5.2.3 Noncarcinogenic Effects

Arsenic interferes with a number of essential physiological activities, including the actions of enzymes, essential cations, and transcriptional events in cells (NRC, 1999). A wide variety of adverse health effects have been associated with chronic ingestion of arsenic in drinking water, occurring at various exposure levels.

Effects on specific organ systems reported in humans exposed to arsenic are listed below in Exhibit 5-1 (NRC, 1999). Exhibit 5-1 provides descriptive information on the specific diseases and/or symptoms associated with categories of diseases.

Exhibit 5-1
Adverse Noncarcinogenic Health Effects Reported in Humans in NRC (1999) as Potentially Associated with Arsenic, by Organ System Affected

cutaneous effects	• hyperpigmentation • hyperkeratoses • melanosis
gastrointestinal and hepatic effects	• noncirrhotic portal hypertension • gastrointestinal hemorrhage secondary to esophageal varices • hepatic enlargement • splenic enlargement • periportal fibrosis of the liver • obliterative intimal hypertrophy of intrahepatic venules resulting in obstruction of portal venous flow, increased splenic pressures, and hypersplenism, and cirrhosis of the liver • diarrhea • cramping
cardiovascular and peripheral vascular effects	• peripheral vascular disease (blackfoot disease) • gangrene of the feet • coldness and numbness in the extremeties • intermittent claudication • ulceration • spontaneous amputation • Raynaud's syndrome • acrocyanosis • ischemic heart disease
cardiovascular and peripheral vascular effects (in children)	• arterial spasms in fingers and toesm • esenteric artery thrombosis • cerebrovascular disease • extensive coronary occlusions • cerebrovascular occlusions • ischemia of the tongue • Raynaud's syndrome • gangrene in extremities
hematological effects	• anemia - normocytic, megoblastic • leukopenia - neutropenia, lymphopenia, eosinophilia • thrombocytopenia • reticulocytosis • erythroid hyperplasia
pulmonary effects	• chronic cough • restrictive and obstructive lung disease • emphysema
immunological effects	• impaired immune response (more specific effects observed in human cell studies and animal studies- see source)
neurological effects	• peripheral neuropathy
endocrine effects	• diabetes mellitus
reproductive and developmental effects	• spontaneous abortion • perinatal death • stillbirth • low birth weight • birth defects including coarctation of the aorta and others
reproductive and developmental effects*	• neural tube defects • ophthalmic abnormalities • numerous skeletal abnormalities • urogenital abnormalities • growth retardation

*Notes in parenthesis indicate where health effects were observed in animal studies rather than human studies. NRC reports results of numerous animal reproductive and developmental studies and notes that there are “very few” human studies.

5.2.4 Susceptible Subgroups

This section discusses the nature of special susceptibilities and identifies population subgroups that may be at higher risk than the general population when exposed to arsenic.

5.2.4.1 Definition

A susceptible subgroup exhibits a response that is different or enhanced when compared to the responses of most people exposed to the same level of arsenic (ATSDR, 1998). Many diseases affect certain subgroups of the population disproportionately. The subgroups may be defined by age, gender, race, ethnicity, socioeconomic status, pre-existing medical conditions, behavioral or physiological differences, or other characteristics. For example, there are pre-existing medical conditions that will increase susceptibility to most toxins, such as a pre-existing disease in the toxin's target organ. Very few diseases affect all population groups (ages, sexes, races) equally. For purposes of evaluating potential benefits to different segments of the population, it is useful to evaluate whether there are susceptible subpopulations that require consideration. The benefit of reducing their exposure may be considerably higher than the benefit associated with reducing exposure among the general population (on a per capita basis).

Special susceptibilities may be indicated by known differences in biological processes that are essential to detoxification of a toxin. In addition to identifying susceptible subgroups based on biological processes, susceptible subgroups are often identified by observing higher-than-average rates of the disease of interest. Increases in the rates of reported diseases may be due to a variety of factors. Some of these indicate an increased susceptibility; others are matters of personal choice and may not be considered relevant in a benefits analysis. One way to approach this issue is to evaluate increased susceptibility when it is based on an increased risk of disease due to factors <u>reasonably beyond the control of the subpopulation</u>. Factors that are usually beyond the control of the individual that may cause increased susceptibility include:

- Constitutional limitations (e.g., illnesses, genetic abnormalities, birth defects such as enzyme deficiencies);

- Concurrent synergistic exposures that cannot reasonably be controlled (e.g., at home or in the workplace); and

- Normal constitutional differences (i.e., differences based on sex, age, race, ethnicity, etc).

Other factors that are not usually considered beyond the individual's control include personal choices, such as smoking, drinking, and drug use. Choice of place of residence or work may or may not be treated as a relevant factor. Ultimately, which types of factors should be included in identifying susceptible subgroups is a matter of public policy.

No studies were located by ATSDR (1998) that focused exclusively on evaluating unusual susceptibility to arsenic. However, some members of the population are likely to be especially susceptible due to a variety of factors. These factors include increased dose (intake per unit of body weight) in children, genetic predispositions, and dietary insufficiency (ATSDR, 1998), as well as pre-existing health conditions.

5.2.4.2 Children

One often-identified susceptible subgroup is children. Due to their increased fluid and food intake in relation to their body weight (NAS, 1995), their dose (milligrams per kilogram of body weight per day - mg/kg/day) of arsenic will be, on average, greater than that of adults. For example, an intake of 1.2 liters per day in a 70 kg adult yields an overall water intake of 0.017 liters per kg of body weight. An infant who consumes 1 liter per day and weighs 10 kg is consuming 0.1 liter per kg of body weight, which is more than 5 times the water intake per kg of an adult. Any contaminant which is present in the water will be delivered at a correspondingly higher level, on a daily basis. Foy et al., noted that in studies of chronic exposure, children appear to be more severely affected, probably due to a higher exposure per body weight (1992 citation, reported in ATSDR, 1998).

The increased daily dose in children can be effectively considered for noncarcinogenic effects because toxicity is evaluated in terms of exposures that can range from relatively short-term to long-term exposure. However, carcinogenic effects (i.e., bladder cancer) are evaluated based on a lifetime of exposure, which takes into consideration the elevated dose that occurs in children. Because the only health effect measured in this benefits assessment is bladder cancer, a sensitivity analysis to consider higher doses of arsenic during childhood was not necessary. However, the numerous noncarcinogenic effects listed in Exhibit 5-1 may be of greater concern for children than adults. As the table indicates, many severe cardiovascular effects have been observed in children. Avoidance of these effects constitutes an unquantified benefit of the rule.

The adverse reproductive effects listed in Exhibit 5-1 give evidence of the susceptibility of a child. The toxic mechanism of action of arsenic involves the inhibition of proliferation of cells, as well as impairment of the embryonal cell division and mitosis (cell reproduction) (Dong and Luo, 1993, Jha et al., 1992, Petres et al., 1977, Leonard and Lauwerys, 1980, Li and Chou, 1992, Mottet and Ferm, 1983 reported in ATSDR, 1998). Arsenic also causes chromosomal aberrations (Jha et al., 1992, Leonard and Lauwerys, 1980, reported in ATSDR, 1998). These all have serious adverse implications for critical developmental processes.

In addition, arsenic crosses the placenta and preferentially accumulates in the embryonic neuroepithelium, as well as occurring in breast milk (Somogyi and Beck, 1994, reported in ATSDR, 1998). The neuroepithelium is particularly susceptible during development because the process of neurulation is being carried out, which involves the development of the neural tube and other essential structures (Dallaire and Beliveau, 1992, Edelman, 1992, Gunn et al., 1992, Li and Chou, 1992, Morris-Kay et al., 1994, Scheonwolf and Smith, 1990, Taubeneck et al., 1994, reported in ATSDR, 1998).

5.2.4.3 Genetic Predispositions and Dietary Insufficiency

Methylation of arsenic in the liver is a pathway for the detoxification of inorganic arsenic. Individuals who are deficient in essential enzymes for this process, or who have a dietary deficiency of methyl donors (choline or methionine), will be at greater risk following inorganic arsenic exposure (Buchet and Lauwerys, 1987; Vahter and Marafante, 1987; Brouwer et al., 1992 cited in ATSDR, 1998). However, liver disease does not appear to increase risk at low levels of arsenic exposure (Buchet et al., 1982; Geubel et al., 1988 cited in ATSDR, 1998). Therefore, these factors are not expected to increase risk levels for a significant portion of the U.S. population.

5.2.4.4 Individuals with Pre-existing Organ Susceptibilities

Individuals may have increased susceptibilities based on specific organ-related factors. Those with pre-existing diseases (e.g., kidney disease), as well as those with congenital defects (a single kidney) will be at greater risk from a toxin that either causes additional damage to that organ, or that relies on that organ for detoxification. In the case of arsenic, both the kidneys and liver are used to detoxify and remove the contaminant. Both single high doses and long-term low doses may cause an accumulation of arsenic in the liver and kidneys, which can impair function. In addition, these organs may be directly damaged by arsenic exposure. A review of Tables 5-1 and 5-2 indicates other organ systems that are targets of arsenic toxicity, including the cardiovascular system (heart, veins, arteries), hematopoietic system, endocrine system, cutaneous system, pulmonary system, gastrointestinal system, immune system, and peripheral nervous system. In individuals with pre-existing damage to these systems or congenital defects in the systems, the likelihood of risk is greater. Due to the higher incidence of most types of disease among the elderly, they are more likely to have pre-existing conditions in these organ systems.

5.2.4.5 Individuals Exposed via Non-water Sources

Although arsenic is ubiquitous at low levels, it is not generally found at levels of concern in food or air, in the absence of elevated local sources. Where background levels are high, however, (e.g., elevated levels in water) it is reasonable to consider the contribution to total exposure that may occur from soil, food, and other local sources. When anthropogenic sources are known to generate elevated arsenic levels in water (e.g., a local smelter), it is more likely that other media may be contaminated as well. The total exposure from all sources is a critical component of evaluating potential health risks and the benefits of avoiding contaminated drinking water in these cases. A reduction in arsenic in drinking water will reduce the overall exposure to individuals in living in contaminated areas (e.g., around certain Superfund sites) or workers exposed to arsenic on the job. Total exposure from all sources is of particular concern for noncancer risks, because background levels from non-drinking water sources will determine whether the total exposure leads to an exceedence of a threshold for effects.

5.3 Quantitative Benefits of Avoiding Bladder Cancer

Quantitative risk metrics (e.g., slope factors or reference doses) are necessary to evaluate cancer or non-cancer risks. Although arsenic causes numerous health effects, bladder cancer is the only endpoint for which an Agency-approved metric for evaluating arsenic related risk currently exists. This cancer slope factor (SF) for bladder cancer is adequate data to perform a risk assessment and was used to calculate cases potentially avoided due to EPA’s proposed drinking water standards. Benefits estimates for avoided cases of bladder cancer were calculated using mean population risk estimates at various MCL levels. Lifetime risk estimates were converted to annual risk factors, and applied to the exposed population to determine the number of cases avoided. Due to a lack of risk data, health benefit estimates for lung cancer were quantified based on the assumption that the risks of a fatal lung cancer case associated with arsenic are 2-5 times that of a fatal bladder cancer case.

5.3.1 Risk Assessment for Bladder Cancer Resulting from Arsenic Exposure

5.3.1.1 Risk Assessment Methodology

Risk assessment is based on the analysis of scientific data to determine the likelihood, nature, and magnitude of harm to public health associated with particular agents, and involves three main analytical components: hazard identification (dose-response assessment), exposure assessment, and risk characterization. Exhibit 5-2 illustrates the steps in a traditional risk assessment process for characterizing the potential human cancer associated with contaminants in drinking water.

Community Water Systems

The following sections summerize how risk reductions were calculated for populations exposed to arsenic levels at or above 3 µg/L. The approach for this analysis included five components, which are described in more detail below. First, EPA used data from the recent EPA water consumption study. Second, Monte-Carlo simulations were used to develop relative exposure factors. Third, arsenic occurrence estimates identified the population exposed to levels above 3 µg/L. Fourth, risk distributions were chosen for the analysis from the 1999 NRC report. Finally, EPA developed estimates of the actual risks faced by exposed populations using Monte-Carlo simulations, using the relative exposure factors, occurrence, and risk distributions mentioned above. A more detailed description of the risk methodology is provided in Appendix B.

<u>Water Consumption.</u>

EPA recently updated its estimates of per capita daily average estimates of water consumption (EPA, 1999). The estimates used data from the combined 1994, 1995, and 1996 Continuing Survey of Food Intakes by Individuals (CSFII), conducted by the U.S. Department of Agriculture (USDA). The CSFII is a complex, multistage area probability sample of the entire U.S. and is conducted to survey the food and beverage intake of the U.S. Estimates of water consumed include direct water, indirect water and total water. “Direct” water is tap water consumed directly as a beverage. “Indirect” water is defined as water added to foods and beverages during final preparation at home or by food service establishments such as school cafeterias and restaurants. For the purpose of the report, indirect water did not include “intrinsic” water which consists of water found naturally in foods (biological water) and water added by commercial food and beverage manufactures (commercial water). “Total” water refers to combined direct and indirect water consumption.

Exhibit 5-2
Components of the Bladder Cancer Risk Assessment

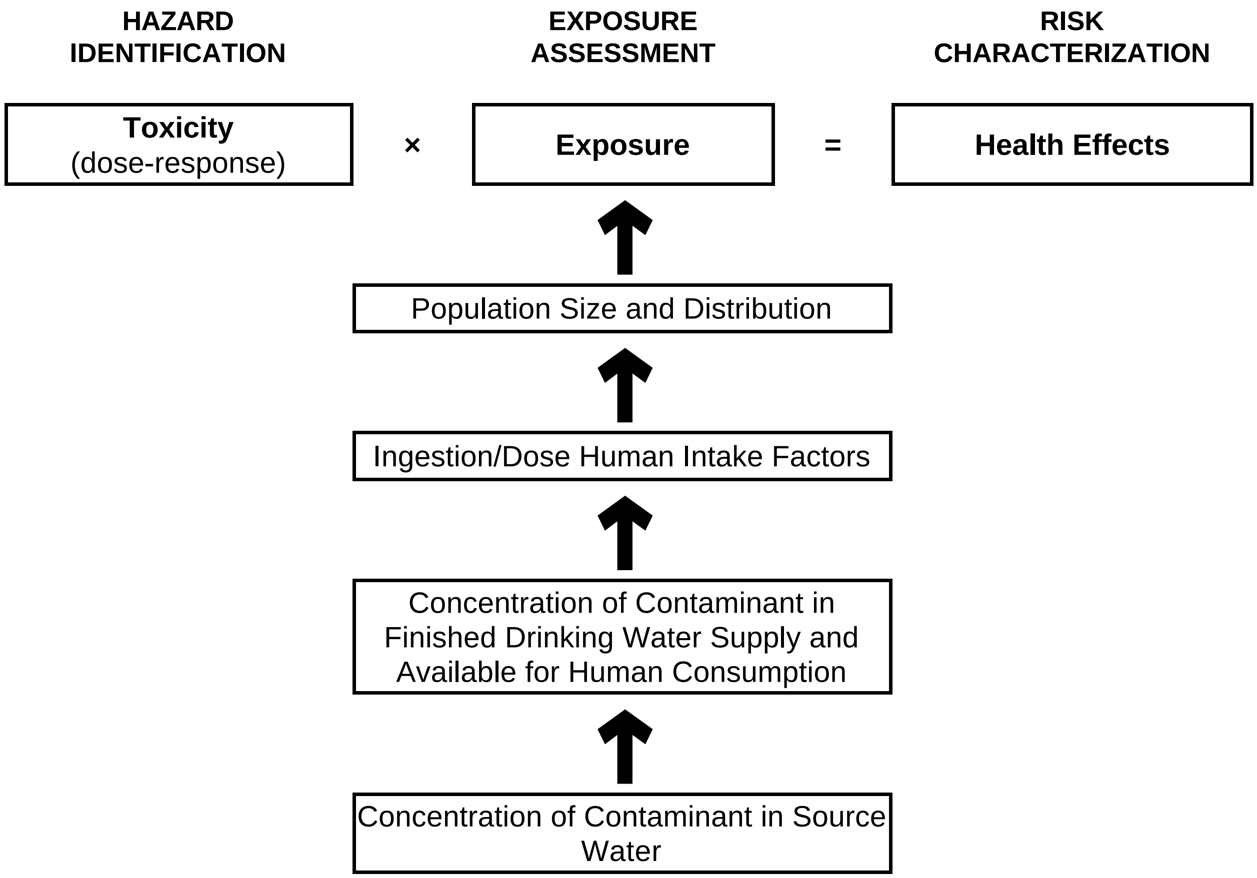


Exhibit 5-3
Source of Water Consumed

Source	Direct Tap Water (drinking)	Indirect Tap Water (from food and beverages)	Bottled water
Community Tap	X	X	
Other Tap Sources	X	X	
Total	X	X	X

Per capita water consumption estimates are reported by source. Sources include community tap water, bottled water, and water from other sources, including water from household wells and rain cisterns, and household and public springs. For each source, the mean and percentiles of the distribution of average daily per capita consumption are reported. The estimates are based on an average of 2 days of reported consumption by survey respondents.

The estimated mean daily average per capita consumption of community tap water by individuals in the U.S. population is 1 liter/person/day. For total water, which includes bottled water, the estimated mean daily average per capita consumption is 1.2 liters per/person/day. These estimates of water consumption are based on a sample of 15,303 individuals in the 50 States and the District of Columbia. The sample was selected to represent the entire population of the U.S. based on 1990 census data.

The estimated 90th percentile of the empirical distribution of daily average per capita consumption of community tap water for the U.S. population is 2.1 liters/person/day; the corresponding number for daily average per capita consumption of total water is 2.3 liters/person/day. In other words, current consumption data indicate that 90 percent of the U.S. population consumes approximately 2 liters/person/day, or less.

Water consumption estimates for selected subpopulations in the U.S. are described in the CSFII, including per capita water consumption by source for gender, region, age categories, economic status, race, and residential status and separately for pregnant women, lactating women, and women in childbearing years. The water consumption estimates by age were used in the computation of the relative exposure factors discussed below.

Monte-Carlo analysis.

Monte-Carlo analysis is a technique for analyzing problems where there are a large number of combinations of input values which makes it impossible to calculate every possible result. A random number generator is used to select input values from pre-defined distributions. For each set of random numbers a single scenario's result is calculated. As the simulation runs, the model is recalculated for each new scenario that continues until a stopping criteria is reached. For the risk distributions calculated in this report, the simulations were carried out 2,000 times. For each simulation, a relative exposure factor, occurrence estimate, and individual risk estimate were calculated. These calculations resulted in estimates of the actual risks faced by populations exposed to arsenic concentrations in their drinking water. The underlying risk distribution are described below.

NRC risk distributions.

In its 1999 report, "Arsenic in Drinking Water," the NRC analyzed bladder cancer risks using data from Taiwan. In addition, NRC examined evidence from human epidemiological studies in Chile and Argentina, and concluded that risks of bladder and lung cancer had comparable risks to those "in Taiwan at comparable levels of exposure (NRC, 1999, page 7)." The NRC also examined the implications of applying different statistical analyses to the newly available Taiwanese data for the purpose of characterizing bladder cancer risk. For Taiwanese male bladder cancer, using a Poisson regression model and no data on unexposed populations, yielded a risk at the current MCL of 1 to 1.347 per 1,000 (NRC, 1999, Table 10-11). In Table 10-12 of the report, excess lifetime risk estimates for bladder cancer in males, calculated using EPA's 1996 cancer guidelines, is presented (EPA 1996). EPA selected two of these distributions to be representative of the risks and uncertainty involved (selecting relatively high and relatively low estimates). These distributions are shown in Exhibit 5-4. [1]

Exhibit 5-4
EPA Assumed Life-Time Bladder Risk Estimates for Bladder Cancer Among Males
(Risk per 1,000 Men)

Mean	95% Upper Confidence Limit
0.731	0.807
1.237	1.548

Relative Exposure Factors.

A Monte-Carlo analysis generated male and female relative exposure factors (REFs) for each of the broad age categories used in the water consumption study. Lifetime male and female REFs were then calculated, where the life-long REFs indicate the sensitivity of exposure to an individual relative to the sensitivity of exposure of an "average" person weighing 70 kilograms and consuming 2 liters of water per day. These life-long REFs can be directly multiplied by the average drinking water consumption to provide estimates of individual lifetime consumption practices. In this analysis, EPA combined the water consumption data with data on population weight from the U.S. Census. Distributions for both community tap water and total water consumption were used because the community tap water estimates may underestimate actual tap water consumption. The weight data included a mean and a distribution of weight for male and females on a year-to-year basis. The means and standard deviations of the life-long REFs derived from this analysis are shown in Exhibit 5-5.

Exhibit 5-5
Life-Long Relative Exposure Factors

	Community Water Consumption Data	Total Water Consumption Data
Male	*Mean* = 0.60 *s.d.* = 0.61	*Mean* = 0.73 *s.d.* = 0.62
Female	*Mean* = 0.64 *s.d.* = 0.6	*Mean* = 0.79 *s.d.* = 0.61

Non-Transient Non-Community Water Systems

Determination of system and individual exposure factors.

In the past, the Agency has directly used SDWIS population estimates for assessing the risks posed to users of NTNC water systems. In other words, it was assumed that the same person received the exposure on a year round basis. Under this approach it was generally assumed that all

[1] All of these risk distributions are linear in the mean, and thus may be conservative assumptions, as the NRC report suggested the true relationship may be sublinear. If the true relationship is sublinear, i.e., lower than the straight line from 50 µg/L to zero, the true risks at levels below 50 µg/L are being overestimated.

NTNC users were exposed for 270 days out of the year and obtained fifty percent of their daily consumption from these systems. As a comparison, TNC users are assumed to use the system for only ten days per year.

With the recent completion of *Geometries and Characteristics of Public Water Systems* (EPA, 1999), however, the Agency has developed a more comprehensive understanding of NTNC water systems. These systems provide water in due course as part of operating another line of business. Many systems are classified as NTNC, rather than TNC water systems, solely because they employ sufficient workers to trigger the "25 persons served for over six months out of the year" requirement. Client utilization of these systems is actually much less and more similar to exposure in TNC water systems. For instance, it is fairly implausible that highway rest areas along interstate highways serve the same population on a consistent basis (with the exception of long distance truckers). Nevertheless, there are highway rest areas in both NTNC and TNC system inventories. The *Geometries and Characteristics of Public Water Systems* report suggests that population figures reported in SDWIS which have been used for past risk assessments generally appear to reflect the number of workers in the establishment coupled with peak day customer utilization.

Under these conditions use of the SDWIS figures for population greatly overestimates the actual individual exposure risk for most of the exposed population and also severely underestimates the number of people exposed to NTNC water[2]. Adequately characterizing individual and population risks necessitates some adjustment of the SDWIS population figures. For chronic contaminants, such as arsenic, health data reflect the consequences of a lifetime of exposure. Consequently, risk assessment requires the estimation of the portion of total lifetime drinking water consumption that any one individual would receive from a particular type of water system. In turn, one needs to estimate the appropriate portions for daily, days per year, and year per lifetime consumption. These estimates need to be prepared for both the workers at the facility and the "customers" of the facility.

This adjustment was accomplished through a comprehensive review of government and trade association statistics on entity utilization by SIC code. These figures, coupled with SDWIS information relating to the portion of a particular industry served by non-community water systems, made possible the development of two estimates needed for the risk assessment: customer cycles per year and worker per population served per day. These numbers are required to distinguish the more frequent and longer duration exposure of workers from that of system customers[3]. A more detailed characterization of the derivation of these numbers is contained in

---

[2]For example, airports constitute only about a hundred of the NTNC water systems. Washington's Reagan National and Dulles, Dallas/Fort Worth, Seattle/Tacoma, and Pittsburgh airports are the five largest of the airports. SDWIS reports that these five airports serve about 300,000 people. In actuality, Bureau of Transportation Statistics suggest that they serve about eleven million passengers per year. Examination of this information and other BTS statistics suggests that these airports serve closer to seven million unique individuals over the course of a year and that exposure occurs on an average of ten times per year per individual customer, not 270 times.

[3]For example, travel industry statistics provide information on total numbers of hotel stays, vacancy rates, traveler age ranges, and average duration of stay. These figures can be combined with the SDWIS peak day

the docket. Exhibit 5-6 provides the factors used in the NTNC risk assessment to account for the intermittent nature of exposure.

Exhibit 5-6
Exposure Factors Used in the NTNC Risk Assessment

NTNCWS	# cycles per yr	worker/ pop/day	worker fraction daily	worker days/yr	worker exposure years	customer fraction daily	days of use/yr	customer exposure years
Water wholesalers	1.00	0.000	-	-	-	0.25	270	70
Nursing homes	1.00	0.230	0.50	250	40	1.00	365	10
Churches	1.00	0.010	0.50	250	40	0.50	52	70
Golf/country clubs	4.50	0.110	0.50	250	40	0.50	52	70
Food retailers	2.00	0.070	0.50	250	40	0.25	185	70
Non-food retailers	4.50	0.090	0.50	250	40	0.25	52	70
Restaurants	2.00	0.070	0.50	250	40	0.25	185	70
Hotels/motels	86.00	0.270	0.50	250	40	1.00	3.4	40
Prisons/jails	1.33	0.100	0.50	250	40	1.00	270	3
Service stations	7.00	0.060	0.50	250	40	0.25	52	54
Agricultural products/services	7.00	0.125	0.50	250	40	0.25	52	50
Daycare centers	1.00	0.145	0.50	250	10	0.50	250	5
Schools	1.00	0.073	0.50	200	40	0.50	200	12
State parks	26.00	0.016	0.50	250	40	0.50	14	70
Medical facilities	16.40	0.022	0.50	250	40	1.00	6.7	10.3
Campgrounds/RV	22.50	0.041	0.50	180	40	1.00	5	50
Federal parks	26.00	0.016	0.50	250	40	0.50	14	70
Highway rest areas	50.70	0.010	0.50	250	40	0.50	7.2	70
Misc. recreation service	26.00	0.016	0.50	250	40	1.00	14	70
Forest Service	26.00	0.016	1.00	250	40	1.00	14	50
Interstate carriers	93.00	0.304	0.50	250	40	0.50	2	70
Amusement parks	90.00	0.180	0.50	250	10	0.50	1	70

Exhibit 5-6
Exposure Factors Used in the NTNC Risk Assessment (continued)

population estimates to allocate daily population among workers, customers and vacancies. The combination of these factors provides an estimate of the number of independent customer cycles experienced in a year.

NTNCWS	# cycles per yr	worker/ pop/day	worker fraction daily	worker days/yr	worker exposure years	customer fraction daily	days of use/yr	customer exposure years
Summer camps	8.50	0.100	1.00	180	10	1.00	7	10
Airports	36.50	0.308	0.50	250	40	0.25	10	70
Military bases		1.000	0.50	250	40			
Non-water utilities		1.000	0.50	250	40			
Office parks		1.000	0.50	250	40			
Manufacturing: Food		1.000	0.50	250	40			
Manufacturing: Non-food		1.000	0.50	250	40			
Landfills		1.000	1.00	250	40			
Fire departments		1.000	1.00	250	40			
Construction		1.000	1.00	250	40			
Mining		1.000	1.00	250	40			
Migrant labor camps		1.000	1.00	250	40			

Once the population adjustment factors were derived, it was possible to determine the actual population served by NTNC water systems. Exhibit 5-7 provides a breakout of these figures by type of establishment. Although not included in Exhibit 5-7, there are other equally important characteristics to note about these systems. With notable exceptions (such as the airports in Washington, DC and Seattle), the systems generally serve a fairly small population on any given day. In fact, 99 percent of the systems serve less than 3,300 users on a daily basis. This means that water production costs will be relatively high on a per gallon basis.

Exhibit 5-7
Composition of NTNCs
(Percentage of Total NTNCWS Population Served by Sector)

Schools	9.7	Medical Facilities	8	Interstate Carriers	7.1	Campgrounds	1.3
Manufacturing	2.7	Restaurants	0.9	State Parks	8.6	Misc. Recreation	1.8
Airports	26.1	Non-food Retail	1.6	Amusement Parks	17.7	Other	3.5
Office Parks	0.6	Hotels/Motels	9.2	Highway Rest Area	1.0		

Risk calculation.

Calculations of individual risk were prepared for each industrial sector. Even within a given sector, however, risk varies as a function of an individual's relative water consumption, body weight, vulnerability to arsenic exposure, and the water arsenic concentration. Computationally, risks were estimated by performing Monte-Carlo modeling. The approach used was similar to the modeling technique applied in estimating the community water system risk estimation, but with two notable exceptions. First, each realization in a given sector was multiplied by the portion of lifetime exposure factor presented in Exhibit 5-4 to reflect the decreased consumption associated with the NTNC system. Secondly, relative exposure factors were limited to age specific ratings where appropriate[4]. For example, in the case of school children, water consumption rates and weights for six to eighteen year-olds were used.

To illustrate the process, it was assumed that a child would attend only NTNCWS-served schools for all twelve years, a somewhat improbable likelihood. Further, it was assumed that a child would get half of their daily water consumption at school (for an average first grader this would correspond to roughly nine ounces of water per school day). Finally, it was assumed that the child would have perfect attendance and attend school for 200 days per year. Exhibit 5-8 below provides a sample output for the upper bound individual risk distribution to school children resulting from exposure to the range of untreated arsenic observed in community groundwater systems[5], as well as an estimate based on more moderate assumptions of four ounces per day and 150 days attendance for four years. Upper and lower bound risk distributions were prepared for both workers and "customers" at all types of NTNC water systems and are contained in Appendix B.

Exhibit 5-8
School Children Risk Associated with Current Arsenic Exposure in NTNCs

Exposure Risks	Moderate Exposure Scenario	Upper Bound Scenario
Mean Lifetime Risk	0.0087×10^{-4}	0.079×10^{-4}
90^{th} Percentile Lifetime Risk	0.019×10^{-4}	0.17×10^{-4}
Lifetime Bladder Cancers [out of 575,000 students]	0.5×10^{-4}	4.5×10^{-4}

The distribution of overall population risks was determined as part of the same simulation by developing sector weightings to reflect the total portion of the NTNCWS population served by each sector. Population weighted proportional sampling of the individual sectors provided an overall distribution of risk among those exposed at NTNC systems.

---

[4]For example, water consumption among school children was weighted to reflect consumption between ages 6 and 18, while factory worker consumption was weighted over ages 20 to 64.

[5]Community groundwater occurrence information was used since NTNC systems are almost exclusively supplied by groundwater sources. Further, as there was no depth dependence of arsenic levels observed in the community information, it is believed that the data are an adequate approximation.

5.3.1.2 Risk Assessment Results and Benefit Estimates

Community Water Systems

<u>Estimated Risk Reductions.</u>

Estimated risk reductions for bladder cancer at various MCL levels were developed using Monte-Carlo simulations. These simulations combined the distributions of relative risk factors associated with arsenic levels at or above 3µg/L, and the distribution of general bladder cancer risk taken from the National Research Council report. Since the relative risk and occurrence distributions represent primarily population and occurrence variability, and the cancer risk distributions represent primarily uncertainty about the true risk, the combined distributions contain both variability and uncertainty. These combined distributions provide more accurate estimates of the actual risks faced by the exposed population, including the portion of the population facing various levels of risk.

Estimated risk levels for bladder cancer at various MCL levels are shown in Exhibit 5-9. Results based on both the community water consumption data and the total water consumption data are shown. Populations at or above 10^{-4} risk levels are also summed in Exhibit 5-9. Since there is uncertainty about these numbers, it is assumed that the range 1 - 1.5 x 10^{-4} represents a risk level of essentially 10^{-4}. It is then assumed that risks above 1.5 x 10^{-4} represent risks greater than 10^{-4}. The after treatment occurrence distributions were assumed to reflect treatment to 80 percent of the MCL level. The latter assumption is made since water systems tend to treat below the MCL level in order to provide a margin of safety.

Exhibit 5-10 provides an estimate about percentages of the exposed populations and the number of people exposed at 10^{-4} risk levels and above, and, using the stated definition for an over 10^{-4} risk level, above 10^{-4}. The numbers in this table are based on community water consumption data and show that at an MCL of 3 µg/L, only a small number (not quantified) face a level of risk greater than 10^{-4}. At an MCL of 5 µg/L, about 0.3 to 0.8 million face such risk levels. At an MCL of 10 µg/L, 0.8 to 4 million are at risk, and at an MCL of 20 µg/L, about 2.4 to 6.4 million would be exposed at such levels. Exhibit 5-11 gives similar information using total water consumption data.

Exhibit 5-9
Mean Bladder Cancer Risks for U.S. Populations Exposed At or Above MCL Options, after Treatment[1]

MCL (µg/L)	**Mean Exposed Population Risk** (Community Water Consumption data)	**Mean Exposed Population Risk** (Total Water Consumption data)	**Mean Exposed Population Risk** (composite of available consumption data)
3	2.1 -3.6 x 10^{-5}	2.6 - 4.5 x 10^{-5}	2.1 - 4.5 x 10^{-5}
5	3.6 - 6.1 x 10^{-5}	4.4 - 7.5 x 10^{-5}	3.6 - 7.5 x 10^{-5}
10	5.5 - 9.2 x 10^{-5}	6.7 - 11.4 x 10^{-5}	5.5 - 11.4 x 10^{-5}
20	6.9 - 11.6 x 10^{-5}	8.4 - 13.9 x 10^{-5}	6.9 - 13.9 x 10^{-5}

[1]The bladder cancer risks presented in this table provide our "best" estimates at this time. Actual risks could be lower, given the various uncertainties discussed, or higher, as these estimates assume that the probability of illness from arsenic exposure in the U.S. is equal to the probability of death from arsenic exposure among the Taiwanese study group.

Exhibit 5-10
Exposed Population at 10^{-4} Risk or Higher for Bladder Cancer After Treatment[1] (Community Water Consumption data)

MCL (µg/L)	% at 10^{-4} Risk or higher	Population at 10^{-4} risk or higher (millions)	% over 10^{-4}*	Population over 10^{-4} (millions)
3	<1 - 2.6%	< 0.3 - 0.7	< 1%	‡
5	1.5 - 12%	0.4 - 3.2	< 1 - 3%	< 0.3 - 0.8
10	11 - 34%	2.9 - 9.1	3 - 15%	0.8 - 4
20	19.5 - 41%	5.2 - 11	9 - 24%	2.4 - 6.4

[1]The bladder cancer risks presented in this table provide our "best" estimates at this time. Actual risks could be lower, given the various uncertainties discussed, or higher, as these estimates assume that the probability of illness from arsenic exposure in the U.S. is equal to the probability of death from arsenic exposure among the Taiwanese study group.
*where over 10^{-4} means 1.5 x 10^{-4} or above; ‡ too low to calculate

Exhibit 5-11
Exposed Population at 10^{-4} Risk or Higher for Bladder Cancer After Treatment[1] (Total Water Consumption data)

MCL (µg/L)	% at 10^{-4} Risk or higher	Population at 10^{-4} risk or higher (millions)	% over 10^{-4}*	Population over 10^{-4} (millions)
3	< 1 - 3%	< 0.3 - 0.8	< 1%	‡
5	3 - 18%	0.8 - 4.8	< 1 - 4%	0.3 - 1.1
10	16 - 50%	4.3 - 13.4	4 - 23%	1.1 - 6.2
20	26 - 53%	7 - 14.2	13 - 33%	3.5 - 8.9

[1]The bladder cancer risks presented in this table provide our "best" estimates at this time. Actual risks could be lower, given the various uncertainties discussed, or higher, as these estimates assume that the probability of illness from arsenic exposure in the U.S. is equal to the probability of death from arsenic exposure among the Taiwanese study group.
*where over 10^{-4} means 1.5 x 10^{-4} or above; ‡ too low to calculate

One adjustment was necessary in order to use the risk distributions contained in the NRC report to calculate arsenic induced bladder cancer cases at each MCL. As mentioned above, the NRC risk distributions were based on the Taiwanese studies. In these studies, information on arsenic related bladder cancer deaths was reported. In order to use these data to determine the probability of contracting bladder cancer as a result of exposure to arsenic, we must assume a probability of mortality given the onset of arsenic induced bladder cancer among the Taiwanese study population. We have decided to bracket the uncertainty about this parameter. For the lower-end estimate of bladder cancer cases, we assume that this conditional probability is 100 percent. In other words, we are assuming that everyone in the Taiwanese study group that contracted bladder cancer died of it. Therefore, for the lower-end estimate of bladder cancer cases, no adjustment to the number of cases estimated using the NRC risk distribution is needed. For the upper-end estimate of bladder cancer cases, we assume that this conditional probability is 80 percent. In other words, we are assuming that for every arsenic induced bladder cancer death recorded among the Taiwanese study population, 1.25 people actually had arsenic induced bladder cancer. Therefore, we multiplied the number of bladder cases derived using the upper-end NRC risk distribution by 1.25 to determine our estimate of the upper-end number of bladder cancer cases at each MCL.

The number of bladder cancer cases avoided at each MCL are shown in Exhibit 5-12, and range from 22 to 52 at an MCL of 3 µg/L, 16 to 45 at an MCL of 5 µg/L, 9 to 26 at an MCL of 10 µg/L, and 4 to 15 at an MCL of 20 µg/L.

Exhibit 5-12
Annual Bladder Cancer Cases Avoided from Reducing Arsenic in CWSs

Arsenic Level (µg/L)	Reduced Mortality Cases**	Reduced Morbidity Cases**	Total Bladder Cancer Cases Avoided*
3	6 - 14	16 - 39	22 - 52
5	4 - 12	12 - 33	16 - 45
10	2 - 7	7 - 19	9 - 26
20	1 - 4	3 - 11	4 - 15

* The lower-end estimate of bladder cancer cases avoided is calculated using the lower-end risk estimate (see Exhibit 5-9) and assumes that the conditional probability of mortality among the Taiwanese study group was 100 percent. The upper-end estimate of bladder cancer cases avoided is calculated using the upper-end risk estimate (see Exhibit 5-9) and assumes that the conditional probability of mortality among the Taiwanese study group was 80 percent.
**Assuming 20-year mortality rate in the U.S. of 26 percent.

Using the "What if?" Scenario for Lung Cancer Benefits

The "What if?" scenario for lung cancer benefits was used to estimate benefits for avoided cases of lung cancer. This scenario is based on the statement in the NRC report "Arsenic in Drinking Water," which states that "some studies have shown that excess lung cancer deaths attributed to arsenic are 2-5 fold greater than the excess bladder cancer deaths (NRC, 1999, pg. 8)." Two-to-five fold greater would be 3.5 fold greater on average.   Also in the U.S. the mortality rate from bladder cancer is 26% and the mortality rate of lung cancer is 88%. This suggests that if the risk of contracting lung cancer were identical to the risk of contracting bladder cancer, one would expect 3.4 times the number of deaths from lung cancer as from bladder cancer. Since these numbers are essentially the same, it seems reasonable to assume that the risk of contracting lung cancer is essentially the same as the rate of contracting bladder cancer,[6] in the context of this "what-if" scenario. If the risk of contracting lung cancer from arsenic in drinking water is approximately equal to the risk of contracting bladder cancer, then the combined risk estimates of contracting either bladder or lung cancer would be approximately double the risk estimates of bladder cancer alone.

The number of lung cancer cases avoided for reducing arsenic in CWSs is presented in Exhibit 5-13, and range from 8 to 80 at an MCL of 3 µg/L, 6 to 68 at an MCL of 5 µg/L, 3 to 40 at an MCL of 10 µg/L, and 2 to 23 at an MCL of 20 µg/L.

Exhibit 5-13
Potential Annual Lung Cancer Cases Avoided from Reducing Arsenic in CWSs

Arsenic Level (µg/L)	Reduced Mortality Cases	Reduced Morbidity Cases	Total Lung Cancer Cases Avoided
3	7 - 70	1 - 10	8 - 80
5	5 - 60	1 - 8	6 - 68
10	3 - 35	0 - 5	3 - 40
20	1 - 20	0 - 3	2 - 23

Economic Measurements of the Value of Risk Reduction

The evaluation stage in the analysis of risk reductions involves estimating the value of reducing the risks. The following sections describe the use of the benefits valuation techniques to estimate the value of the risk reductions attributable to the regulatory options for arsenic in drinking water. First, the approach for valuing the reductions in fatal risks is described, followed by a description of the approach for valuing the reductions in nonfatal risks.

The benefits described in this RIA are assumed to begin to accrue on the effective date of the rule and are based on a calculation referred to as the "value of a statistical life" (VSL). Of the many VSL studies, the Agency recommends using estimates from 26 specific studies that have been

[6] If "X" is the probability of contracting bladder cancer, then 0.26X is the probability of mortality from bladder cancer. If lung cancer deaths are 2 to 5 times as high as bladder cancer, then they are, on average, 3.5 times as high and the average probability of mortality from lung cancer would be 3.5 times 0.26X, or 0.91X. Since we also know that there is a 88% mortality rate from lung cancer, then if the probability of contracting lung cancer is "Y," the probability of mortality from lung cancer can also be represented as 0.88Y. Setting the two ways of deriving the probability of mortality from lung cancer equal, or 0.91X = 0.88Y, one can solve for Y (Y= (0.91/0.88) X). Thus Y is approximately equal to X, and the rate of contracting lung cancer is approximately the same as the rate of contracting bladder cancer.

peer reviewed and extensively reviewed within the Agency.[7] These estimates, which are derived from wage-risk and contingent valuation studies, range from $0.7 million to $16.3 million and approximate a Wiebull distribution with a mean of $4.8 million (in 1990 dollars). Most of these 26 studies examine willingness to pay in the context of voluntary acceptance of higher risks of immediate accidental death in the workplace in exchange for higher wages. This value is sensitive to differences in population characteristics and perception of risks being valued.

EPA updated the VSL estimate from the *The Benefits and Costs of the Clean Air Act, 1970 to 1990* report to a value of $5.8 million in 1997 dollars, according to internal guidance on economic analyses (personal communication, John Bennett 5/15/00). In order to directly compare the estimated national costs of compliance, the VSL used in this analysis was updated from the January 1997 value to $6.06 million in May 1999 dollars, using the Consumer Price Index (CPI-U) for all items.

Several factors may influence the estimate of economic benefits associated with avoided cancer fatalities, including:

1. a possible "cancer premium" (i.e., the additional value or sum that people may be willing to pay to avoid the experiences of dread, pain and suffering, and diminished quality of life associated with cancer-related illness and ultimate fatality);
2. the willingness of people to pay more over time to avoid mortality risk as their income rises;
3. a possible premium for accepting involuntary risks as opposed to voluntary assumed risks;
4. the greater risk aversion of the general population compared to the workers in the wage-risk valuation studies;
5. "altruism" or the willingness of people to pay more to reduce risk in other sectors of the population; and
6. a consideration of health status and life years remaining at the time of premature mortality.

Use of certain of these factors may significantly increase the present value estimate. EPA therefore believes that adjustments should be considered simultaneously. The Agency also believes that there is currently neither a clear consensus among economists about how to simultaneously analyze each of these adjustments nor is there adequate empirical data to support definitive quantitative estimates for all potentially significant adjustment factors. As a result, the primary estimates of economic benefits presented in the analysis of this proposed rule rely on the unadjusted estimate.

To estimate the monetary value of reduced fatal risks (i.e., risks of premature death from cancer) predicted under different regulatory options, value of a statistical life (VSL) estimates are multiplied by the number of premature fatalities avoided. VSL does not refer to the value of an identifiable life, but instead to the value of small reductions in mortality risks in a population. A "statistical" life is thus the sum of small individual risk reductions across an entire exposed population. For example, if 100,000 people would each experience a reduction of 1/100,000 in

[7] U.S. Environmental Protection Agency, *The Benefits and Costs of the Clean Air Act, 1970 to 1990*, October 1997, Appendix I; and U.S. Environmental Protection Agency, *Guidelines for Preparing Economic Analysis (Review Draft)*, June 1999, Chapter 7.

their risk of premature death as the result of a regulation, the regulation can be said to "save" one statistical life (i.e., 100,000 x 1/100,000). If each member of the population of 100,000 were willing to pay $20 for the stated risk reduction, the corresponding value of a statistical life would be $2 million (i.e., $20 x 100,000). VSL estimates are appropriate only for valuing small changes in risk; they are not values for saving a particular individual's life.

Estimates of the willingness to pay to avoid treatable, nonfatal cancers are the ideal economic measures used to value reductions in nonfatal risks. Unfortunately, this information is not available for bladder cancer. However, willingness to pay (WTP) data to avoid chronic bronchitis is available, and has previously been employed by OGWDW (the microbial/disinfection by-product (MDBP) rulemaking) as a surrogate to estimate the WTP to avoid non-fatal bladder cancer. A WTP central tendency estimate of $607,162 (May 1999$) is used to monetize the benefits of avoiding non-fatal cancers (this value was updated from the $536,000 value EPA updated to 1997$ from the Viscusi et al. 1991 study).

To ground-truth the use of the chronic bronchitis WTP value as a proxy for bladder cancer WTP, EPA has also developed cost of illness estimates for bladder cancer, as reported in Exhibit 5-14. These estimates of direct medical costs are derived from a study conducted by Baker et al. (1989), which uses data from a sample of Medicare records for 1974 - 1981. These data include the total charges for inpatient hospital stays, skilled nursing facility stays, home health agency charges, physician services, and other outpatient and medical services. EPA combined these data with estimates of survival rates and treatment time periods to determine the average costs of initial treatment and maintenance care for patients who do not die of the disease. This value of $178,405 at a 3 percent discount rate, serves as a low-end estimate of the WTP to avoid bladder cancer and does not include the value of avoided pain and suffering, lost productivity, or risk premium.

Exhibit 5-14
Lifetime Avoided Medical Costs for Survivors
(preliminary estimates[1])

Type of Cancer	Date Data Collected	Number of Cases Studied	Estimated Mortality Rate	Mean Value per Nonfatal Case (Discount Rate) [1]
Bladder	1974-1981	5% of 1974 Medicare patients (sample from national statistics)	26 percent (after 20 years)	$178,405 (3%) $147,775 (7%) (for typical individual diagnosed at age 70)

1. May 1999 dollars
Source: U.S. Environmental Protection Agency, *Cost of Illness Handbook (draft)*, September 1998.

<u>Estimates of Cancer Health Benefits of Arsenic Reduction</u>

Benefits estimates were calculated using mean population risk estimates at various MCL levels (the composite values of the mean population risks presented in Exhibit 5-9). Lifetime risk estimates were converted to annual risk factors, and applied to the exposed population to determine the number of bladder cases avoided per year (Exhibit 5-12). Exhibit 5-13 describes the number of lung cancer cases avoided per year. These cases were divided into fatal and non-fatal cases avoided, based on survival information. The avoided premature fatalities were valued based on the VSL estimates discussed earlier, as recommended by current EPA guidance for cost/benefit analysis (EPA, 1997). The avoided non-fatal cases were valued based on the willingness to pay estimates for the avoidance of chronic bronchitis.

The results of the benefits valuation are presented in Exhibit 5-15. Total annual health benefits resulting from bladder cancer cases avoided range from $43.6 to $104.2 at an MCL of 3 µg/L, $31.7 to $89.9 at an MCL of 5 µg/L, $17.9 to $52.1 at an MCL of 10 µg/L, and $7.9 to $29.8 at an MCL of 20 µg/L. Potential annual health benefits from avoided cases of lung cancer, when estimated based on the "what if" scenario in which the risks of a fatal lung cancer case associated with arsenic is assumed to be two to five times that of a fatal bladder cancer case, range from $47.2 to $448.0 at an MCL of 3 µg/L, $35.0 to $384.0 at an MCL of 5 µg/L, $19.6 to $224.0 at an MCL of 10 µg/L, and $8.8 to $128.0 at an MCL of 20 µg/L. In addition, other potential non-quantifiable health benefits are summarized in Exhibit 5-15.

Exhibit 5-15
Estimated Monetized Total Cancer Health Benefits and
Non-Quantifiable Health Benefits from Reducing Arsenic in CWSs

Arsenic Level (µg/L)	Annual Bladder Cancer Health Benefits ($millions)[1,2]	"What-if" Scenario and Potential Non-Quantifiable Health Benefits	
		"What-if" Scenario Annual Lung Cancer Health Benefits ($millions)[1,3]	Potential Non-Quantifiable Health Benefits
3	$43.6 - $104.2	$47.2 - $448.0	• Skin Cancer • Kidney Cancer • Cancer of the Nasal Passages • Liver Cancer • Prostate Cancer • Cardiovascular Effects • Pulmonary Effects • Immunological Effects • Neurological Effects • Endocrine Effects • Reproductive and Developmental Effects
5	$31.7 - $89.9	$35.0 - $384.0	
10	$17.9 - $52.1	$19.6 - $224.0	
20	$7.9 - $29.8	$8.8 - $128.0	

1. May 1999 dollars.
2. The lower-end estimate is calculated using the lower-end number of bladder cancer cases avoided (see Exhibit 5-12) and assumes that the conditional probability of mortality among the Taiwanese study group was 100 percent. The upper-end estimate is calculated using the upper-end number of cancer cases avoided (see Exhibit 5-12) and assumes that the conditional probability of mortality among the Taiwanese study group was 80 percent.
3. These estimates are based on the "what if" scenario for lung cancer, where the risks of a fatal lung cancer case associated with arsenic are assumed to be 2-5 times that of a fatal bladder cancer case.

Non-Transient Non-Community Water Systems

Exhibit 5-16 presents a summary of the risk and benefit analyses for regulation of arsenic in NTNC water systems. Exhibit 5-17 presents risk figures for three particular sets of individuals: children in daycare centers and schools, and construction workers. Construction and other strenuous activity workers comprise an extremely small portion of the population served by NTNC systems (less than 0.1 percent), but face the highest relative risks of all NTNCWS users (90^{th} percentile risks of 0.7 to 1.6 x 10^{-4} lifetime risk).

Exhibit 5-16
Mean Bladder Cancer Risks, Exposed Population, and Annual Cancer Benefits in NTNCs[1]

Arsenic Level (µg/L)	Mean Exposed Population Risk (10^{-4})		Total Bladder Cancer Cases Avoided per Year		Annual Benefits ($millions)[2]	
	lower bound	upper bound	lower bound	upper bound	lower bound	upper bound
3	0.0046	0.01	0.132	0.294	$0.610	$2.717
5	0.0077	0.017	0.104	0.229	$0.481	$2.116
10	0.012	0.026	0.064	0.147	$0.296	$1.359
20	0.015	0.033	0.039	0.088	$0.180	$0.814
baseline	0.019	0.042	--	--	--	--

1. Note that this table does not include lung cancer benefits.
2. May 1999 dollars

Exhibit 5-17
Sensitive Group Evaluation of Lifetime Risks

Group	Mean Risk	90^{th} Percentile Risk
Forest Service, Construction and Mining Workers	3.2 - 7 x 10^{-5}	7.2 - 16 x 10^{-5}
School Children	3.8 - 7.9 x 10^{-6}	0.84 - 1.7 x 10^{-5}
Day Care Children	3.4 - 6.8 x 10^{-6}	0.74 - 1.5 x 10^{-5}

However, there is considerable uncertainty about these exposure numbers, as it is quite likely that they overestimate consumption. The risks for children are much lower with an upper bound, 90^{th} percentile estimate of 1.7 x 10^{-5} lifetime risk. What is not possible to determine from the analysis of NTNC systems is the extent to which there is overlap of individual exposure between the various sectors. NTNC establishments generally constitute a small portion of their SIC sectors. In conjunction with the observation that NTNC populations would only serve about eleven percent of the total population if all sectors were mutually exclusive, it would seem reasonable to treat the SIC groups independently. However, it is equally plausible that there are communities where one individual might go from an NTNC day care center to a series of NTNC schools and then work in an NTNC factory. Unfortunately, the Agency presently has no basis for quantitatively estimating the extent to which this would occur.

The Agency is quite concerned about the potential for local issues to arise with respect to combined arsenic exposures. In the rare community where all ground water is contaminated with the highest levels of arsenic, risks could be outside of the Agency's traditionally allowable range.

5.4 Other Benefits of Reductions in Arsenic Exposure

Although health effects are the primary focus of this analysis, arsenic also has negative impacts on the ecology and on public perceptions and acceptance of drinking water. These are briefly discussed below.

5.4.1 Ecological Effects

Ecological effects are not quantified in this benefits assessment. However, they are anticipated to occur at levels of severity that are in proportion to the levels of contamination that occur. Since drinking water is ultimately reintroduced into the environment, arsenic contamination of drinking water is of concern for its potential adverse impacts on the ecology. The avoidance of ecological effects resulting from the proposed rule constitutes an non-quantified benefit of the rule.

Arsenic has numerous ecological effects on multiple biological systems, as indicated in the health effects listed in Exhibit 5-1. While there are differences in the function and disease induction between humans and animals, there are also striking similarities. The anatomy and physiology of most animal systems share many common elements, including most of the basic organ systems and biochemical processes. Effects observed in humans are generally assumed to be similar to those observed in animals, with the exception of higher cognitive functions. This is the basis for the extensive animal laboratory testing programs and requirements that EPA uses to evaluate the toxicity of chemicals on humans.

It is likely that most if not all of the effects observed in humans (listed in Exhibit 5-1) will also be observed in animals. As noted above, there are also numerous animal studies that have demonstrated effects in various species. Arsenic, a heavy metal, bioaccumulates in many biological materials and can move through the food chain through a variety of pathways. In addition to damage caused directly on ecological systems, ecological effects may indirectly cause adverse effect in humans, through ingestion of contaminated plants or animals.

5.4.2 Drinking Water Quality and Public Perception

It is well established that the public often avoids the use of tap water that is suspected to be contaminated. In this context, contamination may suggest biological, chemical, or other water quality issues. When public perception of water quality declines, consumers purchase bottled water if they have the means to do so. In addition or as an alternative, they may avoid the use of tap water, ingesting and cooking with other liquids, substituting pre-mixed baby formula, and using other strategies to limit ingestion. Consumer avoidance of tap water sources usually results in costs to the consumers, either in the cost of obtaining substitute fluids or potential health impacts of reduced fluid intake. In addition, there are numerous cases where government agencies have provided bottled water due to biological or chemical contamination. The levels of contamination at which the government activities occur vary depending on a variety of factors.

The relationship between arsenic in tap water and changes in consumer behavior or government interventions is a complex one. Factors that impact the choice to avoid tap water depend on public information that is provided on levels of contamination, potential health effects, individual aversions to risk taking, and other considerations. A quantitative evaluation of these responses and the potential benefits of avoiding associated costs to the consumer or governments is not included in this benefits assessment. However, it is clear that many consumers purchase bottled water (a multimillion dollar industry) or invested in other methods of improving drinking water quality, such as point-of-use (POU) devices, specifically to avoid ingestion of contaminants such as arsenic. Thus, it is reasonable to conclude that a reduction in arsenic contamination will have the long-term effect of restoring some level of consumer confidence in the water supply.

Chapter 6: Cost Analysis

6.1 Introduction

This chapter presents the national cost estimates for the proposed Arsenic Rule. The costs associated with the proposed rule include: 1) costs borne by water systems to comply with the new MCL standard and modified monitoring requirements, and 2) costs to the States to implement and enforce the rule. Section 6.2 describes the inputs and methodologies used to estimate costs, including the following:

- a description of the technologies that may be used by systems to achieve the MCL (Section 6.2.1),
- the unit costs of different technologies for complying with the MCLs (Section 6.2.2),
- system and State unit costs for monitoring and administration functions (Section 6.2.3),
- the methods used to predict systems' compliance methods and the methods used to calculate costs (Section 6.2.4).

Section 6.3 presents the results of the cost analysis, including the following:

- a summary of national costs for the different regulatory options (Section 6.3.1),
- costs by system size and type for the proposed option (Section 6.3.2),
- and household costs (Section 6.3.3).

6.2 Methodology

6.2.1 Description of Available Technologies

In 1993, EPA developed a document entitled *Treatment and Occurrence-Arsenic in Potable Water Supplies* (EPA,1993) which summarized the results of pilot-scale studies examining low-level arsenic removal, from 50 parts per billion (ppb or µg/L) down to 1 ppb or less. EPA convened a panel of outside experts in January 1994 to review this document and comment on the ability of the technologies to achieve various MCLs. The Agency has since sought stakeholder input on the use of various technologies for arsenic removal under different conditions, and has incorporated that input into its estimates of technology performance and costs. The results are documented in the *Cost and Technology Document for the Arsenic Rule* (US EPA, July 1999). The technology cost functions and removal efficiencies presented in that document are used as inputs for the cost analyses presented in this RIA.

EPA reviewed fourteen treatment technologies. Of these, five are the most relevant for small systems:

- Ion exchange
- Activated alumina
- Reverse osmosis
- Nanofiltration
- Electrodialysis reversal

Two technologies are used primarily in larger systems and are not expected to be installed solely for arsenic removal:

- Coagulation/filtration
- Lime softening

Finally, seven additional alternative technologies were characterized as still emerging:

- Iron-oxide coated sand
- Granular ferric hydroxide
- Iron filings
- Sulfur-modified iron
- Greensand filtration
- Iron addition with microfiltration
- Conventional iron/manganese removal

Some technologies generate wastes which require disposal, or require pre-treatment (e.g., pre-oxidation or corrosion control)in order to be effective. These associated requirements were identified for different technologies and system types, and their costs were included in the costs of treatment where relevant.

In addition to these centralized treatment options, small systems may elect to use point-of-use (POU) or point-of-entry (POE) devices to achieve compliance with the MCLs. POE involves whole house treatment, whereas POU treats water at the tap. The available POE/POU technologies for arsenic removal are essentially smaller versions of reverse osmosis, activated alumina, and ion exchange. The technologies will have to be maintained by the water system, involving some additional recordkeeping and maintenance costs.

Finally, some systems may elect to comply with the lower MCL by obtaining water from alternative sources that meet the standard, or by interconnecting with another water system to combine treatment or share the cost of treatment (referred to as "regionalization").

The result of the review of technologies that would effectively remove arsenic and bring a water system into compliance is summarized in Exhibit 6-1. The list includes 25 treatment trains available to systems, consisting of various combinations of compliance technologies, waste disposal technologies, or pre-treatment technologies as required.

Exhibit 6-1
Arsenic Rule Treatment Trains by Compliance Technologies Component, with Associated Removal Efficiencies

Treatment Technology		Waste Disposal Technology							Corrosion Control	Pre-Oxidation	Removal Efficiency
		POTW	Evaporation Pond	Non-Hazardous Landfill	Direct Discharge	Chemical Precipitation	Mechanical De-Watering	Non-Mechanical De-Watering			
1	Regionalization										90%
2	Alternate Source										90%
3	Modify Lime Softening									✓	80%
4	Modify Coagulation/Filtration									✓	95%
5	Anion Exchange (25 mg/L SO4)	✓							✓	✓	95%
6	Anion Exchange (150 mg/L SO4)	✓							✓	✓	95%
7	Anion Exchange (25 mg/L SO4)		✓	✓					✓	✓	95%
8	Anion Exchange (150 mg/L SO4)		✓	✓					✓	✓	95%
9	Activated Alumina (2,000 BV)			✓*						✓	90%
10	Activated Alumina (10,000 BV)			✓*						✓	90%
11	Reverse Osmosis				✓				✓	✓	95%
12	Reverse Osmosis	✓							✓	✓	95%
13	Reverse Osmosis			✓		✓			✓	✓	95%
14	Coagulation Assisted Microfiltration			✓			✓			✓	90%
15	Coagulation Assisted Microfiltration			✓				✓		✓	90%
16	Oxidation Filtration (Greensand)	✓**									50%
17	Anion Exchange (25 mg/L SO4)			✓		✓			✓	✓	95%
18	Anion Exchange (150 mg/L SO4)			✓		✓			✓	✓	95%
19	Activated Alumina (2,000 BV)	✓		✓						✓	90%
20	Activated Alumina (10,000 BV)	✓		✓						✓	90%
21	Anion Exchange (90 mg/L SO4)	✓							✓	✓	95%
22	Anion Exchange (90 mg/L SO4)		✓	✓					✓	✓	95%
23	POE Activated Alumina								✓	✓	99%
24	POU Reverse Osmosis									✓	99%
25	POU Activated Alumina									✓	99%

* non-hazardous landfill (for spent media)

** POTW for backwash stream

6.2.2 Unit Costs and Compliance Assumptions

Treatment

EPA estimated the costs of the various compliance technologies, including centralized treatment technologies (with associated waste disposal and pre-treatment), POE/POU treatment, and regionalization. Costs of each treatment train are estimated as functions of system size; design flow is used to calculate capital costs and average flow is used to calculate operating and maintenance (O&M) costs. Exhibit 6-2 presents a summary of compliance technology costs by cost component for the treatment trains listed in Exhibit 6-1, annualized over 20 years at a seven percent discount rate. Costs are in May 1999 dollars and are based on average and design flows for median populations of each system size category, assuming one entry point per system. Note that the capital and O&M cost components are listed separately for the treatment and waste disposal components of the treatment train, and totaled to equal the annual cost, excluding corrosion control or pre-oxidation costs. Detailed descriptions of the assumptions and methodologies used to develop these cost estimates are available in the *Cost and Technology Document for the Arsenic Rule* (US EPA, July 1999).

Exhibit 6-2
Average Compliance Technology Costs (Treatment Train 1 through 8)

Size Category	Treatment Train No.	1	2	3	4	5	6	7	8
< 100									
	Treatment Capital Costs	$ 280,000	$ 20,000	$ 8,830	$ 7,370	$ 39,477	$ 39,477	$ 39,477	$ 39,477
	Treatment O&M Costs	$ -	$ -	$ 12,617	$ 7,107	$ 5,614	$ 12,669	$ 5,614	$ 12,669
	Waste Disposal Capital Costs	$ -	$ -	$ 7,400	$ 7,400	$ 3,955	$ 3,955	$ 16,534	$ 47,004
	Waste Disposal O&M Costs	$ -	$ -	$ 564	$ 564	$ 464	$ 566	$ 1,435	$ 3,251
	Annual Costs (7%)	$ 26,430	$ 1,888	$ 14,713	$ 9,065	$ 10,178	$ 17,335	$ 12,336	$ 24,084
101-500									
	Treatment Capital Costs	$ 280,000	$ 20,000	$ 13,530	$ 8,858	$ 83,934	$ 83,934	$ 83,934	$ 83,934
	Treatment O&M Costs	$ -	$ -	$ 14,520	$ 7,556	$ 10,099	$ 22,763	$ 10,099	$ 22,763
	Waste Disposal Capital Costs	$ -	$ -	$ 7,400	$ 7,400	$ 3,955	$ 3,955	$ 69,282	$ 201,124
	Waste Disposal O&M Costs	$ -	$ -	$ 1,575	$ 1,575	$ 694	$ 1,370	$ 4,988	$ 11,698
	Annual Costs (7%)	$ 26,430	$ 1,888	$ 18,071	$ 10,666	$ 19,089	$ 32,430	$ 29,549	$ 61,369
501-1000									
	Treatment Capital Costs	$ 280,000	$ 20,000	$ 20,397	$ 11,244	$ 132,451	$ 132,451	$ 132,451	$ 132,451
	Treatment O&M Costs	$ -	$ -	$ 18,056	$ 8,403	$ 16,999	$ 39,246	$ 16,999	$ 39,246
	Waste Disposal Capital Costs	$ -	$ -	$ 7,400	$ 7,400	$ 3,955	$ 3,955	$ 145,896	$ 423,558
	Waste Disposal O&M Costs	$ -	$ -	$ 3,528	$ 3,528	$ 1,137	$ 2,920	$ 9,626	$ 23,102
	Annual Costs (7%)	$ 26,430	$ 1,888	$ 24,207	$ 13,691	$ 31,012	$ 55,041	$ 52,898	$ 114,831
1,001-3,300									
	Treatment Capital Costs	$ 280,000	$ 20,000	$ 32,164	$ 16,823	$ 770,479	$ 770,479	$ 770,479	$ 770,479
	Treatment O&M Costs	$ -	$ -	$ 28,499	$ 11,005	$ 35,971	$ 86,719	$ 35,971	$ 86,719
	Waste Disposal Capital Costs	$ -	$ -	$ 7,697	$ 7,697	$ 3,955	$ 3,955	$ 343,395	$ 997,008
	Waste Disposal O&M Costs	$ -	$ -	$ 10,072	$ 10,072	$ 2,598	$ 8,033	$ 20,943	$ 51,831
	Annual Costs (7%)	$ 26,430	$ 1,888	$ 42,333	$ 23,391	$ 111,670	$ 167,853	$ 162,055	$ 305,388

NOTE:
1) Refer to Exhibit 6-1 for a description of treatment train technologies.
2) Average costs per size category are based on median population and associated flows, assuming one entry point per system.

Exhibit 6-2 continued
Average Compliance Technology Costs (Treatment Train 1 through 8)

Size Category	Treatment Train No.	1	2	3	4	5	6	7	8
3,300-10,000									
	Treatment Capital Costs	$ 280,000	$ 20,000	$ 225,058	$ 239,649	$ 2,495,535	$ 2,495,535	$ 2,495,535	$ 2,495,535
	Treatment O&M Costs	$ -	$ -	$ 49,872	$ 113,459	$ 8,922	$ 8,922	$ 8,922	$ 8,922
	Waste Disposal Capital Costs	$ -	$ -	$ 9,334	$ 9,334	$ 5,085	$ 5,085	$ 859,811	$ 3,312,119
	Waste Disposal O&M Costs	$ -	$ -	$ 32,781	$ 32,781	$ 8,312	$ 26,268	$ 49,672	$ 127,510
	Annual Costs (7%)	$ 26,430	$ 1,888	$ 104,778	$ 169,742	$ 253,275	$ 271,231	$ 375,315	$ 684,633
10,001-50,000									
	Treatment Capital Costs	$ 280,000	$ 20,000	$1,237,501	$1,393,797	$ 9,160,742	$ 9,160,742	$ 9,160,742	$ 9,160,742
	Treatment O&M Costs	$ -	$ -	$ 162,684	$ 736,014	$ 33,090	$ 33,090	$ 33,090	$ 33,090
	Waste Disposal Capital Costs	$ -	$ -	$ 10,898	$ 10,898	$ 5,085	$ 5,981	$ 3,945,421	$ 15,570,260
	Waste Disposal O&M Costs	$ -	$ -	$ 157,559	$ 157,559	$ 36,512	$ 124,966	$ 166,059	$ 448,436
	Annual Costs (7%)	$ 26,430	$ 1,888	$ 438,083	$1,026,166	$ 934,791	$ 1,023,330	$ 1,436,278	$ 2,815,958
50,001-100,000									
	Treatment Capital Costs	$ 280,000	$ 20,000	$2,055,598	$1,853,803	$ 19,339,675	$ 19,339,675	$ 19,339,675	$ 19,339,675
	Treatment O&M Costs	$ -	$ -	$ 368,722	$1,137,506	$ 70,123	$ 70,123	$ 70,123	$ 70,123
	Waste Disposal Capital Costs	$ -	$ -	$ 13,766	$ 13,766	$ 5,735	$ 7,076	$ 9,956,569	$ 33,925,583
	Waste Disposal O&M Costs	$ -	$ -	$ 413,912	$ 413,912	$ 94,447	$ 327,739	$ 357,083	$ 993,137
	Annual Costs (7%)	$ 26,430	$ 1,888	$ 977,967	$1,727,703	$ 1,990,640	$ 2,224,058	$ 3,192,564	$ 6,091,123
100,001-1,000,000									
	Treatment Capital Costs	$ 280,000	$ 20,000	$6,936,516	$3,672,160	$139,484,072	$139,484,072	$139,484,072	$ 139,484,072
	Treatment O&M Costs	$ -	$ -	$2,753,482	$2,931,378	$ 497,678	$ 497,678	$ 497,678	$ 497,678
	Waste Disposal Capital Costs	$ -	$ -	$ 48,804	$ 48,804	$ 9,572	$ 20,505	$ 62,342,119	$ 140,291,110
	Waste Disposal O&M Costs	$ -	$ -	$3,402,673	$3,402,673	$ 769,897	$ 2,691,813	$ 2,038,240	$ 5,985,719
	Annual Costs (7%)	$ 26,430	$ 1,888	$6,815,520	$6,685,285	$ 14,434,787	$ 16,357,736	$ 21,586,882	$ 32,892,195

NOTE:
1) Refer to Exhibit 6-1 for a description of treatment train technologies.
2) Average costs per size category are based on median population and associated flows, assuming one entry point per system.

Exhibit 6-2 continued
Average Compliance Technology Costs (Treatment Train 9 through 16)

Size Category	9	10	11	12	13	14	15	16
< 100								
	$ 49,780	$ 49,780	$ 156,629	$ 156,629	$ 156,629	$ 65,210	$ 65,210	$ 24,983
	$ 2,816	$ 2,816	$ 25,439	$ 25,439	$ 25,439	$ 13,108	$ 13,108	$ 7,747
	$ -	$ -	$ 3,520	$ 3,520	$ 40,587	$ 23,260	$ 27,122	$ 3,955
	$ 21	$ 21	$ 1,368	$ 1,368	$ 11,267	$ 3,701	$ 2,088	$ 464
	$ 7,536	$ 7,536	$ 41,924	$ 41,924	$ 55,322	$ 25,160	$ 23,911	$ 10,943
101-500								
	$ 210,637	$ 210,637	$ 433,067	$ 433,067	$ 433,067	$ 145,362	$ 145,362	$ 104,869
	$ 9,693	$ 9,693	$ 51,709	$ 51,709	$ 51,709	$ 17,159	$ 17,159	$ 9,495
	$ -	$ -	$ 3,457	$ 3,457	$ 70,251	$ 26,273	$ 37,421	$ 3,955
	$ 137	$ 137	$ 11,724	$ 11,724	$ 17,439	$ 4,941	$ 2,299	$ 694
	$ 29,712	$ 29,712	$ 104,639	$ 104,639	$ 116,658	$ 38,301	$ 36,711	$ 20,462
501-1000								
	$ 485,414	$ 485,414	$ 710,071	$ 710,071	$ 710,071	$ 304,855	$ 304,855	$ 218,393
	$ 23,047	$ 23,047	$ 92,892	$ 92,892	$ 92,892	$ 28,132	$ 28,132	$ 12,948
	$ -	$ -	$ 3,552	$ 3,552	$ 109,999	$ 31,420	$ 52,696	$ 3,955
	$ 360	$ 360	$ 31,207	$ 31,207	$ 27,080	$ 7,330	$ 2,707	$ 1,137
	$ 69,227	$ 69,227	$ 191,460	$ 191,460	$ 197,381	$ 67,205	$ 64,590	$ 35,073
1,001-3,300								
	$ 1,302,755	$ 1,302,755	$ 1,623,013	$ 1,623,013	$ 1,623,013	$ 726,146	$ 726,146	$ 507,481
	$ 67,590	$ 67,590	$ 222,259	$ 222,259	$ 222,259	$ 37,152	$ 37,152	$ 24,350
	$ -	$ -	$ 4,571	$ 4,571	$ 152,058	$ 51,820	$ 122,455	$ 3,955
	$ 1,099	$ 1,099	$ 74,606	$ 74,606	$ 40,523	$ 21,160	$ 5,696	$ 2,598
	$ 191,659	$ 191,659	$ 450,497	$ 450,497	$ 430,336	$ 131,746	$ 122,950	$ 75,224

NOTE:
1) Refer to Exhibit 6-1 for a description of treatment train technologies.
2) Average costs per size category are based on median population and associated flows, assuming one entry point per system.

Exhibit 6-2 continued
Average Compliance Technology Costs (Treatment Train 9 through 16)

Size Category	9	10	11	12	13	14	15	16
3,300-10,000								
	$ 3,803,627	$ 3,803,627	$ 3,935,731	$ 3,935,731	$ 3,935,731	$ 1,510,476	$ 1,510,476	$ 1,253,212
	$ 219,658	$ 219,658	$ 561,953	$ 561,953	$ 561,953	$ 73,586	$ 73,586	$ 63,448
	$ -	$ -	$ 5,382	$ 5,382	$ 197,836	$ 118,824	$ 410,913	$ 5,085
	$ 3,630	$ 3,630	$ 108,199	$ 108,199	$ 65,423	$ 21,276	$ 22,801	$ 8,312
	$ 582,324	$ 582,324	$ 1,042,166	$ 1,042,166	$ 1,017,556	$ 248,656	$ 277,753	$ 190,535
10,001-50,000								
	$ 15,997,473	$ 15,997,473	$ 15,030,714	$ 15,030,714	$ 15,030,714	$ 5,348,970	$ 5,348,970	$ 4,186,608
	$ 1,075,859	$ 1,075,859	$ 2,429,780	$ 2,429,780	$ 2,429,780	$ 280,577	$ 280,577	$ 283,584
	$ -	$ -	$ 7,898	$ 7,898	$ 476,817	$ 177,968	$ 907,819	$ 5,085
	$ 17,881	$ 17,881	$ 526,046	$ 526,046	$ 153,221	$ 55,113	$ 61,314	$ 36,512
	$ 2,603,788	$ 2,603,788	$ 4,375,365	$ 4,375,365	$ 4,046,803	$ 857,394	$ 932,488	$ 715,762
50,001-100,000								
	$ 38,371,441	$ 38,371,441	$ 35,105,717	$ 35,105,717	$ 35,105,717	$ 7,496,682	$ 7,496,682	$ 8,718,795
	$ 2,834,902	$ 2,834,902	$ 5,457,968	$ 5,457,968	$ 5,457,968	$ 580,569	$ 580,569	$ 735,847
	$ -	$ -	$ 12,515	$ 12,515	$ 988,706	$ 285,159	$ 1,816,207	$ 5,735
	$ 47,159	$ 47,159	$ 1,376,897	$ 1,376,897	$ 333,600	$ 124,631	$ 139,960	$ 94,447
	$ 6,504,053	$ 6,504,053	$ 10,149,778	$ 10,149,778	$ 9,198,627	$ 1,439,750	$ 1,599,600	$ 1,653,828
100,001-1,000,000								
	$ 312,631,164	$ 312,631,164	$ 268,100,910	$ 268,100,910	$ 268,100,910	$ 16,835,071	$ 16,835,071	$ 50,584,105
	$ 23,343,166	$ 23,343,166	$ 40,762,901	$ 40,762,901	$ 40,762,901	$ 4,050,692	$ 4,050,692	$ 6,008,680
	$ -	$ -	$ 69,107	$ 69,107	$ 7,263,436	$ 1,459,396	$ 12,597,315	$ 9,572
	$ 388,505	$ 388,505	$ 10,542,021	$ 10,542,021	$ 2,436,597	$ 935,117	$ 1,009,510	$ 769,897
	$ 53,241,841	$ 53,241,841	$ 76,618,275	$ 76,618,275	$ 69,191,945	$ 6,712,677	$ 7,838,411	$ 11,554,262

NOTE:
1) Refer to Exhibit 6-1 for a description of treatment train technologies.
2) Average costs per size category are based on median population and associated flows, assuming one entry point per system.

Exhibit 6-2 continued
Average Compliance Technology Costs (Treatment Train 17 through 23)

Size Category	17	18	19	20	21	22	23
3,300-10,000							
	$ 2,495,535	$ 2,495,535	$ 3,803,627	$ 3,803,627	$ 3,173,443	$ 1,644,085	$ 562,676
	$ 8,922	$ 43,567	$ 219,658	$ 219,658	$ 822,852	$ 586,793	$ 861,662
	$ 120,582	$ 120,582	$ 4,624	$ 4,624	$ -	$ -	$ -
	$ 43,485	$ 43,485	$ 36,409	$ 36,409	$ -	$ -	$ -
	$ 299,350	$ 333,995	$ 615,539	$ 615,539	$ 1,274,679	$ 820,874	$ 941,775
10,001-50,000							
	$ 9,160,742	$ 9,160,742	$ 15,997,473	$ 15,997,473	$ 13,884,129	$ 7,198,773	$ 2,462,155
	$ 33,090	$ 165,678	$ 1,075,859	$ 1,075,859	$ 3,866,644	$ 2,643,298	$ 3,842,689
	$ 271,621	$ 271,621	$ 6,097	$ 6,097	$ -	$ -	$ -
	$ 67,770	$ 67,770	$ 175,430	$ 175,430	$ -	$ -	$ -
	$ 991,208	$ 1,123,796	$ 2,761,913	$ 2,761,913	$ 5,843,432	$ 3,668,241	$ 4,193,244
50,001-100,000							
	$ 19,339,675	$ 19,339,675	$ 38,371,441	$ 38,371,441	$ 34,069,251	$ 17,673,110	$ 6,042,288
	$ 70,123	$ 350,577	$ 2,834,902	$ 2,834,902	$ 9,909,392	$ 6,602,335	$ 9,539,669
	$ 548,757	$ 548,757	$ 8,799	$ 8,799	$ -	$ -	$ -
	$ 117,662	$ 117,662	$ 461,046	$ 461,046	$ -	$ -	$ -
	$ 2,065,112	$ 2,345,566	$ 6,918,771	$ 6,918,771	$ 14,760,087	$ 9,118,589	$ 10,399,955
100,001-1,000,000							
	$ 139,484,072	$ 139,484,072	$ 312,631,164	$ 312,631,164	$ 239,916,151	$ 124,585,586	$ 42,558,851
	$ 497,678	$ 2,488,884	$ 23,343,166	$ 23,343,166	$ 76,696,105	$ 48,323,042	$ 68,900,160
	$ 3,945,878	$ 3,945,878	$ 41,919	$ 41,919	$ -	$ -	$ -
	$ 699,342	$ 699,342	$ 3,790,974	$ 3,790,974	$ -	$ -	$ -
	$ 14,735,792	$ 16,726,998	$ 56,648,268	$ 56,648,268	$ 110,854,767	$ 66,061,227	$ 74,959,583

NOTE:
1) Refer to Exhibit 6-1 for a description of treatment train technologies.
2) Average costs per size category are based on median population and associated flows, assuming one entry point per system.

Exhibit 6-2 continued
Average Compliance Technology Costs (Treatment Train 17 through 23)

Size Category	17	18	19	20	21	22	23
< 100							
	$ 39,477	$ 39,477	$ 49,780	$ 49,780	$ 26,357	$ 13,619	$ 4,671
	$ 5,614	$ 6,431	$ 2,762	$ 2,762	$ 5,420	$ 4,433	$ 6,725
	$ 32,187	$ 32,187	$ 3,500	$ 3,500	$ -	$ -	$ -
	$ 7,404	$ 7,404	$ 584	$ 584	$ -	$ -	$ -
	$ 19,782	$ 20,599	$ 8,375	$ 8,375	$ 9,172	$ 6,372	$ 7,390
101-500							
	$ 83,934	$ 83,934	$ 210,637	$ 210,637	$ 152,478	$ 78,866	$ 27,027
	$ 10,099	$ 13,220	$ 9,793	$ 9,793	$ 34,134	$ 26,552	$ 39,804
	$ 37,318	$ 37,318	$ 3,500	$ 3,500	$ -	$ -	$ -
	$ 7,447	$ 7,447	$ 1,712	$ 1,712	$ -	$ -	$ -
	$ 28,991	$ 32,113	$ 31,719	$ 31,719	$ 55,844	$ 37,781	$ 43,652
501-1000							
	$ 132,451	$ 132,451	$ 485,414	$ 485,414	$ 374,156	$ 193,617	$ 66,325
	$ 16,999	$ 15,164	$ 23,236	$ 23,236	$ 87,479	$ 66,321	$ 98,815
	$ 46,083	$ 46,083	$ 3,500	$ 3,500	$ -	$ -	$ -
	$ 7,713	$ 7,713	$ 3,888	$ 3,888	$ -	$ -	$ -
	$ 41,565	$ 39,729	$ 73,274	$ 73,274	$ 140,750	$ 93,888	$ 108,258
1,001-3,300							
	$ 770,479	$ 770,479	$ 1,302,755	$ 1,302,755	$ 1,049,843	$ 543,574	$ 186,123
	$ 35,971	$ 21,577	$ 67,590	$ 67,590	$ 258,026	$ 189,924	$ 280,998
	$ 70,291	$ 70,291	$ 3,665	$ 3,665	$ -	$ -	$ -
	$ 18,846	$ 18,846	$ 11,170	$ 11,170	$ -	$ -	$ -
	$ 134,179	$ 119,786	$ 202,077	$ 202,077	$ 407,500	$ 267,317	$ 307,497

NOTE:
1) Refer to Exhibit 6-1 for a description of treatment train technologies.
2) Average costs per size category are based on median population and associated flows, assuming one entry point per system.

6.2.3 Monitoring and Administrative Costs

Monitoring Costs

Monitoring under the existing arsenic standard occurs annually for surface water systems, and triennially for ground water systems. Currently, when triggered by a violation the system must perform three additional tests within the month. Under the proposed rule to be promulgated in January 2001, systems will still perform monitoring annually (for surface water systems) or every three years (for ground water systems); however, when triggered by a violation, the system will perform quarterly monitoring rather than three more samples in one month. All large systems must comply no later than three years after promulgation (by December 31, 2004). Small systems must comply within five years of promulgation. Specifically, small surface water systems must comply by December 31, 2006, and small ground water systems must comply by December 31, 2007.

If quarterly monitoring is required it will continue until the State determines that the system is "reliably and consistently" below the MCL. States are able to make this determination after ground water systems have taken two quarterly samples and surface water systems have taken four quarterly samples. Additionally, States may grant a nine year monitoring waiver to qualifying systems, an option not previously available. To be eligible for a waiver, a system must meet the following criteria:

1. Demonstrate adequate source water protection;
2. Demonstrate that the arsenic is naturally occurring;
3. Demonstrate that three previous samples were below the MCL.

The proposed requirements will impose new costs for some systems as follows:

- NTNCs will incur the full costs of the monitoring requirements for the first time, unless they are located in States that already require NTNCs to monitor for arsenic. For NTNCs that are currently required to monitor for arsenic, the incremental monitoring costs will depend on how the proposed national requirements compare with the current State requirements. (It is assumed that states currently require NTNCs to monitor using the ground water requirements. It is also assumed that NTNCs will continue to follow the ground water requirements under the revised rule.)

- CWSs may incur additional costs if they find exceedances more frequently at the proposed MCL.

The cost of monitoring includes preparing and analyzing the sample. Collecting the sample, arranging for delivery to the laboratory, and reviewing the results of the analysis is assumed to require one hour of the system operator's time (at an estimated cost of $28 per hour). EPA has assumed that all systems are equipped to collect samples. Therefore, no additional costs are assumed for installing taps, re-piping of wells or other investments to permit sampling. EPA has assumed that systems will utilize one of two laboratory methods: 1) stabilized temperature platform graphite furnace atomic absorption (STP-GFAA) or 2) graphite furnace atomic absorption (GFAA). Both techniques cost $40 per sample.

Total net monitoring costs were estimated over a 20 year period at discount rates of three and seven percent. The net costs are equal to the difference between the cost of the proposed monitoring requirements and the cost of the current monitoring requirements. Cost and hour burden, to the system and the State are listed below in Exhibit 6-4. The cost of routine monitoring, triggered monitoring, waiver application and public notification are all included in the total system costs. Miscellaneous costs related to sending samples to be analyzed and sending public notification to customers are also included in the system cost.

During the first year of implementation all systems will incur costs related to routine monitoring. In addition, systems in violation will incur cost related to triggered quarterly monitoring. Under the revised rule, a percentage of the systems will have monitoring waivers in subsequent years when monitoring is required Monitoring waivers are not granted under the existing rule, therefore the number of systems required to conduct routine monitoring under the revised rule is less than that under the existing rule. For this reason, the annual net cost of monitoring between the revised rule and the existing rule may be negative, or less expensive, after the initial year of implementation. The inputs and methodology associated with this analysis are presented in detail in the *Information Collection Request for the Proposed Arsenic in Drinking Water Rule* (EPA ,1999)

Administrative Costs

States and systems will incur administrative costs to implement the revised arsenic program proposed under the Arsenic Rule. States and systems will need to allocate time for their staff to establish and maintain the programs necessary to comply with the revised arsenic standard and the new monitoring requirements. Exhibit 6-3(a) lists the one-time state activities involved in starting up the program following promulgation of the proposed rule. For example, start-up activities may include developing and adopting state regulations that meet the new Federal arsenic requirements. Resources are estimated in terms of full time equivalents (FTEs), which EPA has assumed to cost $64,480 per FTE, including overhead and fringe.   Systems also have start-up costs for reviewing the regulation and training operators. Exhibit 6-3(b) lists the one-time system start-up activities. The two primary activities that systems will perform to comply with the revised arsenic rule are reading and understanding the rule and operator training. For all systems the estimated time required to review the rule is eight hours. Systems serving fewer than 10,000 people have an estimated time of 16 hours to train operators; the estimated time for systems serving more than 10,000 people is 32 hours. The rate for all start-up activities for systems serving fewer than 10,000 people is $15.03 per hour and $29.03 per hour for systems serving more than 10,000 people.

States will also be required to spend time responding to systems that report MCL exceedances or systems that request a waiver (Exhibit 6-4). Hour burdens for States to review waiver applications, record monitoring of a sample, and issue a violation letter are the same for small and large systems. The number of hours required to review a single permit is twice as large for systems serving more than 10,000 people than for systems serving less than 10,00 people. The unit cost for all activities is consistent across all activities and size categories ($41.47 per hour) (EPA, 1997).

The number of hours required at the system level to perform the responsibilities related to monitoring are the same for systems serving fewer than 3,300 people and systems serving more than 3,300 people. However, the hourly rate for systems serving more than 3,300 people is almost double ($29.03) the rate for systems serving fewer than 3,300 people ($15.03).

Exhibit 6-3 (a)
Estimated One-Time State Resources Required for Initiation of the Arsenic Rule

Administrative Activity	Estimated State Resources (FTE)	Estimated Cost
One Time Start-up Activities		
Regulation Adoption and Program Development (CWS)	0.5	$32,200
System Training and Technical Assistance (CWS)	1.0	$64,500
System Training and Technical Assistance (NTNC)	1.0	$64,500
Staff Training (CWS)	0.23	$14,800
Subtotal CWS Costs	1.73	$111,500
Subtotal NTNCs Cost	1.0	$64,500
National Total* CWS Costs	100.34	$6,467,000
National Total* NTNCWS Costs	58.0	$3,741,000

*National totals include estimates for all states, territories, and tribes.

Exhibit 6-3 (b)
Estimated One-Time System Resources Required for Initiation of the Arsenic Rule

System Size Category	< 10,000 people		> 10,000 people	
One Time Start-up Activity	**Hours**	**Rate**	**Hours**	**Rate**
Reading and Understanding Rule	8	$15.03	8	$29.03
Operator Training	16	$15.03	32	$29.03

Exhibit 6-4
Unit Resources Required for Monitoring, Implementation, and Administration*

System Size Category	< 10,000 people		> 10,000 people	
State Activity	**Hours**	**Rate**	**Hours**	**Rate**
Review a waiver application	8	$41.47	8	$41.47
Record monitoring of a sample result	1	$41.47	1	$41.47
Issue a single violation letter	4	$41.47	4	$41.47
Review a single permit	16	$41.47	16	$41.47
	<3,000 people		**>3,300 people**	
System Activity	**Hours**	**Rate**	**Hours**	**Rate**
Apply for a waiver	16	$15.03	16	$29.03
Take a sample	1	$15.03	1	$29.03
Report a sample	1	$15.03	1	$29.03
Prepare and Send Public Notification	8	$15.03	8	$29.03

*Estimates are provided in May 1999 dollars, updated from 1997 dollars using the CPI-U for all items.
Source: *Information Collection Request for the Public Water System Supervision Program*.

6.2.4 Predicting Compliance Decisions (Compliance Decision Tree)

There is substantial variability in how systems will elect to comply with the Arsenic Rule. Choices of compliance method will vary depending on baseline source water arsenic concentrations, system size and location, types of treatment currently in place, and availability of alternative sources. In addition, the source water pH, total dissolved solids, sulfides and other salts can change the effectiveness of technologies in removing arsenic.

The RIA reflects this variability by predicting a range of compliance responses for different system types and sizes. The compliance decision tree specifies the percentage of systems in different categories that will choose specific compliance options, given the removal required by the MCL option and the baseline occurrence of arsenic in source water. For example, for a target MCL of 10 µg/L, the decision tree specifies the probability of different compliance choices for systems with different baseline influent concentrations (e.g., <10 µg/L, 10-20 µg/L, etc.), different sizes (e.g., population < or > 1,000), different sources (ground water or surface water), and different existing treatment facilities. The compliance choices are defined by a treatment technology and (where relevant) a waste disposal option, and/or pre-treatment technology.

EPA reviewed a draft of the compliance decision tree at an American Water Works Association (AWWA) technical workgroup meeting in February 1999, and made revisions based on the comments received at that meeting. The final compliance decision tree, as well as a discussion of the assumptions made during its development, is provided in Appendix A ("Cost Analysis Appendix") by system size and type.

6.2.5 Calculating Costs

Different methods were used to assess costs for three different categories of systems. A Monte-Carlo simulation model (SafeWaterXL) was used to estimate costs for community water systems, excluding the largest CWSs. A deterministic spreadsheet analysis was performed for NTNC water systems, while a separate case-by-case analysis were performed for the very large systems (serving more than one million people) that are expected to exceed one or more MCL options in the baseline. The costs for the three system categories were then summed to calculate total national costs. The methodology for calculating the costs for each of these system categories is described separately below, beginning with a description of the SafeWaterXL model.

CWS Costs

The national cost of compliance across CWSs (except those serving over one million people) was estimated using SafeWaterXL, a Monte-Carlo simulation model developed in Microsoft Excel© using the Crystal Ball© Monte-Carlo simulation add-in. SafeWaterXL forecasts a distribution of costs around the mean compliance cost expected for each system size category. The Monte-Carlo provides the flexibility to incorporate as much data as is available, while maintaining uncertainty bounds to prevent any individual input from skewing the results. When sample data is not available as single point estimates, this technique is an invaluable tool.

Historically most drinking water regulatory impact analyses used point-estimates to describe the average system-level costs. By using SafeWaterXL, this analysis contains more detailed descriptions of system-level cost. SafeWater XL describes system-level costs in terms of a distribution. From the distribution, mean and median costs are available, as well as percentile costs.

Model Structure

SafeWaterXL determines regulatory compliance costs for individual systems and subsequently calculates a national average based on the mean value of these data points. To do so, each system is assigned a random concentration from an occurrence distribution. This system concentration is distributed across the number of sites of possible contamination for that system. The average number of sites per system is determined based on the distribution of system intake sites for the size category as estimated from the CWSS. However, SafeWaterXL does not assume that all sites are equally likely to exceed the MCL standard. The likelihood of contamination is determined on a site-by-site basis. The sum of the mean arsenic concentration of all sites within a system must equal the mean arsenic concentration of the system. Given this upper bound, each site is assigned a concentration based on the assumed relative standard deviation (RSD) around the mean system occurrence.

The model then compares the concentration at each site to the proposed MCL standard; no costs are incurred for those sites whose concentrations fall below the specified MCL. If the site is determined to be in violation of the MCL, then SafeWaterXL calculates the percent reduction in arsenic concentration required to reduce the site concentration to 80 percent of the MCL standard (this is a safety factor which includes a 20 percent excess removal to account for system over-design). A treatment train is then assigned to the site based on a decision tree for the size and type of the system. The decision tree and the selected treatment train reflect the removal efficiencies of the chosen technology. For example, a technology is chosen based on matching the removal efficiencies and the percentage removal required at the site (SafeWaterXL identifies three categories of required removal: < 50 percent, 50-90 percent, > 90 percent).

In this manner, capital and O&M costs are calculated at the site level for the selected treatment train. The system's cost of compliance is then determined by summing across the treating sites. For each system in SDWIS in which a violation is expected, a cost is calculated with this method, thereby creating an estimate of national compliance costs. Since household costs are also calculated for each system, a similar distribution of the cost of compliance at the household level are also created.

In order to develop more detailed results the compliance decision tree is employed at the site level, so that only those sites requiring treatment would incur costs. The resulting total national compliance cost is expected to be a truer representation of the impact of the Arsenic Rule on systems. The sections below will describe the data needed to develop cost estimates for the entire universe of systems affected by the Arsenic Rule. After the discussion of data requirements, the SafeWaterXL model is described as it is used for this rule

Model Inputs

Number of Systems: The universe of public and private ground and surface water systems is taken from Safe Drinking Water Information System (SDWIS), EPA's national regulatory database for the drinking water program. Based on data extracted December 1998, a total of 54,352 CWSs and 20,255 NTNCs are subject to the new requirements proposed under the Arsenic Rule. It is necessary to compile this data by system size, water source, and ownership, as costs may vary by these characteristics. SafeWaterXL calculates costs for public and private systems (the latter also includes "other" or "ancillary" systems), and surface and ground water systems. A summary table of this breakdown is provided in Chapter 4, "Baseline Analysis."

Entry points per System: SafeWaterXL estimates each system's cost of compliance at the treatment site level. This modeling approach is used because a system may include more than one treatment site. Entry points are used as a proxy for potential or actual points of treatment. For example, a given water system may have three entry points: one entry point that currently treats, while two may not have treatment in place. Data on the distribution of the number of system entry points for each size category and type was extracted from the Community Water Supply Survey (CWSS). Linear interpolation was used to estimate values for the number of sites in cases where there were no survey data (see Chapter 4, "Baseline Analysis").

Population Served by System: A system's size is determined by the number of people served by that system. These numbers were extracted from the SDWIS database (see Chapter 4, "Baseline Analysis"). Systems are grouped into eight categories to help identify systems with related characteristics so that any data or resources may be pooled during analysis. SafeWaterXL recognizes the following size categories:

- < 100
- 101-500
- 501-1000
- 1,001-3,300
- 3,301-10,000
- 10,001-50,000
- 50,001-100,000
- 100,001- 1,000,000

Flow Rate Parameters: System size is further defined by its flow, which is calculated as a power law function of the population served. These functions were derived by EPA, and their derivation can be found in the Model Systems report (*Geometries and Characteristics of Public Water Systems,* May 1999, EPA pending). The equation form is shown below.

$$Average\ Flow = a_A \cdot (Population)^{b_A} \qquad (Equation\ 1)$$

$$Design\ Flow = \max \begin{cases} 2 \cdot Average\ Flow \\ a_D \cdot (Population)^{b_D} \end{cases} \qquad (Equation\ 2)$$

Where:

	a_A, b_A, a_D, b_D	=	the regression parameters derived for flow vs. population
	Population	=	the population served by the appropriate system type and primary source.

The regression parameters used in the cost model are provided in Exhibit 6-5. Values are provided for design and average flow for public and private ground water and surface water supplies. SafeWaterXL divides system design flow and average daily flow equally among all entry points. Treatment costs are only assigned to the minimum portion of flow that must be treated in order to achieve the new concentration standard, a process referred to as “blending”.

Exhibit 6-5
Flow Regression Parameters
by Water Source and System Ownership

	Average Flow		Design Flow	
	a	**b**	**a**	**b**
Ground Water				
Public	0.08558	1.05840	0.54992	0.95538
Private	0.06670	1.06280	0.41682	0.96078
Public-Purch	0.04692	1.10190	0.31910	0.99460
Private-Purch	0.05004	1.08340	0.32150	0.97940
Surface Water				
Public	0.14004	0.99703	0.59028	0.94573
Private	0.09036	1.03340	0.35674	0.96188
Public-Purch	0.04692	1.11020	0.20920	1.04520
Private-Purch	0.05004	1.08340	0.20580	1.00840

Average Consumption per Household: Household costs depend on the average annual consumption per residential connection. These mean estimates are provided in Chapter 4, "Baseline Analysis." Depending on the system's characteristics, SafeWaterXL multiplies the appropriate mean consumption (kgal) with the system's computed cost per thousand gallons to arrive at the average annual cost of compliance per household for a community water system.

Mean System Occurrence: Arsenic occurrence data are based on the EPA's *Arsenic Occurrence in Public Drinking Water Supplies* report and are represented by a lognormal distribution. The distribution is truncated at 50 µg/L, the current arsenic standard, because it is assumed that all arsenic reductions attributable to the new standard start at the previous standard (i.e. all systems are currently in compliance with the current standard). Baseline occurrence is distinguished between ground and surface water systems and is provided in Chapter 4 ("Baseline Analysis") as a lognormal distribution. Exhibit 6-6 shows the percent of ground and surface water systems with arsenic concentrations greater than 3, 5, 10, and 20 parts per billion (ppb).

Exhibit 6-6
Arsenic Occurrence by Water Source

Source	% of systems greater than (ppb)			
	3	**5**	**10**	**20**
GW	19.90	12.10	5.43	2.06
SW	6.01	2.90	0.75	0.26

Relative Intra-System Standard Deviation of Arsenic Concentrations: The relative intra-system standard deviation of the site concentrations within a system is calculated using data from a 25 state arsenic occurrence study ("Arsenic Occurrence in Public Drinking Water Supplies," EPA 1999). SafeWaterXL uses a default value of 0.64. This standard deviation is applied to the mean system concentration to generate individual entry points concentrations within the system.

Compliance Decision Trees: The decision trees represent EPA's best estimate of the treatment train technologies system operators will choose to achieve a particular percentage reduction in arsenic concentration. Decision trees are specific to the system's size categories and source water. These are provided in Appendix A, "Cost Analysis Appendix."

Removal Efficiencies, Treatment Target, and Blending: Each treatment train is associated with an arsenic removal efficiency that is assumed to be constant across system types. The removal efficiencies for the 25 treatment trains available under the Arsenic Rule were presented in Exhibit 6-1. SafeWaterXL employs these efficiencies with the blending principle, to determine the amount of flow that requires treatment in order for the entry point to meet the treatment target. Blending uses the entry point concentration and treatment train removal efficiency to determine the fraction of flow required to obtain the treatment target. The treatment target is set at 80 percent of the MCL and represents the level to which systems will be over-designed to ensure compliance with the MCL.

SafeWaterXL employs the blending concept through the following equation at the entry point level:

$$\text{Fraction of flow treated} = \min\left\{ \frac{\left(\frac{TreatmentTarget}{SiteConcentration} - 1\right) \cdot (\%\ Site\ Flow)}{\%\ Removal\ Efficiency} \right. \qquad (Equation\ 4)$$

Where:	Treatment Target	=	the target MCL with 80% safety factor
	Site Concentration	=	arsenic concentration at the site
	% Removal Efficiency	=	% removal efficiency of treatment train chosen
	% Site Flow	=	% of total flow at that site

Note that the blending technique is used only for the those systems expected to require greater than 90 percent removal in order to achieve compliance with the new MCL standard. In addition, SafeWaterXL does not employ this technique for those systems that select treatment trains involving POE or POU devices.

Equipment Life, Discount Rate and Capitalization Rates: System and State implementation costs are tracked for a twenty-year period. This time frame was selected for two reasons:
1) technologies are estimated to have a twenty-year life (which includes replacement for some technologies with lives shorter than twenty years);

2) water systems often finance their capital improvements over a twenty year period.

Exhibit 6-7
Summary of Recommended Cost of Capital Estimates
(as of March 1998)

Ownership Type	Size Category	Estimated After-Tax Cost of Capital
NON-SMALL		
Investor owned	10,001-50,000	5.26%
	>50,000	5.94%
Publicly owned	10,001-50,000	5.26%
	>50,000	5.23%
SMALL		
Private	1-500	4.17%
	501-10,000	4.17%
Public	1-500	5.10%
	501-10,000	5.20%

Source: *Development of Cost of Capital Estimates for Public Water Systems* (Draft Final Report). Prepared for U.S. EPA by Apogee/Hagler Bailly, Inc. under subcontract to International Consultants, Inc. June 1998.

Two different adjustments are made in this analysis in order to render future costs comparable with current costs, reflecting the fact that a cost outlay today is a greater burden than an equivalent cost outlay sometime in the future. The first adjustment is made when the cost estimates that are derived are being used as an input in benefit-cost analysis. In this instance, costs are annualized using a social discount rate so that the costs of each regulatory option can be directly compared with the annual benefits of the corresponding regulatory option. Annualization is the same process as calculating a mortgage payment; the result is a constant annual cost to compare with constant annual benefits.

The choice of an appropriate social discount rate has been, and continues to be, a very complex and controversial issue among economists and policy makers alike. Therefore, the Agency compares costs and benefits using two alternative social discount rates, in part to determine the effect the choice of social discount rate has on the analysis. The annualized costs of each regulatory option are calculated and displayed using both a seven percent discount rate required by the Office of Management and Budget (OMB) and a three percent discount rate which the Agency believes more closely approximates the true social discount rate.

The second adjustment is made when the cost estimates that are derived are being used as an input into an economic impact analysis, such as an affordability analysis or an analysis of system-level costs or household-level costs. In these cases, rather than use a social discount rate when determining the annualized costs, an actual cost-of-capital rate is used instead. This rate should reflect the true after-tax cost of capital water systems face, net of any government grants or subsidies. The cost of capital rates used in this analysis are shown in Exhibit 6-7 above.

NTNC Costs

The cost for NTNCs is estimated using the mean values for system population for each system service category, as shown in Chapter Four. As with the CWSs, cost is annualized over a twenty-year period, at discount rates of three and seven percent. Assumptions regarding the monitoring schedule correspond to the monitoring schedule for small ground water systems, including hour burdens and hourly labor rates. The remaining assumptions required for determining cost are described below.

Number of Systems, Sites per System and the Population Served: The non-transient non-community water supply treatment decisions are modeled similarly to those for community water supplies. The number of non-transient non-community water supplies is taken from EPA's SDWIS, and include those systems as described in *Geometries and Characteristics of Public Water Supplies*. For each service area type, the report lists the number of systems and the average population served. The non-food manufacturing service area combines 16 categories that were listed separately in the report. For this service area, the number of systems is the sum of the 16 categories and the average population served is the mean of the individual populations weighted by the number of corresponding systems. Each of these systems has only a single site.

System Flows and Treatment Choices: For each service area, both design and average flows have been derived by the Agency using literature values and best engineering judgment. There is no primary survey data for non-community water systems that is equivalent to the CWSS that provided data for the community water system flow calculations (Smith, personal communication). The design flow is used to calculate the treatment capital costs while the average flow is used in the operating and maintenance cost equations. For the non-transient non-community water supplies, one of two treatment technologies was chosen based on the level of the design flow. For service areas with design flows less than 2,000 gallons per day, POE activated alumina is used; for all others, centralized activated alumina with 2,000 bed volume is chosen (Kapadia, 1999a personal communication). Both treatment trains include pre-oxidation and the centralized activated alumina also includes non-hazardous landfilling of the spent media (Kapadia, 1999a personal communication).

Mean Arsenic Occurrence: The arsenic occurrence distribution used for ground water community water supplies is also used for non-transient non-community water supplies. The number of systems exceeding the MCL for each service area was calculated from the percent of the distribution between the MCL and 100 µg/L. For this analysis, 100 µg/L was chosen as the upper concentration limit because the non-transient non-community supplies have not been previously regulated and occurrence values above the 50 µg/L regulatory level are possible.

Removal Efficiencies, Treatment Target, and Blending: The removal efficiency associated with both POE activated alumina and centralized activated alumina is 95 percent. The NTNC model uses this efficiency with the blending principle in the case of centralized activated alumina to determine the amount of flow that requires treatment in order for the site to meet the treatment target. The treatment target is set at 80 percent of the MCL and represents the level to which systems will be over-designed to ensure compliance with the MCL. For POE activated alumina systems, all the flow is treated which may result in finished water below the treatment target concentration.

Equipment Life, Discount Rate, and Capitalization Rates: As with the community water supplies, the system implementation costs are tracked for a 20 year period. For the two service areas using POE activated alumina, construction and forest service, the equipment is assumed to last ten years with purchases in year zero and year ten. For the centralized activated alumina the equipment is estimated to last 20 years. The cost estimates are annualized in the same manner as those for the community water supplies.

Very Large CWS Costs

EPA evaluated the regulatory costs of compliance for very large systems that would be subject to the new arsenic drinking water regulation. The nation's 25 largest drinking water systems (i.e., those serving a million people or more) supply approximately 38 million people and generally account for about 15 to 20 percent of all compliance-related costs. Accurately determining these costs for future regulations is critical. As a result, EPA has developed compliance cost estimates for the arsenic and radon regulations for each individual system that serves greater than 1 million persons. These cost estimates help EPA to more accurately assess the cost impacts and benefits of the arsenic regulation. The estimates also help the Agency identify lower cost regulatory options and better understand current water systems' capabilities and constraints.

The system costs were calculated for the 24 public water systems that serve a retail population greater than 1 million persons and one public water system that serves a wholesale population of 16 million persons. The following are distinguishing characteristics of these very large systems:

(1) a large number of entry points from diverse sources;
(2) mixed (i.e. ground and surface) sources;
(3) occurrence not conducive to mathematical modeling;
(4) significant levels of wholesaling;
(5) sophisticated in-place treatment;
(6) retrofit costs dramatically influenced by site-specific factors; and
(7) large amounts of waste management and disposal which can contribute substantial costs.

Generic models cannot incorporate all of these considerations; therefore, in-depth characterizations and cost analyses were developed utilizing several existing databases and surveys.

The profile for each system contains information such as design and average daily flows, treatment facility diagrams, chemical feed processes, water quality parameters, system layouts, and intake and aquifer locations. System and treatment data were obtained from the following sources:

(1) the Information Collection Rule (1997);
(2) the Community Water Supply Survey (1995);
(3) the Association of Metropolitan Water Agencies Survey (1998);
(4) the Safe Drinking Water Information System (SDWIS); and
(5) the American Water Works Association WATERSTATS Survey (1997)

While these sources contained much of the information necessary to perform cost analyses, the Agency was still missing some of the detailed arsenic occurrence data in these large water systems. Where major gaps existed, especially in ground water systems, occurrence data obtained from the States of Texas, California, and Arizona, the Metropolitan Water District of Southern California Arsenic Study (1993), the National Inorganic and Radionuclides Study (EPA, 1984), and utility data was used. Based on data from the studies, detailed costs estimates were derived for each of the very large water systems.

Cost estimates were generated for each system at several MCL options. The total capital costs and operational and maintenance (O&M) costs were calculated using the profile information gathered on each system, conceptual designs (i.e., vendor estimates and RS Means), and modified EPA cost models (i.e., Water and WaterCost models). The models were modified based on the general cost assumptions developed in the Phase I Water Treatment Cost Upgrades (EPA, 1998).

EPA consulted with the system operators to determine how each system would comply with various MCL options and to assess the costs of their compliance responses. Preliminary cost estimates were sent to all of the systems for their review. Approximately 30 percent of the systems responded by submitting revised estimates and/or detailed arsenic occurrence data. Based on the information received, EPA revised the cost estimates for those systems. EPA developed cost estimates for three very large systems that are expected to have arsenic levels below 50 µg/L. These systems are located in Houston, TX, Phoenix, AZ, and Los Angeles, CA. This analysis resulted in the estimated costs listed in Exhibit 6-8.

Exhibit 6-8
Annual Treatment Costs for Three Large CWSs Expected to Undertake or Modify Treatment Practice to Comply with the Arsenic Rule
($ millions)

Large CWSs	Population Served	MCL (µg/L)			
		3	5	10	20
Phoenix, AZ	1,360,751				
Annual cost (3%)		$ 4.2	$ 4.1	$ 1.8	$ 0.2
Annual cost (7%)		$ 4.8	$ 4.7	$ 2.1	$ 0.2
Houston, TX	2,216,830				
Annual cost (3%)		$ 4.5	$ 1.6	$ 0.4	$ 0.4
Annual cost (7%)		$ 5.3	$ 1.9	$ 0.4	$ 0.4
Los Angeles, CA	3,700,000				
Annual cost (3%)		$ 2.3	$ 1.8	$ 1.8	$ 1.8
Annual cost (7%)		$ 2.3	$ 1.8	$ 1.8	$ 1.8

6.3 Results

This section presents the results of the national cost analysis. Unless otherwise specified, national costs are presented in May 1999 dollars throughout this chapter.

6.3.1 National Costs

Exhibit 6-9 shows the total national cost breakdown across the four MCL options for the Arsenic Rule. The system and state cost components of the total annual compliance costs are presented at discount rates of three and seven percent. Expected system costs include treatment costs, monitoring costs, and administrative costs of compliance. State costs include monitoring and administrative costs of implementation. These cost components are also displayed. Exhibits 6 through 9 and 6 through 10 show the annual national costs of the Arsenic Rule under two scenarios. Exhibits 6 through 9 shows the costs when both CWSs and NTNCs are required to comply with an MCL. Exhibits 6 through 10 shows the costs when CWSs are required to comply with an MCL, and NTNCs are only required to monitor for Arsenic.

Under the both scenarios, CWS costs are approximately $641 million at the 3 µg/L MCL, $376 million at the 5 µg/L MCL, $162 million at the 10 µg/L MCL, and $61 million at the 20 µg/L MCL (at a three percent discount rate).   State costs associated with CWS administration, at a 3 percent discount rate, are approximately $2.2 million at the 3 µg/L MCL, $1.7 million at the 5 µg/L MCL, $1.5 million at the 10 µg/L MCL, and $1.3 million at the 20 µg/L MCL.

When compliance with an MCL is required, the cost to NTNCs ranges from $26 million at the 3 µg/L MCL, $16 million at the 5 µg/L MCL, $7 million at the 10 µg/L MCL, and $4 million at the 20 µg/L MCL (at a three percent discount rate).   State costs associated with NTNC administration, at a three percent discount rate, are approximately $1.2 million at the 3 µg/L MCL, $1.1 million at the 5 µg/L MCL, $1 million at the 10 µg/L MCL, and $1 million at the 20 µg/L MCL. When NTNCs are only required to monitor, their costs are approximately $1 million across the MCLs (at a three percent discount rate).   State costs associated with NTNC administration under this scenario, at a three percent discount rate, also are approximately $1 million across the MCLs.

Exhibit 6-9
Annual National System and State Compliance Costs
(CWSs and NTNCs Comply With MCL)
($ millions)

	CWS		NTNC		TOTAL	
Discount Rate	**3%**	**7%**	**3%**	**7%**	**3%**	**7%**
MCL = 3 mg/L						
System Costs						
Treatment	$639.2	$746.4	$25.2	$30.5	$664.4	$777.0
Monitoring/ Administrative	$2.2	$3.0	$1.0	$1.2	$3.2	$4.2
State Costs	$1.6	$1.9	$0.8	$0.9	$2.4	$2.9
TOTAL COST	$643.1	$751.4	$27.0	$32.7	$670.1	$784.0
MCL = 5 mg/L						
System Costs						
Treatment	$374.0	$436.0	$14.7	$17.8	$388.7	$453.8
Monitoring/ Administrative	$2.0	$2.8	$1.0	$1.2	$3.0	$3.9
State Costs	$1.3	$1.6	$0.8	$0.9	$2.1	$2.5
TOTAL COST	$377.3	$440.4	$16.4	$19.8	$393.8	$460.2
MCL = 10 mg/L						
System Costs						
Treatment	$160.4	$186.7	$6.1	$7.4	$166.5	$194.1
Monitoring/ Administrative	$1.8	$2.5	$1.0	$1.2	$2.8	$3.7
State Costs	$1.1	$1.3	$0.7	$0.8	$1.8	$2.1
TOTAL COST	$163.3	$190.5	$7.8	$9.3	$171.1	$199.9
MCL = 20 mg/L						
System Costs						
Treatment	$58.9	$68.3	$2.1	$2.6	$61.0	$70.8
Monitoring/ Administrative	$1.7	$2.4	$2.2	$2.4	$3.9	$4.9
State Costs	$1.0	$1.2	$0.7	$0.8	$1.7	$2.0
TOTAL COST	$61.6	$71.8	$5.0	$5.8	$66.5	$77.6

Exhibit 6-10
National Annual System and State Compliance Costs
(CWSs Comply With MCL / NTNCs Monitor)
($ millions)

Discount Rate	CWS 3%	CWS 7%	NTNC* 3%	NTNC* 7%	TOTAL 3%	TOTAL 7%
MCL = 3 mg/L						
System Costs						
Treatment	$639.2	$746.4	--	--	$639.2	$746.4
Monitoring/ Administrative	$2.2	$3.0	$0.9	$1.1	$3.1	$4.1
State Costs	$1.6	$1.9	$0.6	$0.7	$2.2	$2.6
TOTAL COST	$643.1	$751.4	$1.5	$1.8	$644.6	$753.2
MCL =5 mg/L						
System Costs						
Treatment	$374.0	$436.0	--	--	$374.0	$436.0
Monitoring/ Administrative	$2.0	$2.8	$0.9	$1.1	$2.9	$3.9
State Costs	$1.3	$1.6	$0.6	$0.7	$2.0	$2.3
TOTAL COST	$377.3	$440.4	$1.6	$1.8	$378.9	$442.2
MCL = 10 mg/L						
System Costs						
Treatment	$160.4	$186.7	--	--	$160.4	$186.7
Monitoring/ Administrative	$1.8	$2.5	$1.0	$1.1	$2.8	$3.7
State Costs	$1.1	$1.3	$0.6	$0.7	$1.7	$2.1
TOTAL COST	$163.3	$190.5	$1.6	$1.9	$164.9	$192.4
MCL =20 mg/L						
System Costs						
Treatment	$58.9	$68.3	--	--	$58.9	$68.3
Monitoring/ Administrative	$1.7	$2.4	$1.0	$1.1	$2.7	$3.5
State Costs	$1.0	$1.2	$0.7	$0.7	$1.6	$1.9
TOTAL COST	$61.6	$71.8	$1.6	$1.9	$63.2	$73.7

6.3.2 Costs by System Size and Type

This section presents the overall national compliance costs for water systems and for states at three and seven percent discount rates. Exhibits 6-11 and 6-12 show a detailed breakout of treatment and monitoring and administrative costs, respectively, by system type and size for the various MCLs.

Exhibit 6-11
Total Annual CWS Treatment Costs Across MCL Options
by System Size and Type
($ millions)

System Size	MCL (μg/L)			
	3	5	10	20
3% Discount Rate				
<100	$ 22.5	$ 13.9	$ 6.3	$ 2.4
101-500	$ 66.7	$ 41.0	$ 17.9	$ 6.9
501-1,000	$ 35.6	$ 21.8	$ 9.5	$ 3.6
1001-3300	$ 83.4	$ 49.0	$ 21.2	$ 7.9
3,301-10,000	$ 93.9	$ 53.9	$ 23.2	$ 8.3
10,001-50,000	$ 166.8	$ 96.2	$ 40.6	$ 14.3
50,001-100,000	$ 59.3	$ 34.0	$ 14.2	$ 5.0
100,001-1,000,000	$ 100.0	$ 56.6	$ 23.5	$ 8.0
1,000,000 +	$ 11.0	$ 7.6	$ 4.0	$ 2.4
7% Discount Rate				
<100	$ 24.8	$ 15.3	$ 6.9	$ 2.6
101-500	$ 73.5	$ 45.1	$ 19.7	$ 7.6
501-1,000	$ 40.2	$ 24.7	$ 10.7	$ 4.1
1001-3300	$ 96.7	$ 56.7	$ 24.5	$ 9.1
3,301-10,000	$ 113.7	$ 65.1	$ 28.0	$ 10.0
10,001-50,000	$ 199.6	$ 115.2	$ 48.6	$ 17.1
50,001-100,000	$ 70.6	$ 40.5	$ 16.9	$ 6.0
100,001-1,000,000	$ 114.9	$ 65.0	$ 27.0	$ 9.2
>1,000,000	$ 12.4	$ 8.5	$ 4.4	$ 2.5

Exhibit 6-12
Total Annual CWS Monitoring and Administrative Costs Across MCL Options by System Size and Type ($ millions)

System Size	MCL (μg/L)			
	3	5	10	20
3% Discount Rate				
<100	$ 0.5	$ 0.5	$ 0.4	$ 0.4
101-500	$ 0.5	$ 0.5	$ 0.5	$ 0.5
501-1,000	$ 0.2	$ 0.2	$ 0.1	$ 0.1
1001-3300	$ 0.2	$ 0.2	$ 0.2	$ 0.2
3,301-10,000	$ 0.3	$ 0.2	$ 0.2	$ 0.2
10,001-50,000	$ 0.3	$ 0.3	$ 0.2	$ 0.2
50,001-100,000	$ 0.1	$ 0.1	$ 0.04	$ 0.03
100,001-1,000,000	$ 0.1	$ 0.1	$ 0.04	$ 0.03
7% Discount Rate				
<100	$ 0.6	$ 0.6	$ 0.6	$ 0.6
101-500	$ 0.7	$ 0.7	$ 0.7	$ 0.7
501-1,000	$ 0.2	$ 0.2	$ 0.2	$ 0.2
1001-3300	$ 0.3	$ 0.3	$ 0.3	$ 0.3
3,301-10,000	$ 0.4	$ 0.3	$ 0.3	$ 0.3
10,001-50,000	$ 0.4	$ 0.4	$ 0.3	$ 0.3
50,001-100,000	$ 0.1	$ 0.1	$ 0.1	$ 0.05
100,001-1,000,000	$ 0.1	$ 0.1	$ 0.1	$ 0.04

6.3.3 Costs per Household

Household level costs are considered a good proxy for the affordability of rule compliance with regard to CWSs, since water systems recover costs at the household level through increased water rates. This of course assumes that non-residential customers of water systems, such as businesses, can pass along any increase in water costs to their customers through increased prices on their goods or services. In order to calculate the number of households served by systems that will treat, the expected number of treating systems is multiplied by the average number of households per system (varies by system type and size). Exhibit 6-13 presents the total number of households served by CWS that treat, by size category.

Exhibit 6-13
Number of Households in CWSs Expected to Treat
by Size Category and MCL (µg/L) Option

	<100	101-500	501-1,000	1,001-3,300	3,301-10,000	10,001-50,000	50,001-100,000	100,001-1,000,000
3	93,886	366,195	355,994	1,006,599	1,623,698	3,254,167	1,452,752	3,084,826
5	58,654	229,192	223,048	626,510	1,012,724	2,084,853	905,886	1,806,388
10	26,856	103,290	102,186	290,138	477,938	997,914	465,003	936,602
20	10,525	41,357	40,811	117,842	195,671	405,714	188,798	364,907

SafeWaterXL determines household costs separately for each affected CWS, by first dividing the CWSs annual compliance cost by the CWS's average daily flow (1,000 gallons per day), and then multiplied by 365 days to determine the CWS's cost of compliance per 1,000 gallons produced. Finally, the CWS's cost of compliance per 1,000 gallons (kgal) is multiplied by the average annual consumption per residential connection (kgal), to arrive at the average annual cost of compliance per household for the CWS. The estimates of average annual consumption per residential connection used in this analysis are provided in Chapter 4, "Baseline Analysis."

Given expected household costs for each individual system, the average is then calculated for each size category. Exhibit 6-14 shows the average annual household costs by system size, across the four regulatory options.

The range of household costs for the MCL of 5 µg/L ranges from less than \$2 to approximately \$373; the costs for the MCL of 3 µg/L range from less than \$3 to \$374; the costs for the MCL of 10 µg/L, range from less than \$1 to \$378; and the costs for the MCL of 20 µg/L, range from less than \$1 to \$398.

Exhibits 6–15 through 6-18 compare the distribution of annual household costs across public water systems serving fewer than 10,000 people, for MCLs 3, 5, 10, and 20, respectively. The exhibits demonstrate the maximum annual costs that different percentages of households in treating systems face. Comparison of Exhibits 6-15 through 6-18 illustrates that regulatory compliance costs decrease across MCLs. This observation is depicted by the consistent shift to the left of cost curves across system size categories, when comparing incremental increases in the MCL.

Exhibit 6-14
Mean Annual Household Costs Across MCL Options by System Size

SIZE CATEGORIES	MCL (μg/L)			
	3	5	10	20
<100	$368.13	$363.65	$357.17	$348.72
101-500	$258.68	$253.64	$246.38	$237.67
501-1,000	$106.07	$103.74	$98.35	$93.25
1,001-3,300	$63.61	$60.38	$56.51	$51.80
3,301-10,000	$44.28	$40.77	$37.04	$32.52
10,001-50,000	$36.39	$33.22	$29.13	$24.99
50,001-100,000	$29.52	$26.64	$22.80	$19.44
100,001-1,000,000	$23.47	$21.20	$18.32	$15.41
1,000,000 +	$2.70	$1.73	$0.89	$0.55
All categories	$43.73	$39.18	$33.05	$23.62

Exhibit 6-15
Annual Treatment Costs Per Household Across Public GW CWSs Expected to Treat and Serving < 10,000 People
MCL 3 µg/L

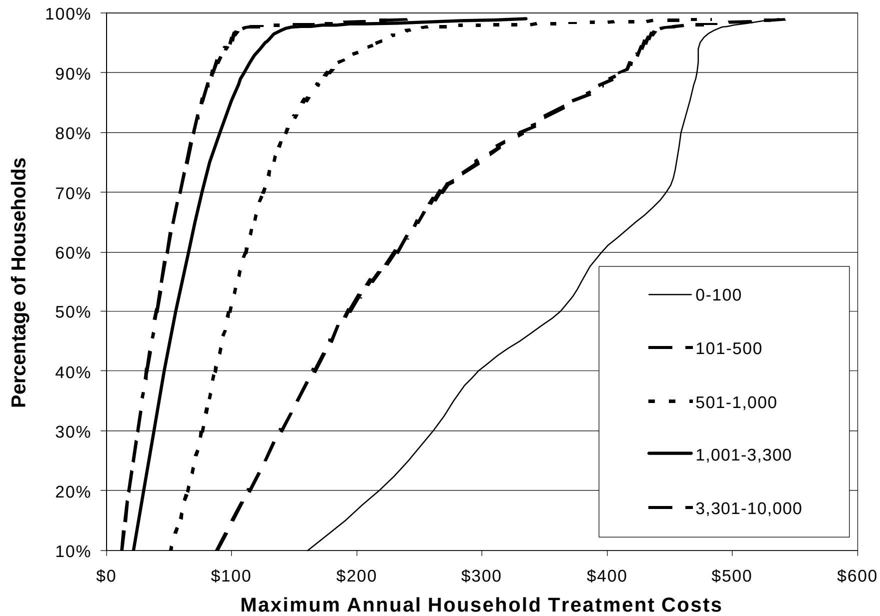


Exhibit 6-16
Annual Treatment Costs Per Household Across Public GW CWSs Expected to Treat and Serving < 10,000 People
MCL 5 µg/L

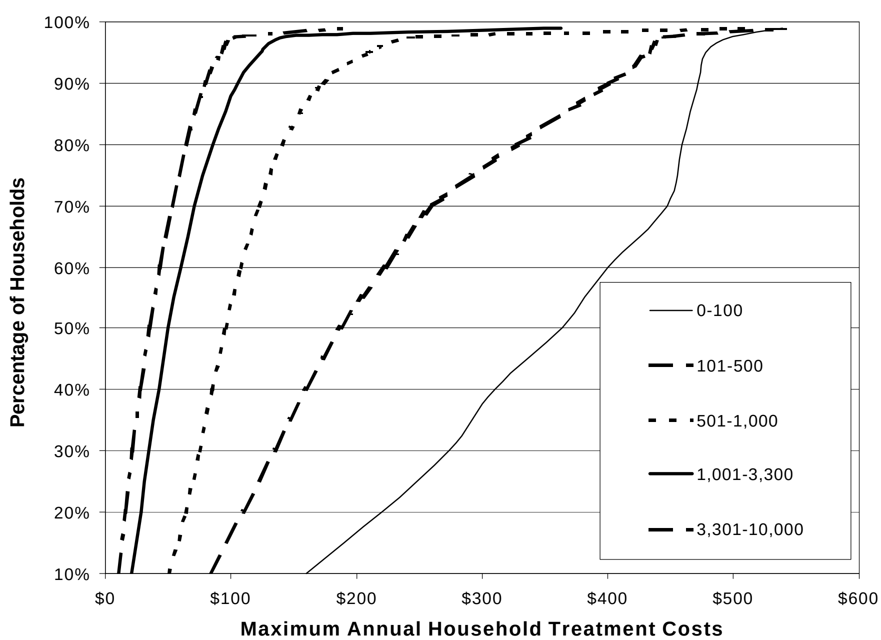


Exhibit 6-17
Annual Treatment Costs Per Household Across Public GW CWSs Expected to Treat and Serving < 10,000 People
MCL 10 µg/L

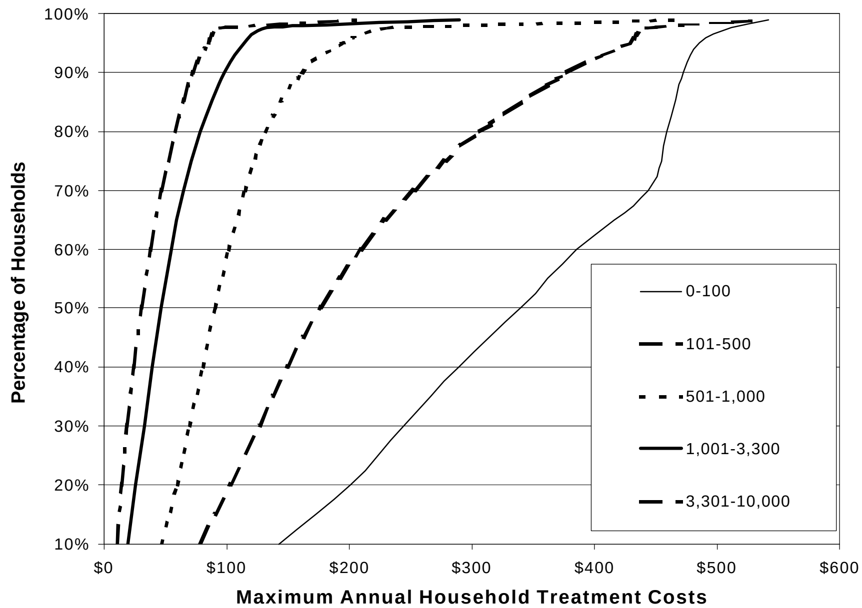
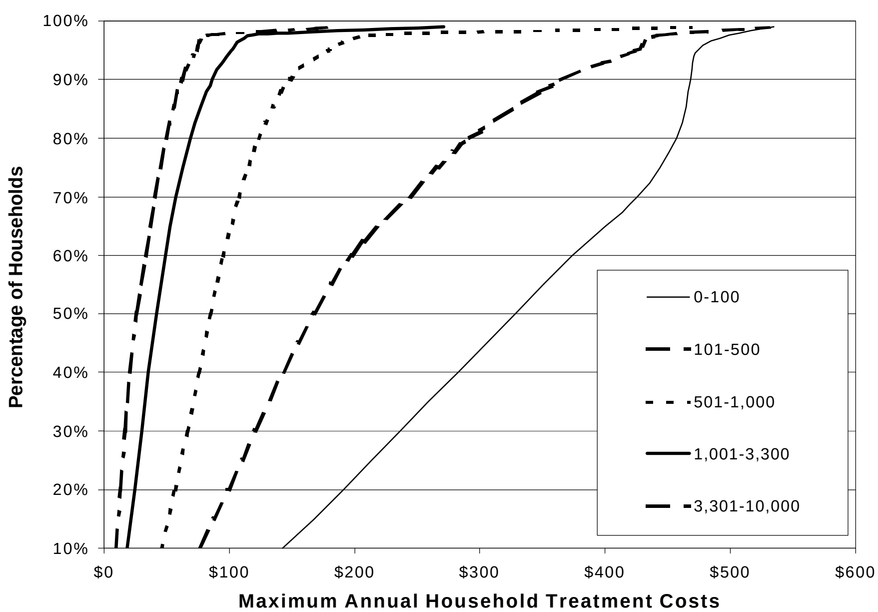


Exhibit 6-18
Annual Treatment Costs Per Household Across Public GW CWSs Expected to Treat and Serving < 10,000 People
MCL 20 µg/L



Chapter 7: Comparison of Costs and Benefits

7.1 Introduction

In this RIA, EPA has analyzed the cost and benefits of regulating arsenic concentrations in drinking water to four different MCL standards. The four options considered reflect increasing levels of protection against exposure to arsenic in drinking water, employing a range of MCLs from 20 µg/L to 3 µg/L. As the MCL provisions for the four options become increasingly strict, the associated costs and benefits also increase incrementally. Chapter 5 ("Benefits Analysis") describes in detail the estimated national health benefits of the Arsenic Rule options, while Chapter 6 ("Cost Analysis") describes the projected national compliance cost estimates. This chapter presents a summary and comparison of the national benefits and costs and a cost-effectiveness analysis for each of the MCL options.

7.2 Summary of National Costs and Benefits

7.2.1 National Cost Estimates

National compliance costs to PWSs for treatment (both annualized capital and O&M), monitoring and administrative activities, and costs to states, including any one-time start-up costs, for regulatory implementation and enforcement, were estimated and described in Chapter 6. The national costs for community water systems to comply with the four MCL options ranges from $61.6 million (MCL=20 µg/L) to $643.1 million (MCL=3 µg/L) annually based on a discount rate of three percent. Assuming a seven percent discount rate, the range of total national cost for community water systems ranges from $71.8 million to $751.4 million annually. The national cost of compliance with the Arsenic Rule options for NTNCs is approximately $1.5 million at a 3 percent discount rate, and $2 million at a 7 percent discount rate.

7.2.2 National Benefits Estimates

Chapter 5 contains a detailed summary of the methodology used to estimate a range of national health benefits from avoided bladder cancer cases as a result of the four Arsenic Rule MCL options. The dollar value of the estimated health benefits associated with each of the four rule options were calculated based on lower and upper bound estimates of avoided bladder cancer cases. Although the value of reducing the risk of lung cancer was estimated, these estimates contain a great deal of uncertainty. Therefore, only the value of reducing the risk of bladder cancer will be used in the comparison of benefits and costs. For community water systems that must install treatment equipment or make other modifications to their treatment processes resulting in reduced arsenic concentrations, the national benefits range from $7.9 million (MCL=20 µg/L) to $43.6 million (MCL=3 µg/L) annually, based on the lower bound estimates of bladder cancer cases avoided. Under the upper bound scenario, the health benefits from avoided bladder cancer increase from $29.8 million at an MCL of 20 µg/L to $104.2 million annually at an MCL of 3 µg/L.

7.3 Comparison of Benefits and Costs

This section presents a comparison of total national benefits and costs for each of the Arsenic Rule options considered. Three separate analyses are considered, including a summary of benefit/cost ratios and net-benefits, a direct comparison of aggregate national cost and benefits, and the results of a cost-effectiveness analysis of each regulatory option.

7.3.1 National Net Benefits and National Benefit-Cost Comparison

Exhibit 7-1 describes the net benefits and the benefit/cost ratios under various MCL options for PWSs at 3 and 7 percent discount rates. Under both the lower and upper bound scenarios of avoided bladder cancer cases in Exhibit 7-1, the net benefits are negative and decreasing as the Arsenic Rule MCL options become increasingly more stringent. Similarly, the benefit/cost ratios are less than one and decrease with each more stringent MCL option. Costs outweigh the quantified benefits under the four MCL options, with benefit/cost ratios all below one, and range from 0.07 (MCL=3 µg/L) to 0.48 (MCL=20 µg/L) at a 3 percent discount rate, and from 0.06 (MCL=3 µg/L) to 0.42 (MCL=20 µg/L) at a 7 percent discount rate. Of the MCL options examined, the net benefits are maximized at an MCL of 20 µg/L. The benefit cost ratio is also greatest at an MCL of 20 µg/L.

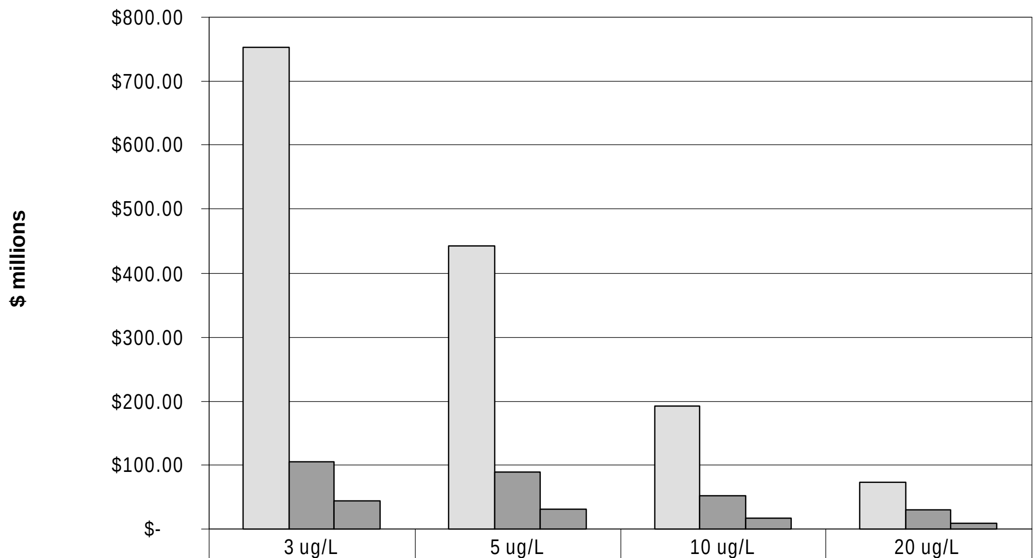
Exhibit 7-1
Summary of Annual National Net Benefits and Benefit-Cost Ratios,
CWSs Comply With MCL and NTNCs Only Monitor*
(Bladder Cancer Cases Only, in $ millions)

MCL (μg/L)		3	5	10	20
3% Discount Rate					
lower bound	Net Benefits	$ (599.5)	$ (345.6)	$ (145.4)	$ (53.7)
lower bound	Benefit/Cost Ratio	0.07	0.08	0.11	0.13
upper bound	Net Benefits	$ (538.9)	$ (287.4)	$ (111.2)	$ (31.8)
upper bound	Benefit/Cost Ratio	0.16	0.24	0.32	0.48
7% Discount Rate					
lower bound	Net Benefits	$ (707.8)	$ (408.7)	$ (172.6)	$ (63.9)
lower bound	Benefit/Cost Ratio	0.06	0.07	0.09	0.11
upper bound	Net Benefits	$ (647.2)	$ (350.5)	$ (138.4)	$ (42.0)
upper bound	Benefit/Cost Ratio	0.14	0.20	0.27	0.42

*Costs include treatment, O&M, monitoring, and administrative costs to CWSs, monitoring and administrative costs to NTNCWSs, and State costs for administration of water programs.
The lower-end estimate of bladder cancer cases avoided is calculated using the lower-end risk estimate (see Exhibit 5-9) and assumes that the conditional probability of mortality among the Taiwanese study group was 100 percent. The upper-end estimate of bladder cancer cases is calculated using the upper-end risk estimate (see Exhibit 5-9) and assumes that the conditional probability of mortality among the Taiwanese study group was 80 percent.

Exhibit 7-2 graphically depicts the absolute difference between the total value of national costs and benefits under each proposed MCL at a 7 percent discount rate.

Exhibit 7-2
Comparison of Costs and Benefits of Bladder Cancer Cases Avoided
(CWSs Comply with MCL / NTNCs Monitor, 7% Discount Rate)



	3 ug/L	5 ug/L	10 ug/L	20 ug/L
Costs	$753.16	$442.21	$192.40	$73.72
Benefits (upper bound)	$104.20	$89.90	$52.10	$29.80
Benefits (lower bound)	$43.60	$31.70	$17.90	$7.90

Finally, Exhibit 7-3 shows the results of an analysis in which the average national cost of achieving each unit reduction in cases of bladder cancer avoided, was calculated. The average annual cost per cancer case avoided was computed at each MCL option, for both 3 and 7 percent discount rates. At a 3 percent discount rate, the cost per bladder cancer case ranges from $12.3 million to $29.4 million at an MCL of 3 µg/L, from $8.4 million to $23.8 million at an MCL of 5 µg/L, from $6.3 million to $18.3 million at an MCL of 10 µg/L, and from $4.2 million to $15.9 million at an MCL of 20 µg/L. At a 7 percent discount rate, the cost per bladder cancer case ranges from $14.4 million to $34.4 million at an MCL of 3 µg/L, from $9.8 million to $27.7 million at an MCL of 5 µg/L, from $7.3 million to $21.4 million at an MCL of 10 µg/L, and from $4.9 million to $18.6 million at an MCL of 20 µg/L.

Exhibit 7-3
Cost per Bladder Cancer Case Avoided for the Proposed Arsenic Rule
(CWSs Comply with MCL / NTNCs Monitor, in $ millions)

Arsenic Level (µg/L)	lower bound**	upper bound**
3% Discount Rate		
3	$ 29.4	$ 12.3
5	$ 23.8	$ 8.4
10	$ 18.3	$ 6.3
20	$ 15.9	$ 4.2
7% Discount Rate		
3	$ 34.4	$ 14.4
5	$ 27.7	$ 9.8
10	$ 21.4	$ 7.3
20	$ 18.6	$ 4.9

*Costs all treatment, O&M, monitoring, and administrative costs to CWSs, monitoring and administrative costs to NTNCWSs, and State costs for administration of water programs.
**Lower/upper bounds correspond to estimates of bladder cancer cases avoided.

7.3.2 Cost-Effectiveness

Cost-effectiveness analysis is another commonly used measure of the economic efficiency with which regulatory options are meeting the intended regulatory objectives. Exhibit 7-4 is a comparison of annual national costs (computed at a seven percent discount rate) and annual cases of bladder cancer avoided at each MCL option. The two lines represent the cost per cancer case avoided under the lower and upper bound estimates of bladder cancer cases avoided. These plotted lines depict the trend in marginal cost and benefits (expressed as health effects avoided) between each point on these curves (corresponding to each MCL option). Points along these lines represent each increment of cost that is incurred in order to achieve the next increment of risk reduction, i.e. additional bladder cancer case avoided. The steepness of the curves under both benefits scenarios suggests that additional increments of risk reduction and benefits are achieved at increasingly greater cost to the nation.

Exhibit 7-4
Comparison of Annual Costs to Cases of Bladder Cancer per Year
(7% Discount Rate)

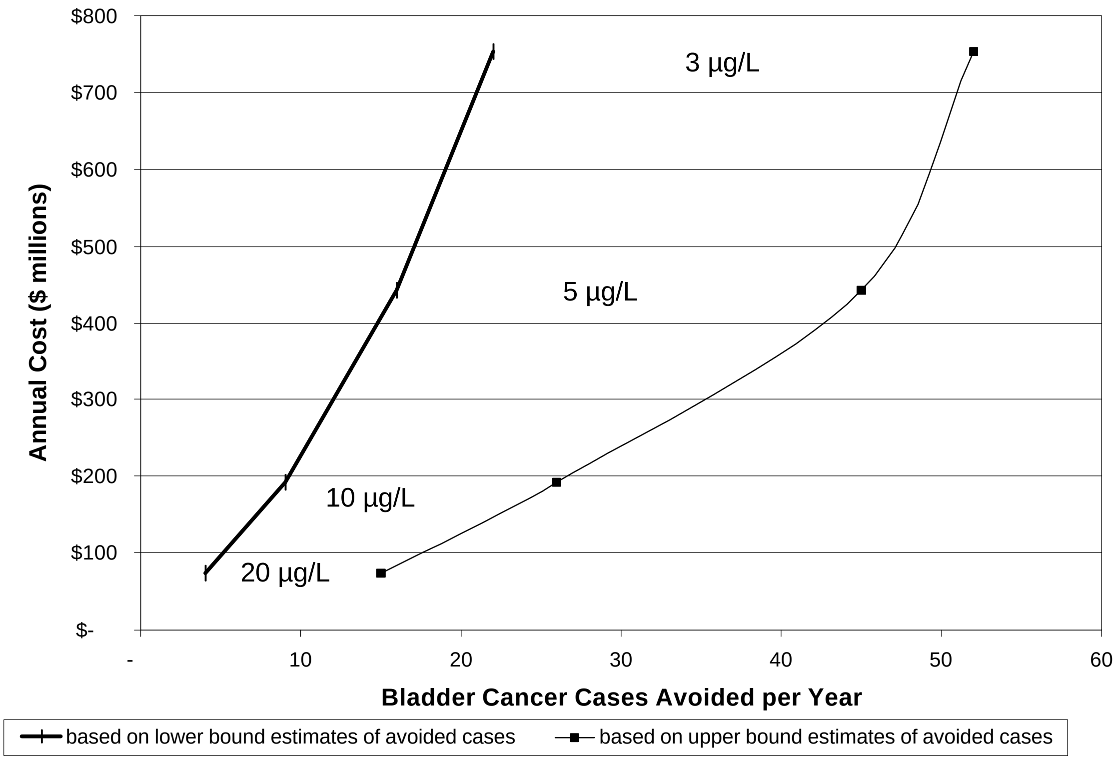
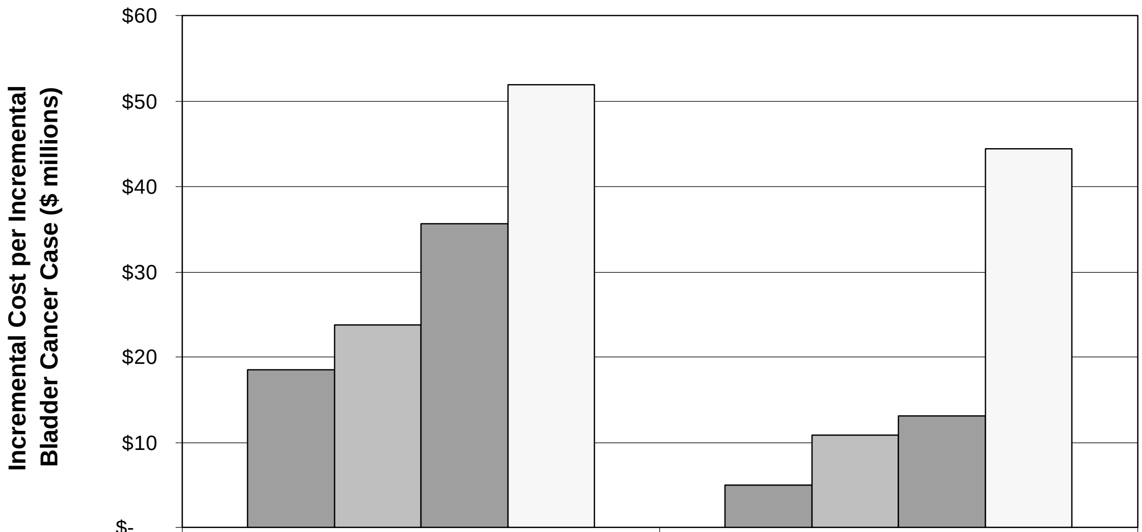


Exhibit 7-5 further reinforces the fact that as the MCL becomes more stringent, the incremental cost per cancer case avoided increases. For example, the additional cases of bladder cancer avoided in moving from an MCL of 10 µg/L to 5 µg/L are achieved at a cost per case of $13 million annually under the high bound and seven percent discount rate scenario. Similarly, in moving from an MCL of 5 µg/L to a more stringent MCL of 3 µg/L, the cost per case avoided increases to $44 million per year under this same scenario.

Exhibit 7-5
Incremental Cost per Incremental Bladder Cancer Case Avoided
(CWSs, 7% Discount Rate, in $ millions)



	Lower bound estimates of avoided cases	Upper bound estimates of avoided cases
MCL 20 ug/L	$18	$5
MCL 10 ug/L	$24	$11
MCL 5 ug/L	$36	$13
MCL 3 ug/L	$52	$44

7.4 Other Benefits

Exhibit 5-15 provides the estimated benefits associated with the results of the "What-if" scenario for lung cancer. At an MCL of 5 µg/L, EPA estimates that the potential benefit of reducing the risk of lung cancer ranges from $35 to $384 million. Also, Chapter 5 discusses a number of important non-monetized benefits of reducing arsenic exposure. Chief among these are certain health impacts known to be caused by arsenic (such as skin cancer). In 1988 EPA published a risk estimate which used the skin cancer data from Taiwan. EPA calculated a Maximum Likelihood Estimate (MLE) for skin cancer of 3×10^{-5} for females and 7×10^{-5} for males drinking 2 liters a day contaminated with 1 µg/L of arsenic. At the current MCL of 50 µg/L and two liters per day, the risk would be 5×10^{-3}. A number of epidemiologic studies conducted in several countries (e.g., Taiwan, Japan, England, Hungary, Mexico, Chile, and Argentina) report an association between arsenic in drinking water and skin cancer in exposed populations. Studies conducted in the US have not demonstrated an association between inorganic arsenic in drinking water and skin cancer. However, these studies may not have included enough people in their design to detect these types of effects.

The potential monetized benefits associated with skin cancer reduction would not change the total benefits of the rule to an appreciable degree, even if the assumption were made that the risk of skin cancer were equivalent to that of bladder cancer, using EPA's 1988 risk assessment. Skin cancer is highly treatable (at a cost of illness of less than $3,500 for basal and squamous cell carcinomas vs. a cost-of-illness of $178,000 for non-fatal bronchitis) in the U.S., with few fatalities (less than 1%).

In addition to potentially reducing the risk of skin cancer, there are also a large number of other health effects associated with arsenic, as presented in Exhibit 5-1, which are not monetized in this analysis, due to lack of appropriate data.

Other benefits not monetized in this analysis include customer peace of mind from knowing drinking water has been treated for arsenic and reduced treatment costs for currently unregulated contaminants that may be co-treated with arsenic. To the extent that reverse osmosis is used for arsenic removal, these benefits could be substantial. Reverse osmosis is the primary point of use treatment, and it is expected that very small systems will use this treatment to a significant extent. (These benefits of avoided treatment cannot currently be monetized; however, they can be readily monetized in the future, as decisions are made about which currently unregulated contaminants to regulate.)

Chapter 8: Economic Impact Analyses

8.1 Introduction

EPA is required to perform a series of analyses that addresses the distribution of regulatory impacts associated with the proposed Arsenic Rule. This chapter presents analyses that support EPA's compliance with the following federal mandates:

- Executive Order 12886 (Regulatory Planning and Review);
- Regulatory Flexibility Act (RFA) of 1980, as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996;
- National Affordability determination required by the 1996 amendments to the Safe Drinking Water Act (SDWA);
- Unfunded Mandates Reform Act (UMRA) of 1995;
- Technical, Financial, and Managerial Capacity Assessment required by Section 1420(d)(3) of the 1996 amendments to the Safe Drinking Water Act (SDWA);
- Executive Order 13045 (Protection of Children From Environmental Health Risks and Safety Risks);
- Executive Order 12989 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations);
- Paperwork Reduction Act; and
- Health Risk Reduction and Cost Analysis (HRRCA) as required by Section 1412(b)(3)(C) of the 1996 SDWA Amendments;
- Initial Regulatory Flexibility Analysis (IRFA)

These analyses draw on the cost analyses presented in Chapter 6 and an analysis of administrative requirements presented in a separate document, *Information Collection Request for the Arsenic Rule*. Throughout this chapter, it is assumed that CWSs will have to comply with the newly proposed MCL, while NTNCs will only have to monitor for Arsenic.

Several of these federal mandates require an explanation of why the rule is necessary, the statutory authority upon which it is based, and the primary objectives it is intended to achieve. Background information on the problems addressed by the proposed rule, and EPA's statutory authority for promulgating the rule are presented in Chapter 2. In this chapter, Section 8.2 presents the RFA and SBREFA analysis of impacts on small entities. Also described are the economic impacts of the proposed rule on households. Section 8.3 discusses coordination of the arsenic rule with other Federal rules. The minimization of economic burden, UMRA, system capacity assessments, and the Paperwork Reduction Act are addressed in Sections 8.4, 8.5, 8.6 and 8.7, respectively. Section 8.8 discusses the rules' protection of children's health, Section 8.9 addresses environmental justice issues and Section 8.10 contains the HRRCA.

8.2 Regulatory Flexibility Act and Small Business Regulatory Enforcement Fairness Act

8.2.1 Summary of EPA's Small Business Consultations

Under the Regulatory Flexibility Act, 5 U.S.C. 601 et seq., as amended by the Small Business Regulatory Enforcement Fairness Act of 1996, EPA is required to prepare a regulatory flexibility analysis unless the Agency certifies that a rule will not have "a significant economic impact on a substantial number of small entities." If it is determined that the rule will have a significant impact on a substantial number of small entities the Agency must convene a Small Business Advocacy Review (SBAR) Panel prior to publication of the proposed rule. The SBAR Panel has 60 days to consult with small entity representatives (SERs) likely to be impacted by the rule and to make recommendations designed to reduce the impact of the proposed rule on small entities. The Agency must consider these recommendations when drafting the proposed rule.

As required by section 609(b) of the RFA, as amended by SBREFA, EPA also conducted outreach to small entities and convened a Small Business Advocacy Review Panel to obtain advice and recommendations of representatives of the small entities that potentially would be subject to the rule's requirements.

EPA identified 22 representatives of small entities, in this situation small systems, that were most likely to be subject to the proposal. In December, 1998, EPA prepared and distributed to the small entity representatives (SERs) an outreach document on the arsenic rule titled "Information for Small Entity Representatives Regarding the Arsenic in Drinking Water Rule" (EPA 1998).

On December 18, 1998, EPA held a SER conference call for small systems from Washington D.C. to provide a forum for input on key issues related to the planned proposal of the arsenic in drinking water rule. These issues included, but were not limited to issues related to the rule development, such as arsenic health risks, treatment technologies, analytical methods, and monitoring. Fifteen SERs from small water systems participated on the call from the following States: Alabama, Arizona, California, Georgia, Massachusetts, Montana, Nebraska, New Hampshire, New Jersey, Utah, Virginia, Washington, and Wisconsin.

Efforts to identify and incorporate small entity concerns into this rulemaking culminated with the convening of a SBAR Panel on March 30, 1999, pursuant to section 609 of RFA/SBREFA. The four person Panel was headed by EPA's Small Business Advocacy Chairperson and included the Director of the Standards and Risk Management Division within EPA's Office of Ground Water and Drinking Water, the Administrator of the Office of Information and Regulatory Affairs with the Office of Management and Budget, and the Chief Counsel for Advocacy of the SBA. For a 60-day period starting on the convening date, the Panel reviewed technical background information related to this rulemaking, reviewed comments provided by the SERs, and met on several occasions. The Panel also conducted its own outreach to the SERs and held a conference call on April 21, 1999 with the SERs to identify issues and explore alternative approaches for accomplishing environmental protection goals while minimizing impacts to small entities. Consistent with the RFA/SBREFA requirements, the Panel evaluated the assembled materials and small-entity comments on issues related to the elements of the IRFA (See section 8.2.1) . A copy of the June 4, 1999 Panel report is included in the docket for this proposed rule (U.S. EPA, 1999).

The proposed rule addresses all of the recommendations on which the Panel reached consensus. In addition, to help small systems comply with the arsenic rule, EPA is committed to addressing several other Panel recommendations regarding guidance, which are discussed in detail in the pages to follow.

Treatment Technologies, Waste Disposal, and Cost Estimates

The Panel recommended the following: further develop the preliminary treatment and waste disposal cost estimates; fully consider these costs when identifying affordable compliance technologies for all system size categories; and provide information to small water systems on possible options for complying with the MCL, in addition to installing any listed compliance technologies.

In response to these recommendations the Treatment and Cost document describes: development of cost estimates for treatment and waste disposal; identification of affordable compliance technologies, including the consideration of cost; and options for complying with the MCL other than installing compliance technologies, such as selecting to regionalize.

Regarding POU devices, the Panel recommended the following: continue to promote the use of POU devices as alternative treatment options for very small systems where appropriate; account for all costs, including costs that may not routinely be explicitly calculated; consider liability issues from POU/POE devices when evaluating their appropriateness as compliance technologies; and investigate waste disposal issues with POE devices.

In response to these recommendations, EPA will include in the proposed rule's preamble: an expanded description regarding available POU compliance treatment technologies and conditions under which POU treatment may be appropriate for very small systems; a description of the components which contribute to the POU cost estimates; a discussion that clarifies that water systems will be responsible for POU operation and maintenance to prevent liability issues from customers maintaining equipment themselves.

Relevance of Other Drinking Water Regulations

The Panel recommended the following: include discussion of the co-occurrence of arsenic and radon in the proposed rule for arsenic; take possible interactions among treatments for different contaminants into account in costing compliance technologies and determining whether they are nationally affordable for small systems; and encourage systems to be forward-looking and test for the multiple contaminants to determine if and how they would be affected by the upcoming rules.

In response, the proposed rule's preamble will include a discussion on the co-occurrence analysis of radon and arsenic: the treatment section of the preamble will be expanded to describe the relationship of treatment for arsenic with other drinking water rules and how this issue was taken into account in cost estimates. In addition, the preamble will encourage systems to consider other upcoming rules when making future plans on monitoring or treatment.

Small Systems Variance Technologies and National Affordability Criteria

The Panel recommended the following: include a discussion of the issues surrounding appropriate adjustment of its national affordability criteria to account for new regulatory requirements; consider revising its approach to national affordability criteria, to the extent allowed by statutory and regulatory requirements, to address the concern that the current cumulative approach for adjusting the baseline household water bills is based on chronological order rather than risk; and examine the data in the 1995 Community Water Supply Survey to determine if in-place treatment baselines can be linked with the current annual water bill baseline in each of the size categories for the proposed rule.

In response to these recommendation, the treatment section of proposed rule's preamble will include an expanded discussion about the national affordability criteria and how it may be adjusted to account for new regulations. In addition, information regarding methodology and rationale will be added to explain the national affordability approach.

Monitoring and Arsenic Species

The Panel recommended the following: EPA consider allowing States to use recent compliance monitoring data to satisfy initial sampling requirements or to obtain a waiver; and that EPA continue to explore whether or not to make a regulatory distinction between organic and inorganic arsenic based on compliance costs and other considerations.

In response, the monitoring section of the rule's preamble and the proposed regulatory language will describe the allowance of monitoring data that meet analytical requirements and have reporting limits sufficiently below the revised MCL and collected after 1990.

Considerations in setting the MCL

The Panel recommended the following: in performing its obligations under SDWA EPA should take cognizance of the scientific findings, the large scientific uncertainties, the large potential costs (including treatment and waste disposal costs), and the fact that this standard is scheduled for review in the future; give full consideration to the provisions of the Executive Order 12866 and to the option of exercising the new statutory authority under SDWA Sections 1412(b)(4)(C) and 1412(b)(6)(A) in the development of the arsenic rule; and fully consider all of the "risk management" components of its rulemaking effort to ensure that the financial and other impacts on small systems are factored into its decision-making processes. The Panel also recommended that EPA take into account both quantifiable and non-quantifiable costs and benefits of the standard and the needs of sensitive sub-populations.

In response to all these recommendations, EPA describes in detail the factors that were considered in setting in the MCL and provides the rationale for this selection.

Applicability of proposal

The Panel recommended that EPA carefully consider the appropriateness of extending the scope of the rule to Non-Transient, Non-Community Water Systems (NTNCWSs).

In response, the arsenic proposal does not apply to NTNCWSs and the MCL section of the rule's preamble will describe the basis for this decision, including the incremental costs and benefits attributable to coverage of these water systems.

Other Issues

The Panel recommended that EPA encourage small systems to discuss their infrastructure needs for complying with the arsenic rule with their primacy agency to determine their eligibility for DWSRF loans, and if eligible, to ask for assistance in applying for the loans. In response, the UMRA analysis has been expanded to discuss funding options for small systems and to encourage systems to be proactive in communicating with their primacy agency.

Regarding health effects, the Panel recommended the following: further evaluate the Utah study and its relationship to the studies on which the NRC report was based and give it appropriate weight in the risk assessment for the proposed arsenic standard; and examine the NRC recommendations in the light of the uncertainties associated with the report's recommendations, and any new data that may not have been considered in the NRC report. In response to these recommendations, the benefits analysis includes a discussion of the qualitative benefits evaluation and use of research data.

8.2.2 Definition of Small Entity for the Arsenic Rule

The Agency has proposed, taken comment, and finalized its intent to define "small entity" as a public water system that serves 10,000 or fewer persons for purposes of its regulatory flexibility assessments under the RFA for all future drinking water regulations. (See the Consumer Confidence Reports Final Rule, 63 FR 44511, Aug. 19, 1998 and Proposed Rule, 63 FR 7620 Feb.13, 1998.) The Agency discussed at length, in the preamble to the proposed Consumer Confidence rule, the basis for its decision to use this definition and to use a single definition of small public water system whether the system was a "small business", "small nonprofit organization", or "small governmental jurisdiction." EPA also consulted with the Small Business Administration on the use of this definition as it relates to small businesses. The Agency has used this definition in developing subsequent regulations under the Safe Drinking Water Act. In defining small entities in this manner, EPA recognizes that baseline conditions in source water and treatment and operational practices may differ for systems serving fewer than 10,000 people versus systems serving 10,000 or more persons.

According to the latest estimates (December 1998) contained in the EPA's public water system database, Safe Drinking Water Information System (SDWIS), there are 54,352 community water systems and 20,255 non-transient noncommunity water supplies providing potable water to the public. Of these, 90 percent of the CWSs (50,776) and nearly all of the NTNCWSs (20,235) are classified by EPA as small entities. Exhibit 8-1 presents a breakdown of the universe of small water systems by size category, type, and ownership.

Exhibit 8-1
Profile of the Universe of Small Water Systems
Regulated Under the Arsenic Rule

Type Water System	System Size Category				
	<100	101-500	501-1,000	1,001-3,300	3,301-10,000
Publicly-Owned:					
CWS	1,729	5,795	3,785	6,179	3,649
NCWS	1,783	3,171	1,182	361	29
Privately-Owned:					
CWS	13,640	11,266	2,124	1,955	654
NCWS	8,178	4,162	902	411	56
Total Systems:					
CWS	15,369	17,061	5,909	8,134	4,303
NCWS	9,961	7,333	2,084	772	85
TOTAL	25,330	24,394	7,993	8,906	4,388

Source: Safe Drinking Water Information System (SDWIS), December 1998 freeze.

Of the total number of small systems governed by the proposed rule, 72 percent of the systems are CWSs and 28 percent are NTNCWSs. A table of the total number of systems regulated by the proposed rule is provided in Chapter 4, "Baseline Analysis."

8.2.3 Requirements for the Initial Regulatory Flexibility Analysis

The Regulatory Flexibility Act requires EPA to complete an Initial Regulatory Flexibility Analysis (IRFA) addressing the following:

- The need for the rule;
- The objectives of and legal basis for the proposed rule;
- A description of, and where feasible, an estimate of the number of small entities to which the rule will apply;
- A description of the proposed reporting, record keeping, and other compliance requirements of the rule, including an estimate of the types of small entities, which will be subject to the requirements and the type of professional skills necessary for preparation of reports or records;
- An identification, to the extent practicable, of all relevant federal rules that may duplicate, overlap, or conflict with the proposed rule; and

- A description of “any significant regulatory alternatives” to the proposed rule that accomplish the stated objectives of the applicable statutes, and that minimize any significant economic impact of the proposed rule on small entities. Significant regulatory alternatives may include:

  - Establishing different compliance or reporting requirements or timetables that take into account the resources of small entities;
  - Clarifying, consolidating, or simplifying compliance and reporting requirements under the rule for small entities;
  - Using performance rather than design standards; and
  - Exempting small entities from coverage of the rule or any part of the rule.

8.2.4 Small Entity Impacts

The results of the economic impact analysis for small water systems under the MCL options of 3, 5, 10, and 20 µg/L are summarized below. Estimates of the number of small systems expected to be affected and the cost of complying with each component of the regulatory approach are presented.

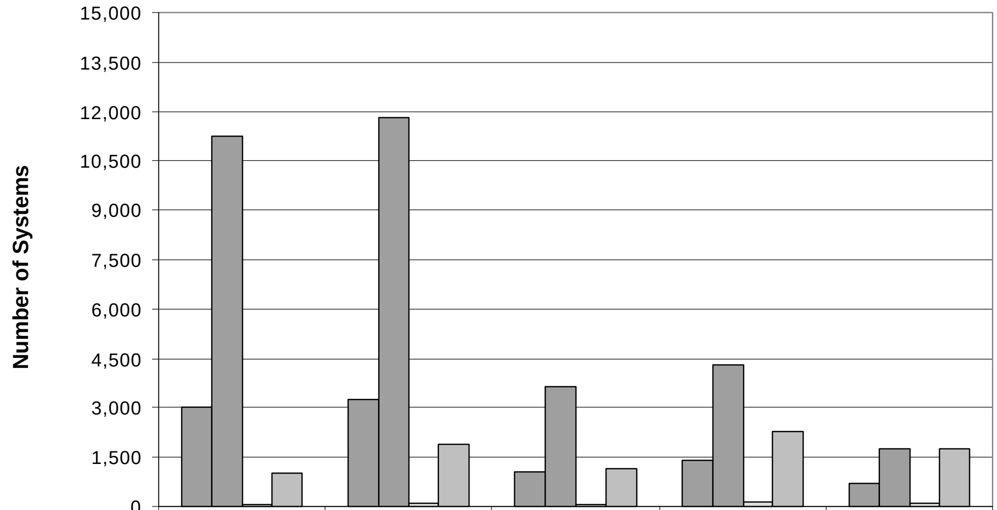
As seen in Exhibit 8-2, at an MCL of 5 µg/L, approximately thirteen percent of community water systems serving less than 100 people are expected to be affected by the Arsenic Rule. In general, for the small systems size categories, the Arsenic Rule is expected to affect approximately twelve percent of the universe of CWSs.

Table 8-2
Number of CWSs Expected to Undertake or Modify Treatment Practice

	<100	101-500	501-1,000	1,001-3,300	3,301-10,000	10,001-50,000	50,001-100,000	100,001-1,000,000
MCL 3								
GW	3,024	3,256	1,058	1,406	696	434	53	33
SW	62	109	67	137	94	76	16	16
MCL 5								
GW	1,898	2,048	671	893	444	286	35	21
SW	32	57	34	70	50	41	8	8
MCL 10								
GW	874	934	312	424	218	144	19	11
SW	10	18	11	23	16	13	3	4
MCL 20								
GW	343	377	126	177	91	61	8	5
SW	3	5	3	5	5	3	1	1

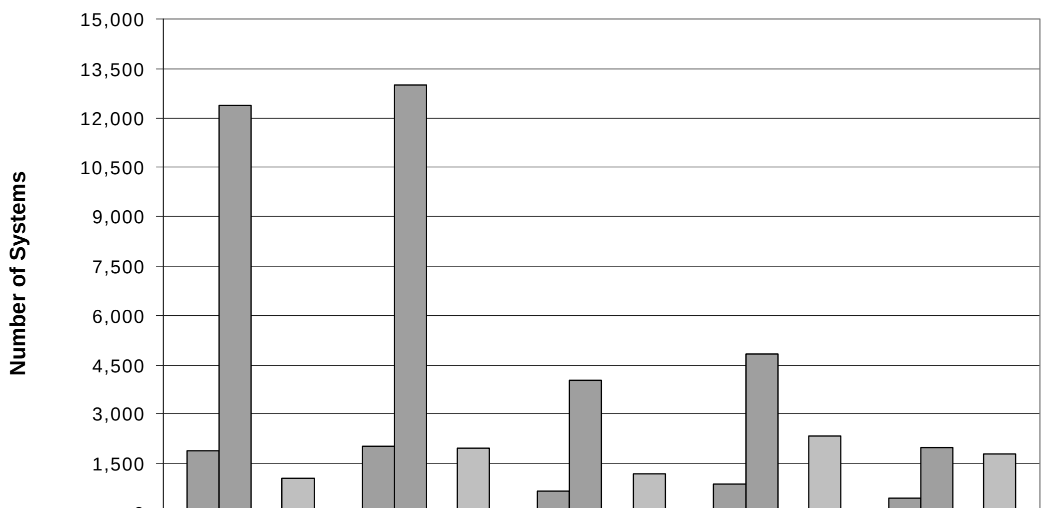
It is useful to put the number of systems affected by the rule in to context by comparing the number of systems expected to be affected by the promulgation of the Arsenic Rule to the number of systems not expected to undertake or modify any of their existing treatment practices. Exhibits 8-3, 8-4, 8-5, and 8-6 show these comparisons for MCLs of 3, 5, 10, 20 µg/L..

Exhibit 8-3
Number of CWSs Expected to Undertake or Modify Treatment Practice
MCL 3 µg/L



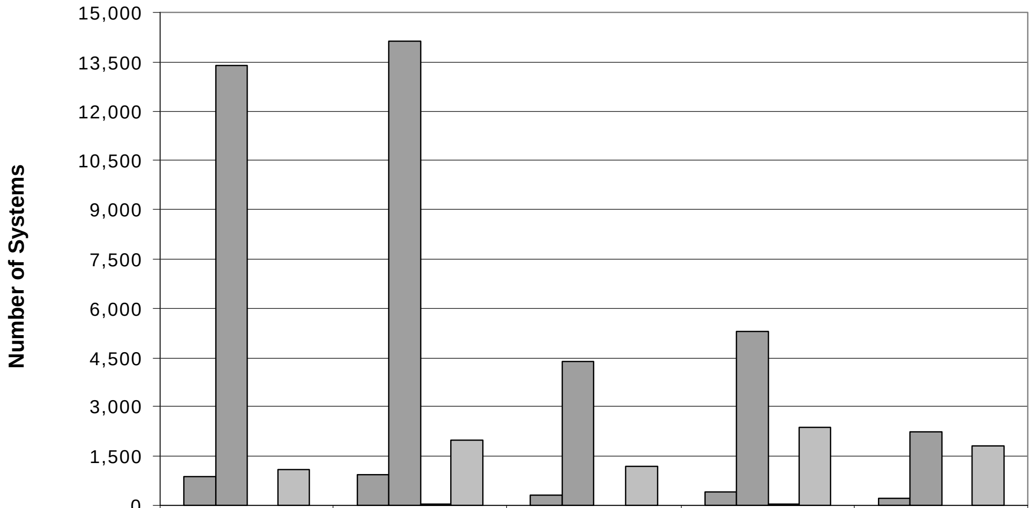
	<100	101-500	501-1,000	1,001-3,300	3,301-10,000
Treating GW systems	3,024	3,256	1,058	1,406	696
Not treating GW systems	11,253	11,802	3,631	4,308	1,763
Treating SW systems	62	109	67	137	94
Not treating SW systems	1,030	1,894	1,153	2,283	1,750

Exhibit 8-4
Number of CWSs Expected to Undertake or Modify Treatment Practice
MCL 5 µg/L



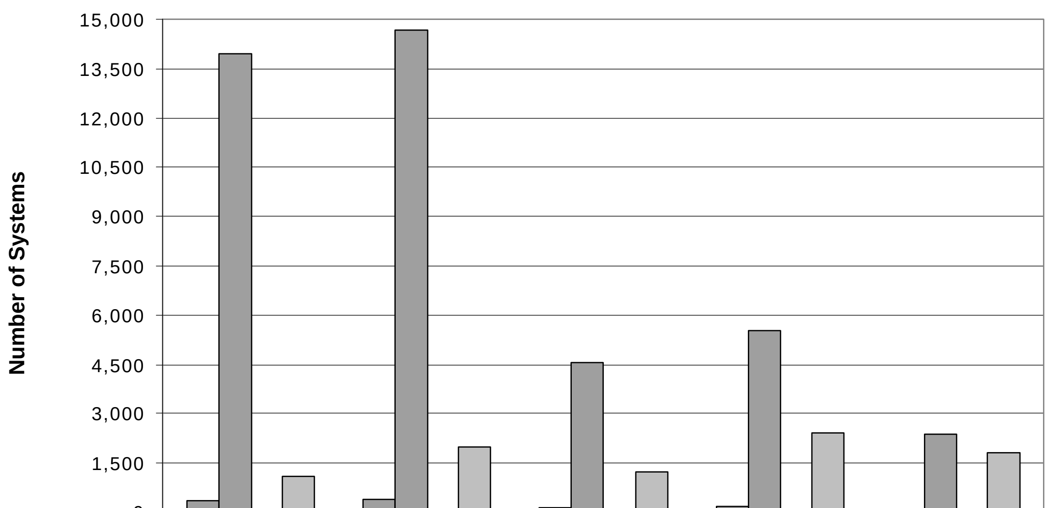
	<100	101-500	501-1,000	1,001-3,300	3,301-10,000
Treating GW systems	1,898	2,048	671	893	444
Not treating GW systems	12,379	13,010	4,018	4,821	2,015
Treating SW systems	32	57	34	70	50
Not treating SW systems	1,060	1,946	1,186	2,350	1,794

Exhibit 8-5
Number of CWSs Expected to Undertake or Modify Treatment Practice
MCL 10 µg/L



	<100	101-500	501-1,000	1,001-3,300	3,301-10,000
Treating GW systems	874	934	312	424	218
Not treating GW systems	13,403	14,124	4,377	5,290	2,241
Treating SW systems	10	18	11	23	16
Not treating SW systems	1,082	1,985	1,209	2,397	1,828

Exhibit 8-6
Number of CWSs Expected to Undertake or Modify Treatment Practice
MCL 20 µg/L



	<100	101-500	501-1,000	1,001-3,300	3,301-10,000
Treating GW systems	343	377	126	177	91
Not treating GW systems	13,934	14,681	4,563	5,537	2,368
Treating SW systems	3	5	3	5	5
Not treating SW systems	1,089	1,998	1,217	2,415	1,839

Exhibit 8-7 details the average system-level annual compliance costs for small systems that are expected to undertake or modify treatment. As one would expect, the costs, per treating system, are slightly higher under the most stringent MCL.

Exhibit 8-7
Average Annual System Compliance Costs for CWSs*

MCL (µg/L)	CWS Size Category				
	<100	101-500	501-1,000	1,001-3,300	3,301-10,000
3					
Treatment**	$ 7,523	$ 20,551	$ 33,440	$ 58,153	$ 131,121
Monitoring/ Administrative	$ 37	$ 37	$ 34	$ 36	$ 76
5					
Treatment**	$ 7,414	$ 20,163	$ 32,745	$ 54,633	$ 120,330
Monitoring/ Administrative	$ 35	$ 35	$ 32	$ 33	$ 69
10					
Treatment**	$ 7,316	$ 19,460	$ 31,018	$ 50,892	$ 109,215
Monitoring/ Administrative	$ 34	$ 34	$ 30	$ 30	$ 63
20					
Treatment**	$ 7,124	$ 18,705	$ 29,347	$ 46,472	$ 95,928
Monitoring/ Administrative	$ 34	$ 33	$ 29	$ 28	$ 55

*CWS system costs were calculated using a commercial discount rate.
**Treatment cost only applies if system undertakes or modifies treatment for arsenic.

Of course, system treatment costs range within size each size catagory. Also, it is important to look at both absolute compliance costs, as well as compliance costs relative to current operating expenditures. Using data on total current expenses from the CWSS (1995), EPA developed a Monte-Carlo simulation model to estimate the effect of increased small system expenditures as a result of Arsenic Rule compliance. Exhibits 8-8 through 8-17 show the distribution of system compliance costs, as well as the distribution of the percentage increase in total operating expenses that will result from the proposed arsenic rule. A separate exhibit is provided for each small size catagory and each proposed MCL.

Exhibit 8-8
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving < 100 People (MCL 3 µg/L)

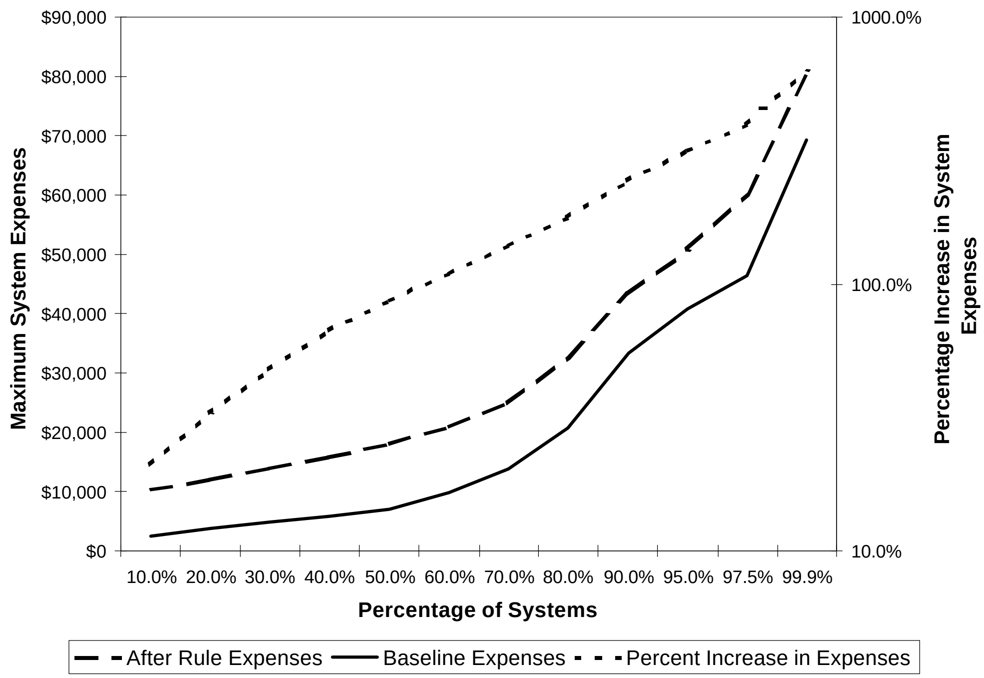


Exhibit 8-9
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving <100 People (MCL 5 µg/L)

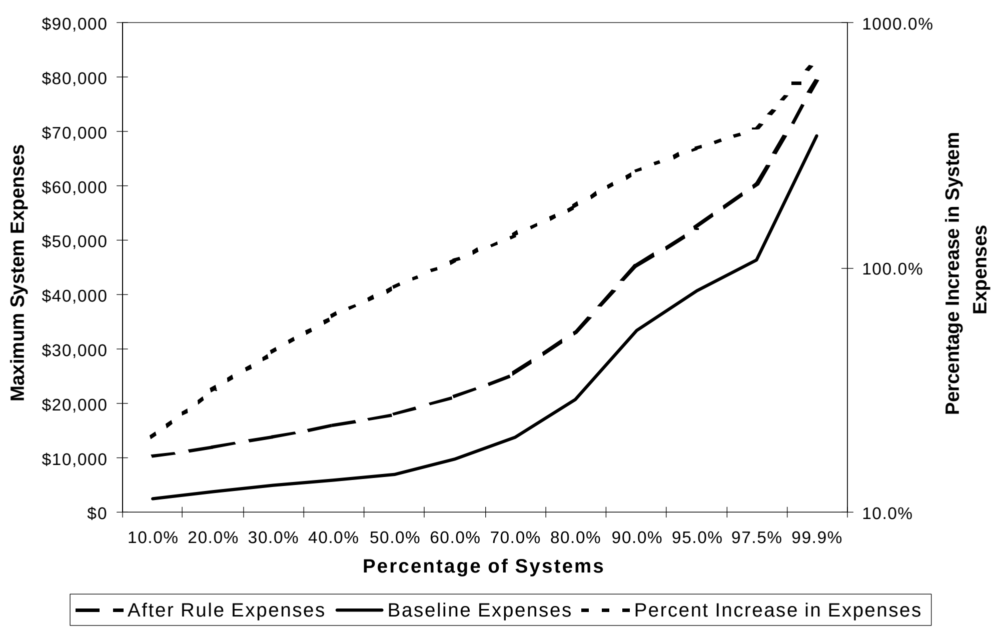


Exhibit 8-10
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving < 100 People (MCL 10 µg/L)

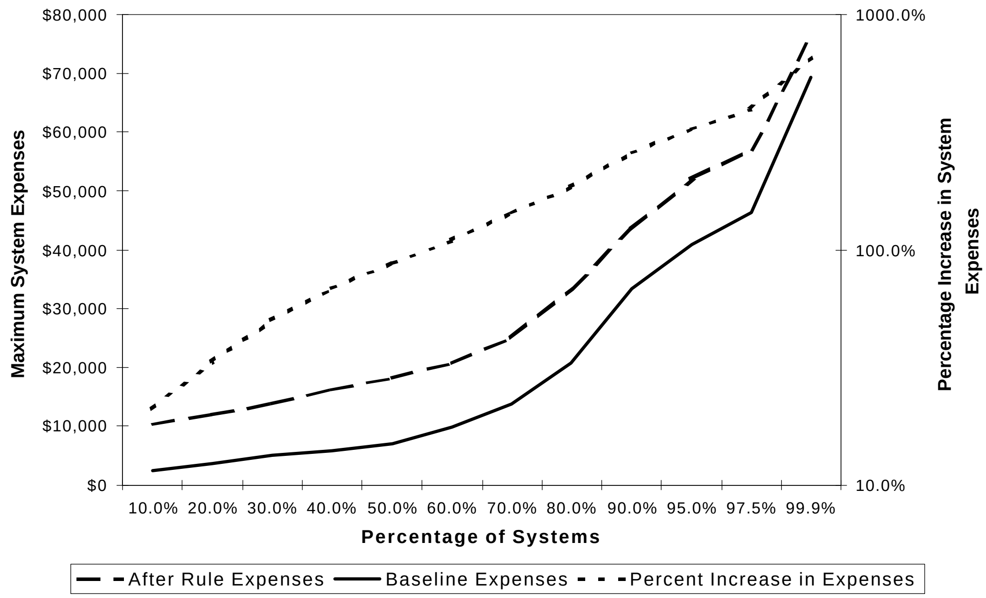


Exhibit 8-11
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving < 100 People (MCL 20 µg/L)

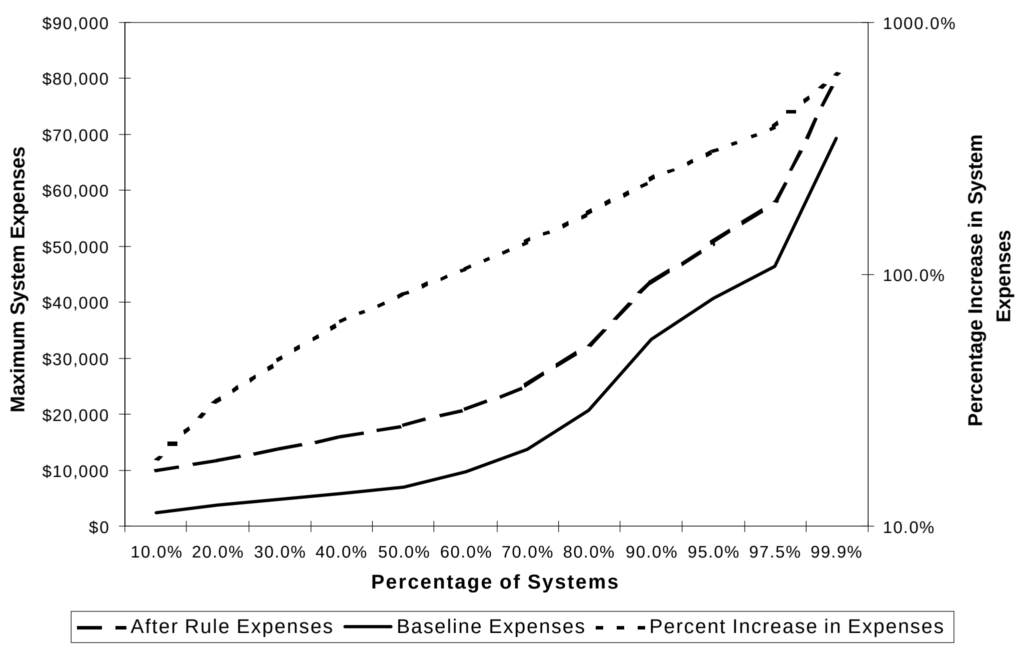


Exhibit 8-12
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 101-500 People (MCL 3 µg/L)

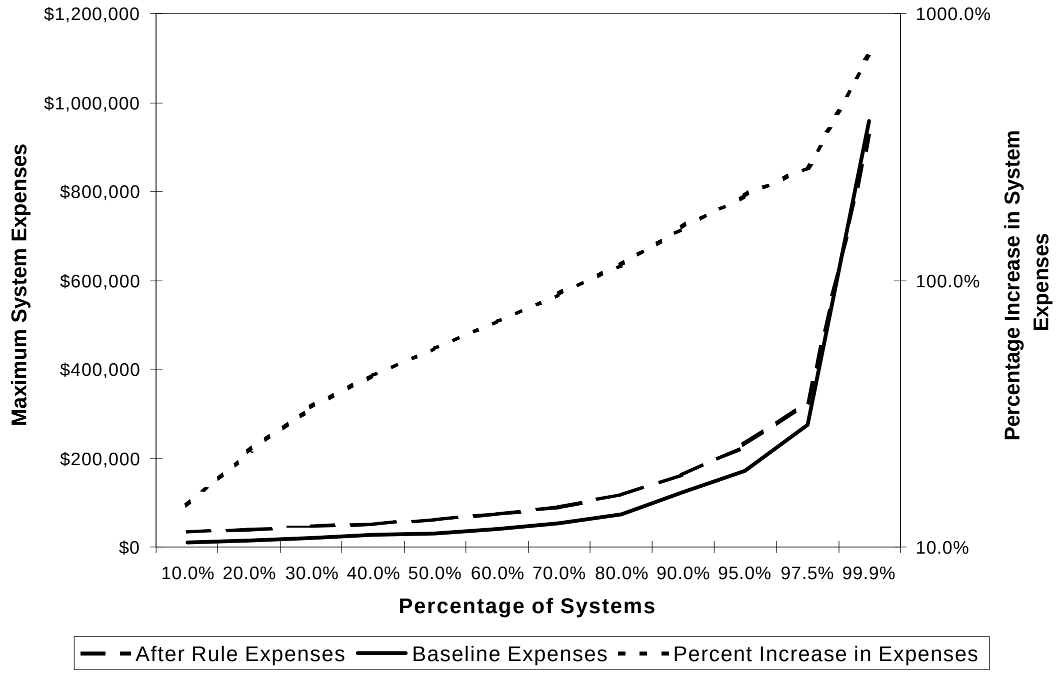


Exhibit 8-13
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 101-500 People (MCL 5 µg/L)

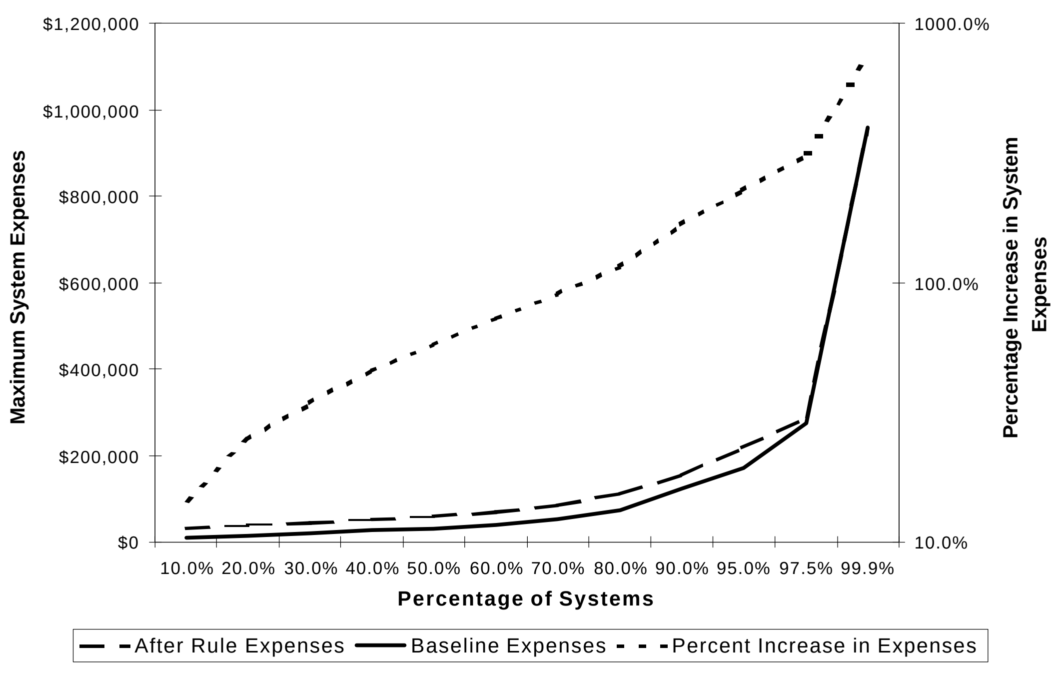


Exhibit 8-14
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 101-500 People (MCL 10 µg/L)

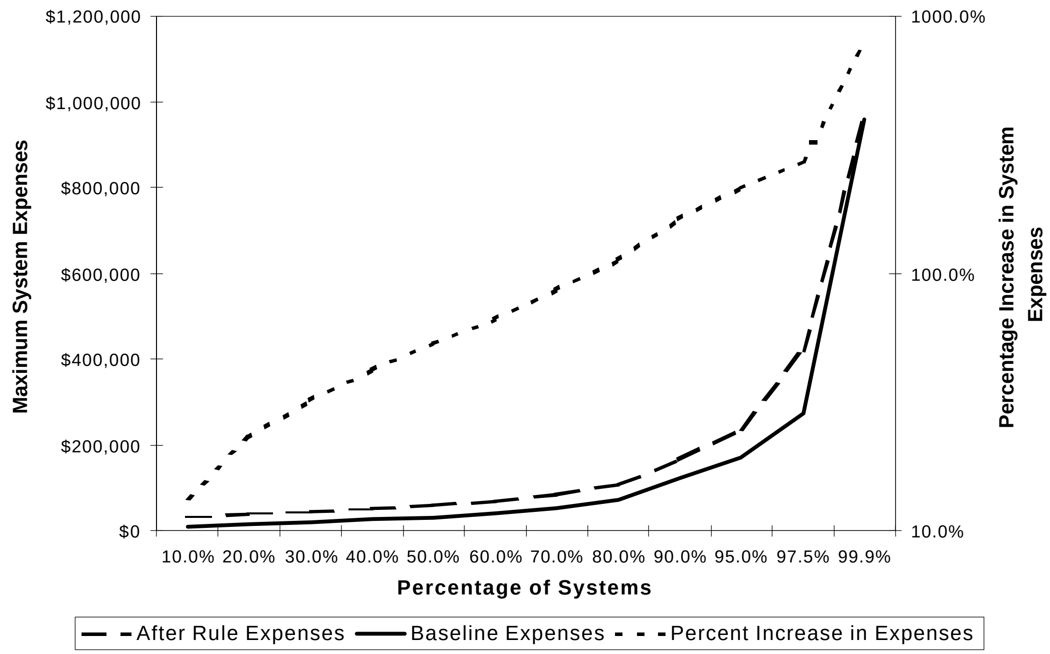


Exhibit 8-15
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 101-500 People (MCL 20 µg/L)

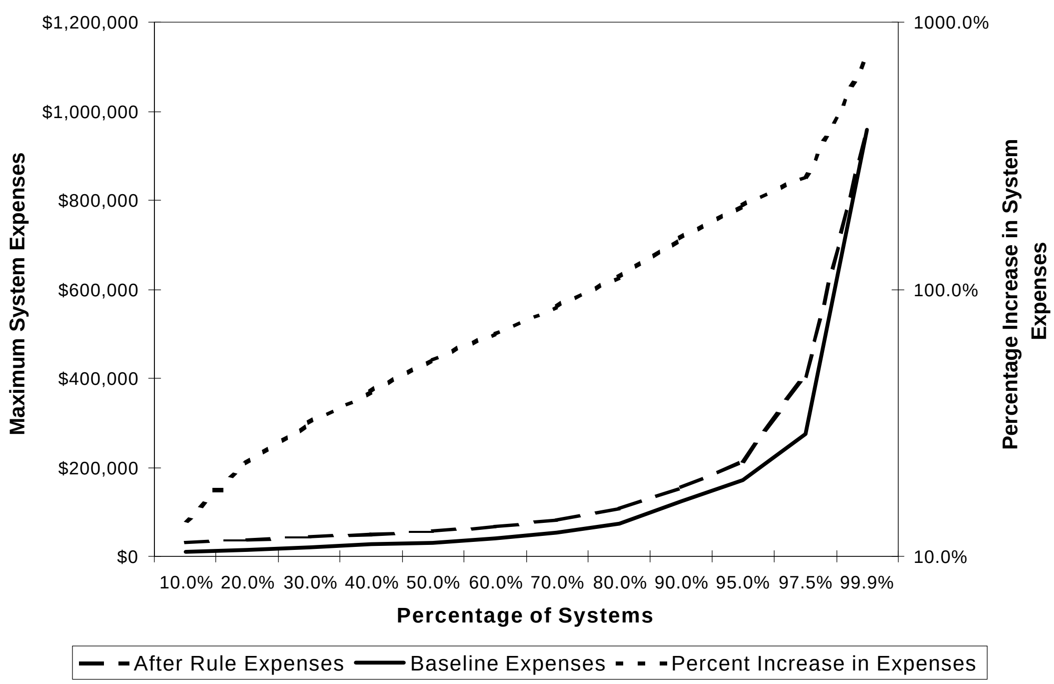


Exhibit 8-16
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 501-1,000 People (MCL 3 μg/L)

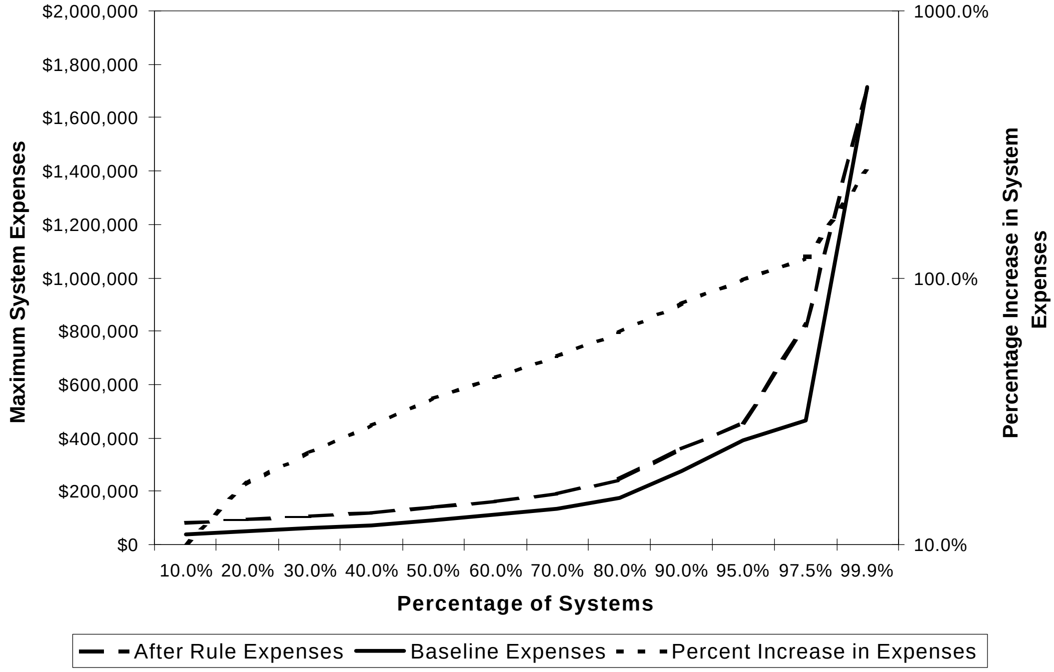


Exhibit 8-17
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 501-1,000 People (MCL 5 μg/L)

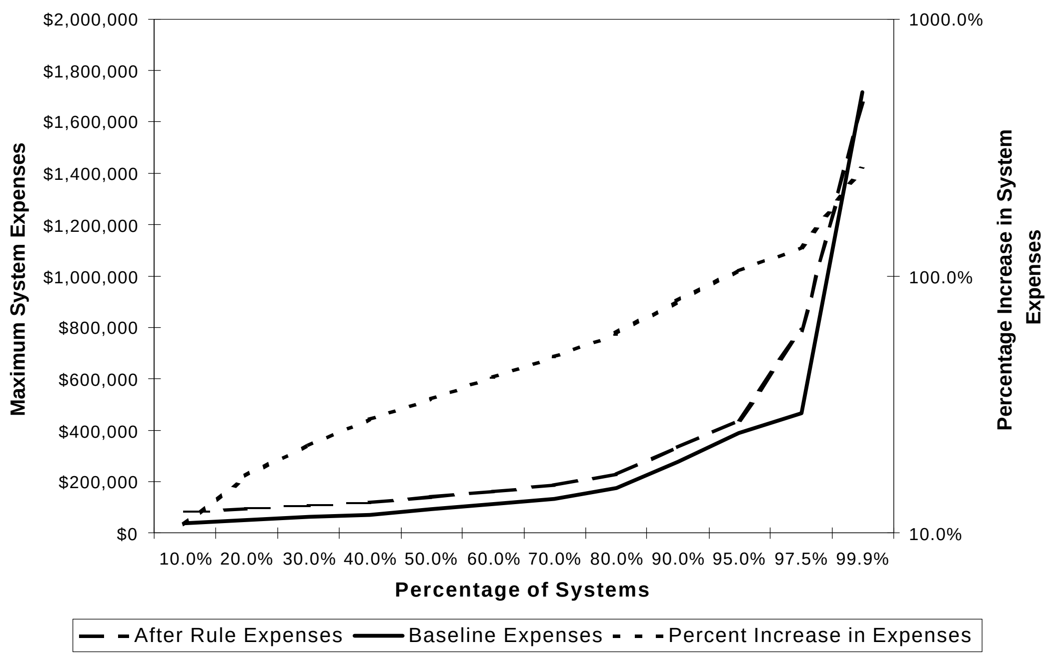


Exhibit 8-18
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 501-1,000 People (MCL 10 µg/L)

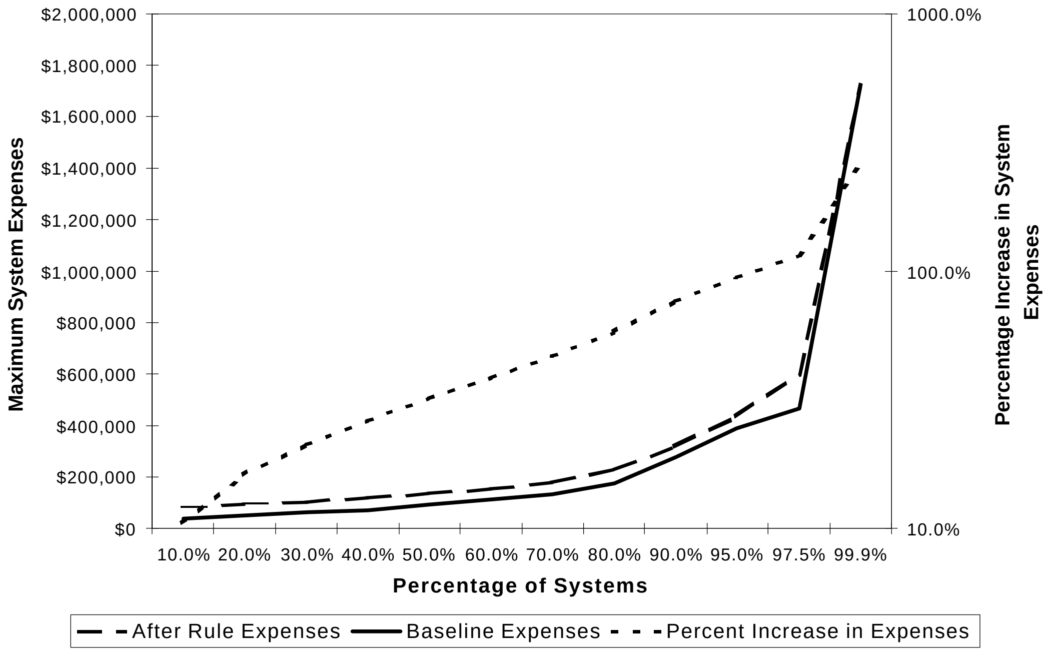


Exhibit 8-19
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 501-1,000 People (MCL 20 µg/L)

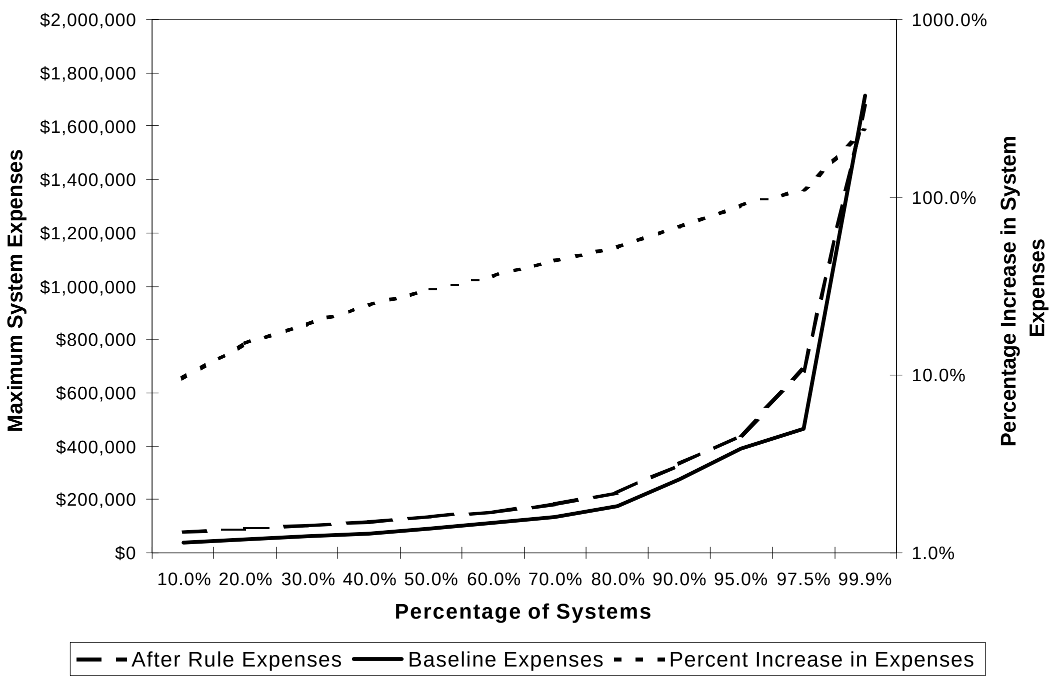


Exhibit 8-20
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 1,001-3,000 People (MCL 3 µg/L)

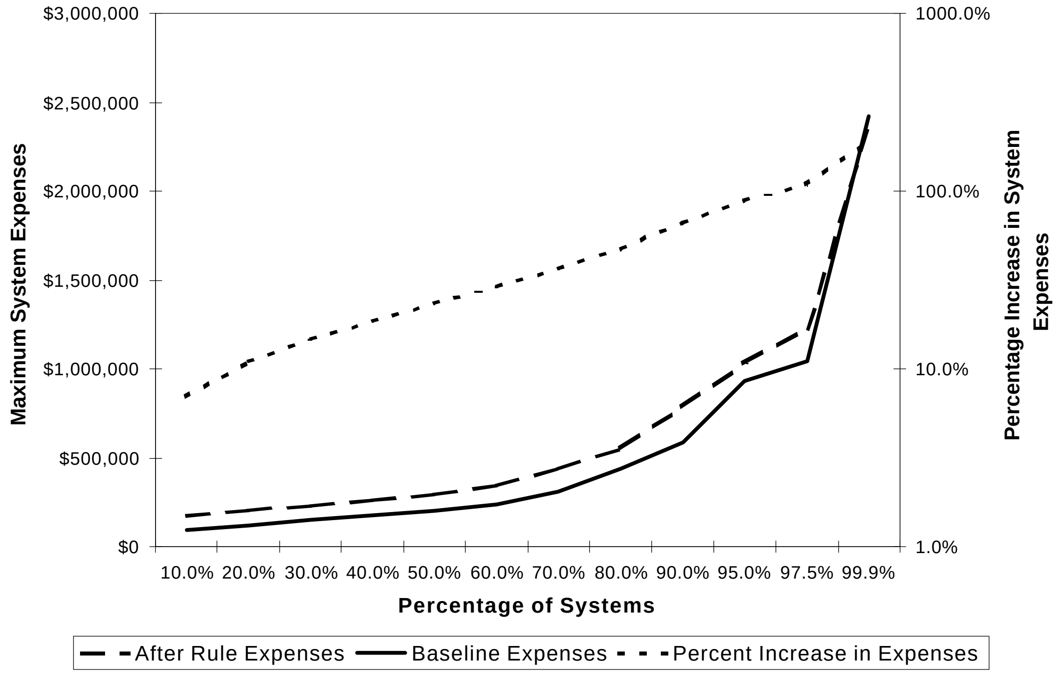


Exhibit 8-21
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 1,001-3,300 People (MCL 5 µg/L)

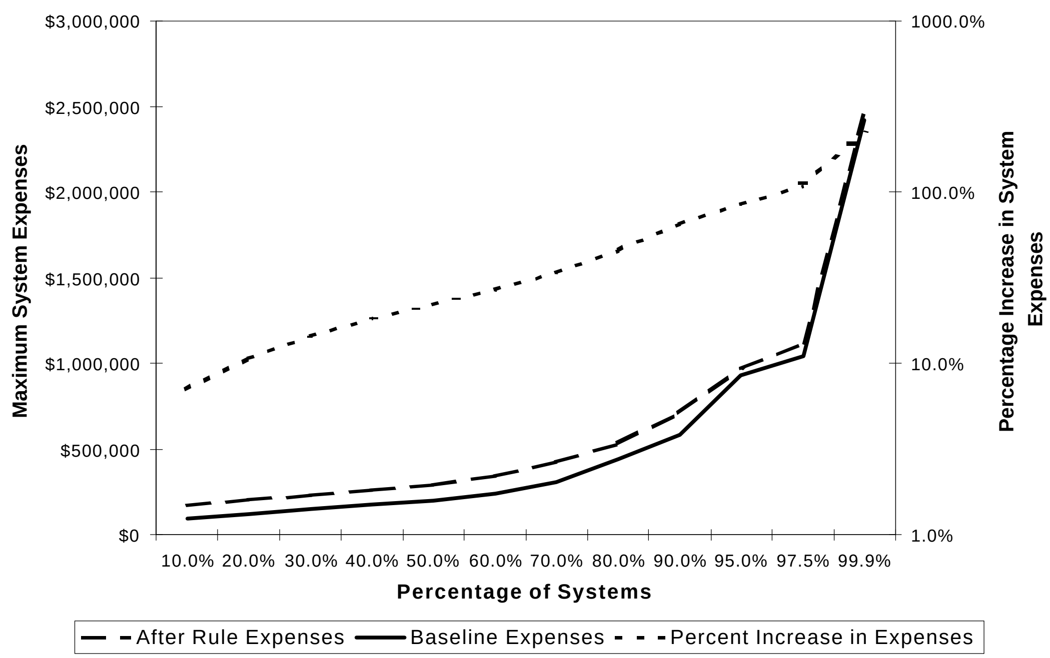


Exhibit 8-22
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 1,001-3,300 People (MCL 10 µg/L)

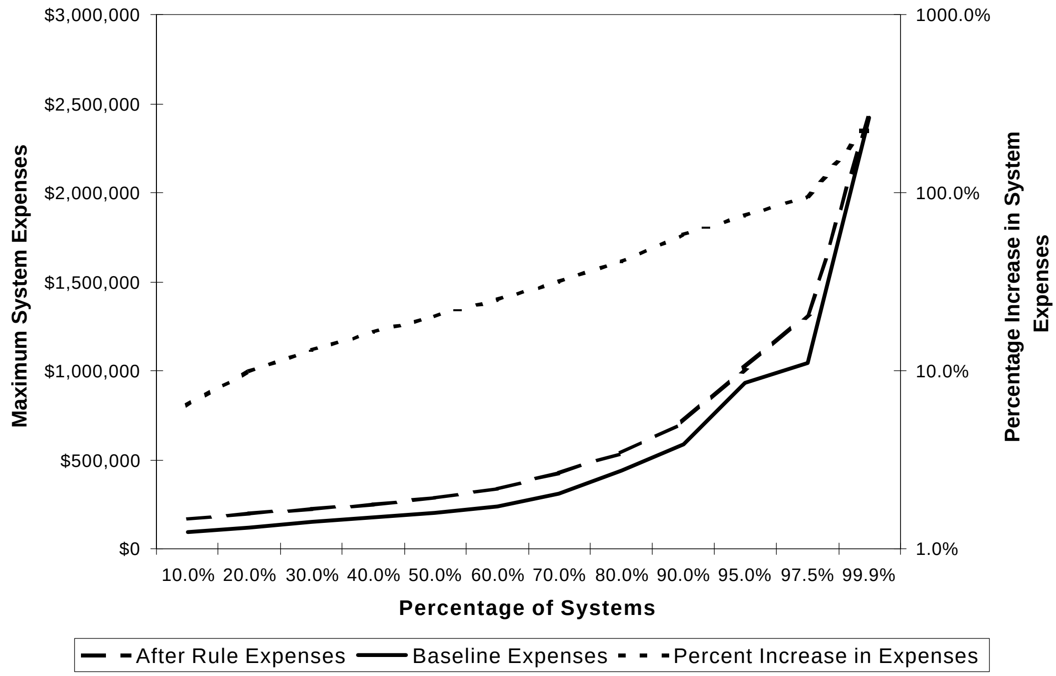


Exhibit 8-23
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 1,001-3,000 People (MCL 20 µg/L)

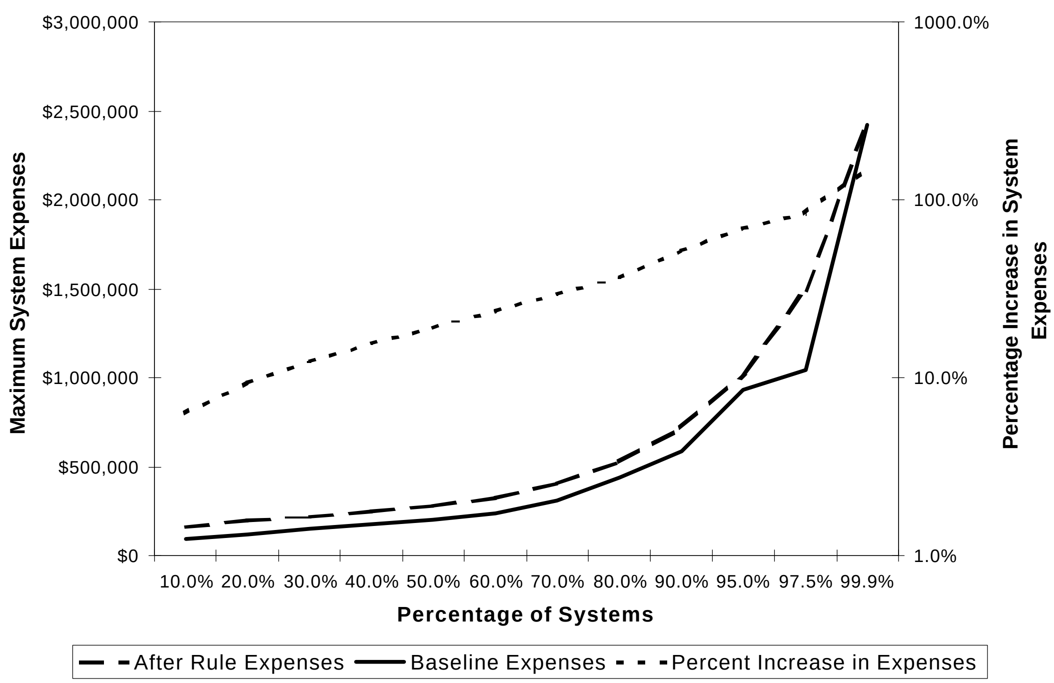


Exhibit 8-24
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 3,301-10,000 People (MCL 3 µg/L)

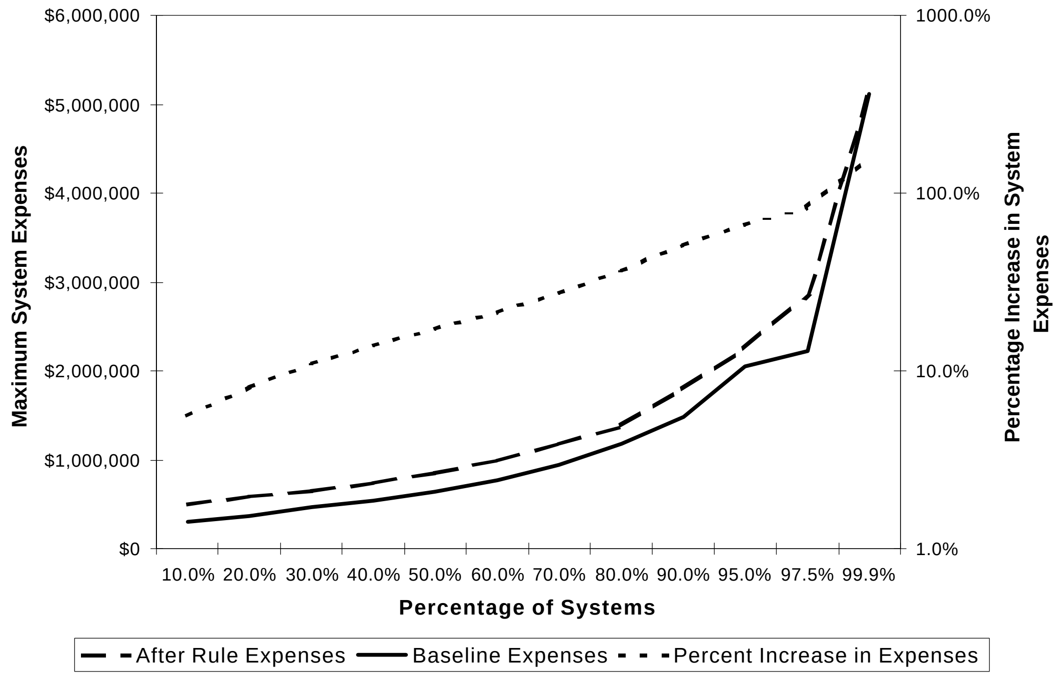
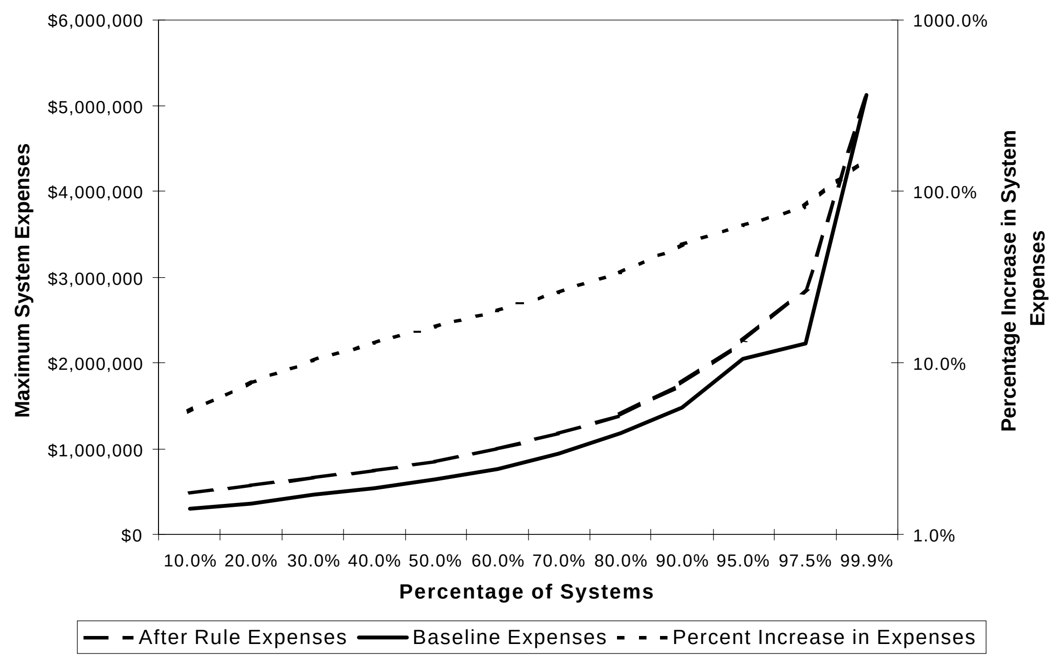


Exhibit 8-25
Comparison of CWS Baseline and Post-Compliance Total Expenses for Systems Serving 3,301-10,000 People (MCL 5 µg/L)



8.2.5 Small System Affordability

Section 1415(e)(1) of SDWA allows States to grant variances to small water systems (i.e., systems having fewer than 10,000 customers) in lieu of complying with an MCL if EPA determines that there are no nationally affordable compliance technologies for that system size/water quality combination. The system must then install an EPA-listed variance treatment technology (§1412(b)(15)) that makes progress toward the MCL, if not necessarily reaching it. To list variance technologies, three showings must be made:

1) EPA must determine, on a national level, that there are no compliance technologies that are affordable for the given small system size category/source water quality combination.

2) If there is no nationally affordable compliance technology, then EPA must identify a variance technology the may not reach the MCL but that will allow small systems to make progress toward the MCL (it must achieve the maximum reduction affordable). This technology must also be listed as a small systems variance technology by EPA in order for small systems to be able to rely on it for regulatory purposes.

3) EPA must make a finding on a national level, that use of the variance technology would be protective of public health.

States must then make a site-specific determination for each system as to whether or not the system can afford to meet the MCL based on State-developed affordability criteria. If the State determines that compliance is not affordable for the system, it may grant a variance, but it must establish terms and conditions, as necessary, to ensure that the variance is adequately protective of human health.

In the Agency's draft national-level affordability criteria published in the August 6, 1998 *Federal Register*, EPA discussed the affordable treatment technology determinations for the contaminants regulated before 1996. The national-level affordability criteria were derived as follows. First an "affordability threshold" was calculated. The affordability threshold was based on the total annual household water bill as a percentage of household income. In developing this threshold value, EPA considered the percentage of median household income spent by an average household on comparable goods and services such items as housing (28%), transportation (16%), food (12%), energy and fuels (3.3%), telephone (1.9%), water and other public services (0.7%), entertainment (4.4%) and alcohol and tobacco (1.5%).

Another of the key factors that EPA used to select an affordability threshold was cost comparisons with other risk reduction activities for drinking water. Section 1412(b)(4)(E)(ii) of the SDWA identifies both Point-of-Entry and Point-of-Use devices as options for compliance technologies. EPA examined the projected costs of these options. EPA also investigated the costs associated with supplying bottled water for drinking and cooking purposes. The median income percentages that were associated with these risk reduction activities were: Point-Of-Entry (> 2.5%), Point-of-Use (2%) and bottled water (> 2.5%).

Based on the foregoing analysis, EPA developed an affordability criteria of 2.5% of median household income, or about $750, for the affordability threshold (EPA, 1998). The median water bill for households in each small system category was then subtracted from this threshold to determine the additional expenditure per household that was considered affordable for new treatment. This difference is referred to as the "available expenditure margin." Based on EPA's 1995 Community Water System Survey, median water bills were about $250 per year for small system customers. Thus, an average available expenditure margin of up to $500 per year per household was considered affordable for the contaminants regulated before 1996. EPA next identified treatment technologies for all pre-1996 contaminants with average per household costs below $500 per year. Therefore it was not necessary to list any small system variance technologies for existing contaminant rules.

Applying this criterion to the case of arsenic in drinking water, EPA has determined that affordable technologies exist for all system size categories and has therefore not identified a variance technology for any system size or source water combination at the proposed MCL. (See Exhibit 8-28, Mean Annual Household Costs Across MCL Options by System Size.) In other words, annual household costs after installation of the compliance technology are projected to be below the available affordability threshold for all system size categories for the proposed MCLs. EPA solicits comment on its determination in this case as well as its affordability criteria more generally.

Exhibit 8-28
Mean Annual Costs to Households Served by CWSs, by Size Category

SIZE CATEGORIES	MCL (μg/L)			
	3	5	10	20
<100	$368.13	$363.65	$357.17	$348.72
101-500	$258.68	$253.64	$246.38	$237.67
501-1,000	$106.07	$103.74	$98.35	$93.25
1,001-3,300	$63.61	$60.38	$56.51	$51.80
3,301-10,000	$44.28	$40.77	$37.04	$32.52
10,001-50,000	$36.39	$33.22	$29.13	$24.99
50,001-100,000	$29.52	$26.64	$22.80	$19.44
100,001-1,000,000	$23.47	$21.20	$18.32	$15.41
1,000,000 +	$2.70	$1.73	$0.89	$0.55
All categories	$43.73	$39.18	$33.05	$23.62

EPA recognizes that individual water systems may have higher than average treatment costs, fewer than average households to absorb these costs, or lower than average incomes, but believes that the affordability criteria should be based on characteristics of typical systems and should not address situations where costs might be extremely high or low or excessively burdensome. EPA believes that there are other mechanisms that may address these situations to a certain extent. In any case, EPA believes that small system variances should be the exception and not the rule.

EPA expects the available expenditure margin to be lower than $500 per household per year for the Arsenic Rule because some sources of data, for example the Current Population Survey, indicate that water rates are currently increasing faster than median household income. Thus, the "baseline" for annual water bills will rise as treatment is installed for compliance with regulations promulgated after 1996, but before the Arsenic Rule is promulgated.

EPA notes, however, that high water costs are often associated with systems that have already installed treatment to comply with a NPDWR. Such in-place treatment facilities may facilitate compliance with future standards. EPA's approach to establishing the national-level affordability criteria did not incorporate a baseline for in-place treatment technology. Assuming that systems with high baseline water costs would need to install a new treatment technology to comply with a NPDWR may thus overestimate the actual costs for some systems.

To investigate this issue, during the derivation of the national-level affordability criteria, EPA examined a group of five small surface water systems with annual water bills above $500 per household per year. All of these systems had installed disinfection and filtration technologies to comply with the Surface Water Treatment Rule. If these systems were required to install treatment to comply with the revised arsenic standard, modification of the existing processes would be much more cost-effective than adding a new technology. As a result, because these systems have already made the investment in treatment technology, and the cost is incorporated into current annual household water bills, costs to the household may not increase substantially.

Installing new technologies may interfere with treatment in-place or require additional treatment to address side effects which will increase costs over the arsenic treatment technology base costs. (An example is corrosion control for lead and copper, which may need to be adjusted to accommodate other treatment). While EPA tries to account for such interference in its cost estimates for each new compliance technology, it is not possible to anticipate all the site specific issues which may arise.

EPA believes that there is another mechanism in the SDWA to address cost impacts on small systems composed primarily of low-income households. Systems that meet criteria established by the State could be classified disadvantaged communities under Section 1452(d) of the SDWA. They can receive additional subsidization under the Drinking Water State Revolving Fund (DWSRF) program, including forgiveness of principal. Under DWSRF, States must provide a minimum of 15% of the available funds for loans to small communities and have the option of providing up to 30% of the grant to provide additional loan subsidies to the disadvantaged systems, as defined by the State.

8.3 Coordination With Other Federal Rules

Several Federal drinking water rules are under development involving treatment requirements that may relate to the treatment of arsenic for this drinking water rule. Although it is very difficult to determine how compliance with the proposed Arsenic Rule might effect compliance with other drinking water regulations, the following briefly describes each rule, the impact the Arsenic Rule may have on that rule, and/or how each rule may impact the arsenic standard. The Arsenic Rule is expected to be promulgated in a similar time frame as the Ground Water Rule, the Radon Rule, and the Microbial and Disinfection By-Product Rule.

Ground Water Rule (GWR)

The goals of the GWR are to: (1) provide a consistent level of public health protection; (2) prevent waterborne microbial disease outbreaks; (3) reduce endemic waterborne disease; and (4) prevent fecal contamination from reaching consumers. To assure public health protection, EPA has the responsibility to develop a GWR which not only specifies the appropriate use of disinfection, but also addresses other components of ground water systems. This general provision is supplemented with an additional requirement that EPA develop regulations specifying the use of disinfectants for ground water systems as necessary. To meet these requirements, EPA is working with stakeholders to develop a GWR proposal by Fall 1999 and a final rule by Fall 2000.

The GWR will result in more systems using disinfection. If a system does add a disinfection technology, it may contribute to arsenic pre-oxidation. This largely depends on the type of disinfection technology employed. For example, if a system chooses a technology such as ultraviolet radiation, it may not affect arsenic pre-oxidation. However, if it chooses chlorination, it will contribute to arsenic pre-oxidation. Arsenic pre-oxidation from arsenic (III) to arsenic (V) will enhance the removal efficiencies of the technologies. Another option is that systems may use membrane filtration for the GWR. In that case, depending on the size of the membrane, some arsenic removal can be achieved. Thus, the GWR is expected to alleviate some of the burden of the Arsenic Rule.

Radon

Like the Ground Water Rule, the Radon Rule will also be finalized before the Arsenic Rule. In the 1996 Amendments to the SDWA, Congress [Section 1412(b)(13)] directed EPA to propose an MCLG and NPDWR for radon by August 1999 and finalize the regulation by August 2000 (§1412 (b)(13)). One option for compliance with the Radon Rule is that systems may employ aeration. Aeration alone, however, will not likely be sufficient to oxidize arsenic (III) to arsenic (V). However, if systems do aerate, they may be required by State regulations to also disinfect. The disinfection process may oxidize the arsenic, depending on the type of disinfection employed. In particular, ultraviolet disinfection may not assist in arsenic oxidation (still under investigation by US EPA), whereas chemical disinfection or oxidation is likely to. Thus, the Radon Rule is expected to alleviate some of the burden of the Arsenic Rule.

Microbial and Disinfection By-product Regulations

To control disinfection and disinfection byproducts and to strengthen control of microbial pathogens in drinking water, EPA is developing a group of interrelated regulations, as required by the SDWA. These regulations, referred to collectively as the Microbial Disinfection By-product (M/DBP) Rules, are intended to address risk trade-offs between the two different types of contaminants.

EPA proposed a Stage 1 Disinfectants/Disinfection By-products Rule (DBPR) and Interim Enhanced Surface Water Treatment Rule (IESWTR) in July 1994. EPA issued the final Stage 1 DBPR and IESWTR in November, 1998.

The Agency has finalized and is currently implementing a third rule, the Information Collection Rule, that will provide data to support development of subsequent M/DBP regulations. These subsequent rules include a Stage 2 DBPR and a companion Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).

Stage 1 DBPR and IESWTR will primarily affect large surface water systems, so EPA does not expect much overlap with small systems treating for arsenic. Stage 2 DBPR and possibly the LT2ESWTR, however, would have significance as far as arsenic removal is concerned. For systems removing DBP precursors, systems may use nanofiltration. The use of nanofiltration would also be relevant for removing arsenic, and as a result, would ease some burden when systems implement these later rules.

8.4 Minimization of Economic Burden

The proposed Arsenic Rule includes several provisions that will insure that the economic burden to water systems is minimized, while still ensuring that the public health objectives of the rule are met. First, the rule is developed around the concept of a performance target known as the maximum contaminant level (MCL). Rather than prescribe a single treatment technique that must be installed in all water systems, EPA is only requiring those systems that currently provide finished water with an arsenic concentration above the target to undertake or modify treatment. As seen above, this will exclude the vast majority of systems from having to undertake any additional treatment under this proposed rule. In addition, if a system does have to undertake or modify treatment, EPA is allowing systems to choose from a broad list of technologies, and is encouraging systems to choose the treatment technique that minimizes their total costs.

Second, EPA is allowing states to grant nine year monitoring waivers to those systems that have a history of arsenic monitoring results below the proposed MCL, and that do not show a substantial risk of future arsenic contamination. This provision of the rule will further reduce the cost to systems that currently provide finished water with low arsenic concentrations.

Finally, EPA is allowing small systems with finished water concentrations above the proposed MCL to install POU or POE technologies. This option will further allow small systems to minimize their total cost of compliance with the proposed rule.

8.5 Unfunded Mandates Reform Act

Title II of the Unfunded Mandates Reform Act of 1995 (UMRA), P.L. 104-4, establishes requirements for Federal agencies to assess the effects of their regulatory actions on State, local, and Tribal governments, and the private sector. Under UMRA Section 202, EPA generally must prepare a written statement, including a cost-benefit analysis, for proposed and final rules with "Federal mandates" that may result in expenditures to State, local, and Tribal governments, in the aggregate, or to the private sector, of $100 million or more in any one year.

Before promulgating an EPA rule for which a written statement is needed, Section 205 of the UMRA generally requires EPA to identify and consider a reasonable number of regulatory alternatives and adopt the least costly, most cost effective or least burdensome alternative that achieves the objectives of the rule. The provisions of Section 205 do not apply when they are inconsistent with applicable law. Moreover, Section 205 allows EPA to adopt an alternative other than the least costly, most cost effective or least burdensome alternative if the Administrator publishes an explanation why the more “costly” alternative was preferred for the final rule.

Prior to establishing any regulatory requirements that may significantly or uniquely affect small governments, including Tribal governments, EPA must develop a small government agency plan under Section 203 of the UMRA . The plan must provide for notifying potentially affected small governments, enabling officials of affected small governments to have meaningful and timely input in the development of EPA regulatory proposals with significant Federal intergovernmental mandates, and informing, educating and advising small governments on compliance with the regulatory requirements.

EPA has determined that this rule contains a Federal mandate that may result in expenditures of $100 million or more for State, local, and Tribal governments, in the aggregate and the private sector in any one year. Accordingly, under Section 202 of the UMRA, EPA is obligated to prepare a written statement addressing:

1. The authorizing legislation;

2. Cost-benefit analysis including an analysis of the extent to which the costs of State, local and Tribal governments will be paid for by the Federal government;

3. Estimates of future compliance costs and disproportionate budgetary effects;

4. Macro-economic effects;

5. A summary of EPA’s consultation with State, local, and Tribal governments and their concerns, including a summary of the Agency’s evaluation of those comments and concerns; and

6. Identification and consideration of regulatory alternatives and the selection of the least costly, most cost-effective or least burdensome alternative that achieves the objectives of the rule.

The legislative authority for the arsenic rule is discussed in Chapter 2. Items two through five are addressed below, with the exception of future compliance costs, which are discussed in Chapter 6. Regulatory alternatives, the last item, are addressed in Chapters 3, 6 and 7.

8.5.1 Social Costs and Benefits

Chapters Five, Six and Seven contain a detailed cost-benefit analysis in support of the Arsenic Rule. At a 7 percent discount rate, the proposed rule is expected to have a total annualized cost of $645 million for a MCL of 3 µg/L, $445 million for a MCL 5 µg/L, $195 million for a MCL of 10 µg/L, and $63.9 million for a MCL of 20 µg/L.

EPA estimates the proposed arsenic rule will have total health benefits as a result of avoided bladder cancer cases of approximately $43.6 to $104.2 million if the MCL were set at 3 µg/L, $31.7 to $89.9 million if the MCL were to be set at 5 µg/L, $17.9 to $52.1 million if the MCL were set at 10 µg/L, and $7.9 to $29.8 million if the MCL were set at 20 µg/L. These monetized health benefits of reducing arsenic exposures in drinking water are attributable to the reduced incidence of fatal and non-fatal bladder cancer. Currently under baseline assumptions (no control of arsenic exposure), there are annual fatal cancers and non-fatal cancers associated with arsenic exposures through CWSs. At an arsenic MCL level of 3 µg/L, an estimated 6 to 14 fatal cancers and 16 to 39 non-fatal cancers per year are prevented; at a arsenic level of 5 µg/L, an estimated 4 to 12 fatal cancers and 12 to 33 non-fatal cancers per year are prevented; at 10 µg/L, 2 to 7 fatal and 7 to 19 non-fatal cancers per year are prevented; and at 20 µg/L, 1 to 4 fatal and 3 to 11 non-fatal cancers per year are prevented.

EPA estimates that should avoided lung cancer cases be monetized as well, the potential benefits from reducing lung cancer cases would range from $47.2 to $448.0 million at an MCL of 3 µg/L, $35.0 to $384.0 million at an MCL of 5 µg/L, $19.6 to $224.0 million at an MCL of 10 µg/L, and $8.8 to $128.0 million at an MCL of 20 µg/L. EPA estimates that the potential number of lung cancer cases avoided ranges from 8 to 80 at an MCL of 3 µg/L, from 6 to 68 at an MCL of 5 µg/L, from 3 to 40 at an MCL of 10 µg/L, and from 2 to 23 at an MCL of 20 µg/L. A more detailed discussion of the lung cancer risk and benefits calculation may be found in Chapter 5, "Benefits Analysis."

In addition to quantifiable benefits, in Chapter 5, EPA has identified many potential non-quantifiable benefits associated with reducing arsenic exposures in drinking water. These potential benefits are not able to be quantified at this time, but may include reduced risk skin cancer, and numerous non-cancerous health effects. In addition, certain non-health related benefits may exists, such as ecological improvements and an increase in consumers' perception of drinking water.

8.5.2 State Administrative Costs

States will incur a range of administrative costs in complying with the arsenic rule. Administrative costs can include program management, inspections, and enforcement activities. EPA estimates the total annual costs of State administrative activities for compliance with the MCL at a 7 percent discount rate are approximately $5.5 million for an MCL of 3 µg/L, $5.0 million for an MCL of 5 µg/L, $4.6 million at an MCL of 10µg/L, and $4.4 million for an MCL of 20µg/L.

Various Federal programs exist to provide financial assistance to State, local, and Tribal governments in complying with this rule. The Federal government provides funding to States that have a primary enforcement responsibility for their drinking water programs through the Public Water Systems Supervision (PWSS) Grants program. Additional funding is available from other programs administered either by EPA or other Federal agencies. These include the Drinking Water State Revolving Fund (DWSRF) and Housing and Urban Development's Community Development Block Grant Program. For example, the SDWA authorizes the Administrator of the EPA to award capitalization grants to States, which in turn can provide low cost loans and other types of assistance to eligible public water systems. The DWSRF also assists public water systems with financing the costs of infrastructure needed to achieve or maintain compliance with SDWA requirements. Each State will have considerable flexibility to determine the design of its program and to direct funding toward its most pressing compliance and public health protection needs. States may also, on a matching basis, use up to ten percent of their DWSRF allotments for each fiscal year to assist in running the State drinking water program.

Under PWSS Program Assistance Grants, the Administrator may make grants to States to carry out public water system supervision programs. One State use of these funds is to develop primacy programs. States may "contract" with other State agencies to assist in the development or implementation of their primacy program. However, States may not use program assistance grant funds to contract with regulated entities (i.e., water systems). PWSS Grants may be used by States to set-up and administer a State program which includes such activities as: public education, testing, training, technical assistance, developing and administering a remediation grant and loan or incentive program (excludes the actual grant or loan funds), or other regulatory or non-regulatory measures.

8.5.3 Future Compliance Costs and Disproportionate Budgetary Effects

To meet the requirement in Section 202 of the UMRA, EPA analyzed future compliance costs and possible disproportionate budgetary effects of the MCL options. The Agency believes that the cost estimates, shown in Exhibit 8-7 and discussed in more detail in Chapter Six, accurately characterize future compliance costs of the proposed rule.

With regard to the disproportionate impacts, EPA considered available data sources in analyzing the disproportionate impacts upon geographic or social segments of the nation or industry. No rationale for disproportionate impacts based on geographic area were identified. To the extent that there may be disproportionate impacts to low-income or other segments of the population, EPA will prepare a small entity compliance guide, a monitoring/analytical manual, and a small systems technology manual that will assist the public and private sector. To fully consider the potential disproportionate impacts of this proposed rule, this analysis also developed three other measures:

(1) reviewing the impacts on small versus large systems;
(2) reviewing the costs to public versus private water systems; and
(3) reviewing the household costs for the proposed rule.

The first measure, the national impacts on small versus large systems, is shown in Exhibit 8-29. Small systems are defined as those systems serving 10,000 people or less and large systems are those systems that serve more than 10,000 people.

The second measure of disproportionate impacts evaluated is the relative total costs to public versus private water systems, by size. Exhibit 8-29 also presents the annual system level costs for public and private systems by system size category for 3 µg/L, 5 µg/L, 10 µg/L, and 20 µg/L. The costs are comparable for public and private systems across system sizes for all options. For example, for systems serving less than 100 people at the 5 µg/L MCL public system treatment costs are $9 thousand and private system treatment costs are $7 thousand. This pattern may be due in large part to the limited number of treatment options, resulting in similar treatment choices by both public or private systems.

Exhibit 8-29
Average Annual Cost per CWS by Ownership

System Size	Treatment and Monitoring Costs		Total Cost
	Public	Private	All Systems
MCL = 3 μg/L			
<100	$ 9,475	$ 7,354	$ 7,559
101-500	$ 25,228	$ 18,570	$ 20,588
501-1,000	$ 34,688	$ 31,646	$ 33,474
1,001-3,300	$ 60,929	$ 51,097	$ 58,189
3,301-10,000	$ 135,573	$ 111,396	$ 131,197
10,001-1,000,000	$ 578,591	$ 547,969	$ 573,423
1,000,000 +	$ 3,885,713	--	$ 3,885,713
MCL = 5 μg/L			
<100	$ 9,720	$ 7,212	$ 7,450
101-500	$ 24,560	$ 18,223	$ 20,198
501-1,000	$ 34,124	$ 30,697	$ 32,778
1,001-3,300	$ 57,277	$ 48,198	$ 54,666
3,301-10,000	$ 124,552	$ 102,005	$ 120,399
10,001-1,000,000	$ 518,647	$ 459,930	$ 508,640
1,000,000 +	$ 2,669,474	--	$ 2,669,474
MCL = 10 μg/L			
<100	$ 9,453	$ 7,135	$ 7,350
101-500	$ 23,584	$ 17,675	$ 19,551
501-1,000	$ 32,271	$ 29,160	$ 31,048
1,001-3,300	$ 53,357	$ 44,785	$ 50,921
3,301-10,000	$ 113,338	$ 91,244	$ 109,278
10,001-1,000,000	$ 458,340	$ 415,520	$ 450,835
1,000,000 +	$ 1,395,498	--	$ 1,395,498
MCL = 20 μg/L			
<100	$ 9,121	$ 6,950	$ 7,157
101-500	$ 22,778	$ 16,954	$ 18,738
501-1,000	$ 30,493	$ 27,668	$ 29,376
1,001-3,300	$ 48,399	$ 41,625	$ 46,501
3,301-10,000	$ 99,872	$ 79,128	$ 95,983
10,001-1,000,000	$ 394,742	$ 334,737	$ 384,868
1,000,000 +	$ 921,121	--	$ 921,121

*Costs were calculated at a commercial interest rate and include system treatment, monitoring, and administrative costs; note that systems serving over 1 million people are public surface water systems.

The third measure, household costs, can also be used to gauge the impact of a regulation and to determine whether there are disproportionately higher impacts in particular segments of the population. A detailed analysis of household cost impacts by system size is presented in Chapter 6. The costs for households served by public and private water systems are presented in Exhibit 8-30. As expected, cost per household increases as system size decreases. Cost per household is higher for households served by smaller systems than larger systems for two reasons. First, smaller systems produce less water than large systems and are therefore unable to utilize economies of scale. Consequently, each household must bear a greater percentage share of the system's costs.

Table 8-30 presents the costs per household for systems exceeding the MCL. For each size category there is a moderate difference in annual cost per household for 3 µg/L, 5 µg/L, 10 µg/L and 20 µg/L across source and ownership. In general, costs per household are higher for private systems than for public systems. This difference could be attributable to a discrepancy in the cost of capital for public versus private entities. For public systems, the cost per household ranges from approximately $25 to $342 per year at 5 µg/L and from approximately $22 to $329 per year at 10 µg/L (excluding systems serving greater than 1 million people). For private systems, the ranges are $22 to $369 per year, and $19 to $363 per year, respectively. The range of costs for 3 µg/L and 20 µg/L is similar.

To further evaluate the impacts of these household costs, the average costs per household were compared to median household income data for each system-size category. The result of this calculation, presented in Exhibit 8-31 for public and private systems, indicate a household's likely share of incremental costs in terms of its household income. For all system sizes and MCLs average household costs as a percentage of median household income are less than one percent.

Exhibit 8-30
Annual Compliance Costs per Household for CWSs Exceeding MCLs

System Size	Groundwater		Surface Water	
	Public	Private	Public	Private
MCL = 3 μg/L				
<100	$ 338.44	$ 374.86	$ 328.94	$ 335.61
101-500	$ 218.59	$ 285.61	$ 135.98	$ 183.96
501-1,000	$ 108.63	$ 112.60	$ 45.44	$ 46.72
1,001-3,300	$ 62.17	$ 83.24	$ 21.13	$ 27.91
3,301-10,000	$ 44.67	$ 62.96	$ 18.34	$ 22.94
10,001-1,000,000	$ 31.29	$ 31.29	$ 26.49	$ 22.81
1,000,000 +	--	--	$ 2.70	--
MCL = 5 μg/L				
<100	$ 341.78	$ 369.21	$ 323.48	$ 330.05
101-500	$ 213.11	$ 280.76	$ 135.22	$ 182.65
501-1,000	$ 106.00	$ 108.40	$ 44.86	$ 46.35
1,001-3,300	$ 58.31	$ 77.54	$ 20.07	$ 26.57
3,301-10,000	$ 40.60	$ 57.25	$ 16.89	$ 21.54
10,001-1,000,000	$ 28.12	$ 28.63	$ 24.73	$ 21.91
1,000,000 +	--	--	$ 1.73	--
MCL = 10 μg/L				
<100	$ 329.17	$ 363.09	$ 317.80	$ 325.64
101-500	$ 203.40	$ 273.04	$ 132.74	$ 180.88
501-1,000	$ 99.45	$ 102.19	$ 42.98	$ 44.48
1,001-3,300	$ 53.70	$ 71.97	$ 18.62	$ 25.49
3,301-10,000	$ 36.30	$ 50.41	$ 14.68	$ 18.55
10,001-1,000,000	$ 24.09	$ 24.47	$ 22.03	$ 19.06
1,000,000 +	--	--	$ 0.89	--
MCL = 20 μg/L				
<100	$ 320.13	$ 352.42	$ 310.11	$ 324.84
101-500	$ 195.99	$ 262.01	$ 132.68	$ 179.93
501-1,000	$ 93.27	$ 96.63	$ 42.26	$ 44.04
1,001-3,300	$ 48.03	$ 66.12	$ 18.20	$ 24.87
3,301-10,000	$ 31.38	$ 44.14	$ 13.35	$ 17.53
10,001-1,000,000	$ 20.27	$ 20.39	$ 19.96	$ -
1,000,000 +	--	--	$ 0.55	--

*Costs to households were calculated at a commercial interest rate and include system treatment, monitoring, and administrative costs; note that systems serving over 1 million people are public surface water systems.

Exhibit 8-31
Annual Compliance Costs per Household for CWSs Exceeding MCLs, as a Percent of Median Household Income

System Size	Groundwater		Surface Water	
	Public	Private	Public	Private
MCL = 3 μg/L				
<100	0.85%	0.95%	0.83%	0.85%
101-500	0.55%	0.72%	0.34%	0.46%
501-1,000	0.27%	0.28%	0.11%	0.12%
1,001-3,300	0.16%	0.21%	0.05%	0.07%
3,301-10,000	0.11%	0.16%	0.05%	0.06%
10,001-1,000,000	0.08%	0.08%	0.07%	0.06%
1,000,000 +	--	--	0.01%	--
MCL = 5 μg/L				
<100	0.86%	0.93%	0.82%	0.83%
101-500	0.54%	0.71%	0.34%	0.46%
501-1,000	0.27%	0.27%	0.11%	0.12%
1,001-3,300	0.15%	0.20%	0.05%	0.07%
3,301-10,000	0.10%	0.14%	0.04%	0.05%
10,001-1,000,000	0.07%	0.07%	0.06%	0.06%
1,000,000 +	--	--	0.00%	--
MCL = 10 μg/L				
<100	0.83%	0.92%	0.80%	0.82%
101-500	0.51%	0.69%	0.33%	0.46%
501-1,000	0.25%	0.26%	0.11%	0.11%
1,001-3,300	0.14%	0.18%	0.05%	0.06%
3,301-10,000	0.09%	0.13%	0.04%	0.05%
10,001-1,000,000	0.06%	0.06%	0.06%	0.05%
1,000,000 +	--	--	0.00%	--
MCL = 20 μg/L				
<100	0.81%	0.89%	0.78%	0.82%
101-500	0.49%	0.66%	0.33%	0.45%
501-1,000	0.24%	0.24%	0.11%	0.11%
1,001-3,300	0.12%	0.17%	0.05%	0.06%
3,301-10,000	0.08%	0.11%	0.03%	0.04%
10,001-1,000,000	0.05%	0.05%	0.05%	0.00%
1,000,000 +	--	--	0.00%	--

*Costs to household were calculated at a commercial interest rate and include system treatment, monitoring, and administrative costs; median household income in May 1999 was $39,648 updated from the 1998 annual median household income from the Census

8.5.4 Macroeconomic Effects

As required under UMRA Section 202, EPA is required to estimate the potential macro-economic effects of the regulation. These include effects on productivity, economic growth, full employment, creation of productive jobs, and international competitiveness. Macro-economic effects tend to be measurable in nationwide econometric models only if the economic impact of the regulation reaches 0.25 percent to 0.5 percent of Gross Domestic Product (GDP). In 1998, real GDP was $7,552 billion so a rule would have to cost at least $18 billion annually to have a measurable effect. A regulation with a smaller aggregate effect is unlikely to have any measurable impact unless it is highly focused on a particular geographic region or economic sector. The macro-economic effects on the national economy from the arsenic rule should be negligible based on the fact that, assuming 100 percent compliance with an MCL, the total annual costs are approximately $750 million at the 3 µg/L level, $440 million at the 5 µg/L level, $190 million at the 10 µg/L level, and $73 million at the 20 µg/L level (at a 7 percent discount rate). In addition, the costs are not expected to be highly focused on a particular geographic region or industry sector.

8.5.5 Consultation with State, Local, and Tribal Government

Under UMRA section 204, EPA is to provide a summary of its consultation with elected representatives (or their designated authorized employees) of affected State, local, and Tribal governments in this rulemaking. EPA initiated consultations with governmental entities and the private sector affected by this rulemaking through various means. This included five stakeholder meetings announced in the *Federal Register* and open to any one interested in attending in person or by phone, and presentations at meetings of the American Water Works Association (AWWA), the Association of State Drinking Water Administrators (ASDWA), the Association of California Water Agencies (ACWA), and the Association of Metropolitan Water Agencies (AMWA). Participants in EPA's stakeholder meetings also included representatives from the National Rural Water Association, AMWA, ASDWA, AWWA, ACWA, Rural Community Assistance Program, State departments of environmental protection, State health departments, State drinking water programs, and a Tribe. EPA also made presentations at Tribal meetings in Nevada, Alaska, and California.

To address the proposed rule's impact on small entities, the Agency consulted with representatives of small water systems and convened a Small Business Advocacy Review Panel in accordance with the Regulatory Flexibility Act (RFA) as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA). Two of the small entity representatives were elected officials from local governments. EPA also invited State drinking water program representatives to participate in a number of workgroup meetings. In addition to these consultations, EPA participated in and gave presentations at AWWA's Technical Workgroup for Arsenic. State public health department and drinking water program representatives, drinking water districts, and ASDWA participated in the Technical Workgroup meetings. A summary of State, local, and Tribal government concerns on this proposed rulemaking is shown in the next section.

In order to inform and involve Tribal governments in the rulemaking process, EPA staff attended the 16th Annual Consumer Conference of the National Indian Health Board on October 6-8, 1998 in Anchorage, Alaska. Over nine hundred attendees representing Tribes from across the country were in attendance. During the conference, EPA conducted two workshops for meeting participants. The objectives of the workshops were to present an overview of EPA's drinking water program, solicit comments on key issues of potential interest in upcoming drinking water regulations, and to solicit advice in identifying an effective consultative process with Tribes for the future.

EPA, in conjunction with the Inter Tribal Council of Arizona (ITCA), also convened a Tribal consultation meeting on February 24-25, 1999, in Las Vegas, Nevada to discuss ways to involve Tribal representatives, both Tribal council members and tribal water utility operators, in the stakeholder process. Approximately twenty-five representatives from a diverse group of Tribes attended the two-day meeting. Meeting participants included representatives from the following Tribes: Cherokee Nation, Nezperce Tribe, Jicarilla Apache Tribe, Blackfeet Tribe, Seminole Tribe of Florida, Hopi Tribe, Cheyenne River Sioux Tribe, Menominee Indian Tribe, Tulalip Tribes, Mississippi Band of Choctaw Indians, Narragansett Indian Tribe, and Yakama Nation.

The major meeting objectives were to:

(1) identify key issues of concern to Tribal representatives;
(2) solicit input on issues concerning current OGWDW regulatory efforts;
(3) solicit input and information that should be included in support of future drinking water regulations; and
(4) provide an effective format for Tribal involvement in EPA's regulatory development process.

EPA staff also provided an overview on the forthcoming arsenic rule at the meeting. The presentation included the health concerns associated with arsenic, EPA's current position on arsenic in drinking water, the definition of an MCL, an explanation of the difference between point-of-use and point-of-entry treatment devices, and specific issues for Tribes. The following questions were posed to the Tribal representatives to begin discussion on arsenic in drinking water:

(1) What are the current arsenic levels in your water systems?
(2) What are Tribal water systems affordability issues in regard to arsenic?
(3) Does your Tribe use well water, river water or lake water?
(4) Does your Tribe purchase water from another drinking water utility?

The summary for the February 24-25, 1999 meeting was sent to all 565 Federally recognized Tribes in the United States.

EPA also conducted a series of workshops at the Annual Conference of the National Tribal Environmental Council which was held on May 18-20, 1999 in Eureka, California. Representatives from over 50 Tribes attended all, or part, of these sessions. The objectives of the workshops were to provide an overview of forthcoming EPA regulations affecting water systems; discuss changes to operator certification requirements; discuss funding for Tribal water systems;

and to discuss innovative approaches to regulatory cost reduction. Meeting summaries for EPA's Tribal consultations are available in the public docket for this proposed rulemaking.

8.5.6 State, Local, and Tribal Government Concerns

State and local governments raised several concerns, including the high costs of the rule to small systems; the burden of revising the State primacy program; the high degree of uncertainty associated with the benefits; and the high costs of including Non-Transient Non-Community Water Systems (NTNCWSs). EPA modified the revision of State primacy in order to decrease the burden of the new arsenic regulation in response to State concerns, to minimize paperwork and documentation of existing programs that would manage the arsenic regulation.

Tribal representatives were generally supportive of regulations which would ensure a high level of water quality, but raised concerns over funding for regulations. With regard to the forthcoming proposed arsenic rule, many Tribal representatives saw the health benefits as highly desirable, but felt that unless additional funds were made available, implementing the regulation would be difficult for many Tribes.

EPA understands the State, local, and Tribal government concerns with the above issues. The Agency believes the options for small systems, proposed for public comment in this rulemaking, will address stakeholder concerns pertaining to small systems and will help to reduce the financial burden to these systems.

8.5.7 Regulatory Alternatives Considered

As required under Section 205 of the UMRA, EPA considered several regulatory alternatives in developing an MCL for arsenic in drinking water. In preparation for this consideration, this Regulatory Impact Analysis evaluated arsenic levels of 3 µg/L, 5 µg/L, 10 µg/L, and 20 µg/L. Also evaluated were two scenarios for NTNCWSs: NTNCWSs treat and monitor, NTNCWSs only monitor and do not treat.

This analysis also evaluated national costs and benefits of States choosing to reduce arsenic exposure in drinking water. EPA believes that the regulatory approaches proposed for arsenic in today's notice are the most cost-effective options that achieve the objectives of the rule and provide the highest degree of public health protection.

8.5.8 Impacts on Small Governments

In developing this rule, EPA consulted with small governments pursuant to section 203 of the UMRA to address impacts of regulatory requirements in the rule that might significantly or uniquely affect small governments. In preparation for the proposed Arsenic Rule, EPA conducted analysis on small government impacts and included small government officials or their designated representatives in the rule making process. EPA conducted stakeholder meetings on the development of the arsenic rule which gave a variety of stakeholders, including small governments, the opportunity for timely and meaningful participation in the regulatory development process. Groups such as the National Association of Towns and Townships, the

National League of Cities, and the National Association of Counties participated in the proposed rulemaking process. Through such participation and exchange, EPA notified potentially affected small governments of requirements under consideration and provided officials of affected small governments with an opportunity to have meaningful and timely input into the development of the regulatory proposal.

In addition, EPA will educate, inform, and advise small systems, including those run by small governments, about the arsenic rule requirements. One of the most important components of this process is the Small Entity Compliance Guide, required by the Small Business Regulatory Enforcement Fairness Act of 1996 after the rule is promulgated. This plain-English guide will explain what actions a small entity must take to comply with the rule. Also, the Agency is developing fact sheets that concisely describe various aspects and requirements of the Arsenic Rule.

8.6 Effect of Compliance With the Arsenic Rule on the Technical, Financial, and Managerial Capacity of Public Water Systems

Section 1420(d)(3) of the SDWA as amended requires that, in promulgating a NPDWR, the Administrator shall include an analysis of the likely effect of compliance with the regulation on the technical, financial, and managerial capacity of public water systems. The following analysis has been performed to fulfill this statutory obligation.

Overall water system capacity is defined in EPA guidance (EPA 816-R-98-006) (EPA 1998) as the ability to plan for, achieve, and maintain compliance with applicable drinking water standards. Capacity has three components: technical, managerial, and financial.

Technical capacity is the physical and operational ability of a water system to meet SDWA requirements. Technical capacity refers to the physical infrastructure of the water system, including the adequacy of source water and the adequacy of treatment, storage, and distribution infrastructure. It also refers to the ability of system personnel to adequately operate and maintain the system and to otherwise implement requisite technical knowledge. A water system's technical capacity can be determined by examining key issues and questions, including:

- Source water adequacy. Does the system have a reliable source of drinking water? Is the source of generally good quality and adequately protected?

- Infrastructure adequacy. Can the system provide water that meets SDWA standards? What is the condition of its infrastructure, including well(s) or source water intakes, treatment, storage, and distribution? What is the infrastructure's life expectancy? Does the system have a capital improvement plan?

- Technical knowledge and implementation. Is the system's operator certified? Does the operator have sufficient technical knowledge of applicable standards? Can the operator effectively implement this technical knowledge? Does the operator understand the system's technical and operational characteristics? Does the system have an effective operation and maintenance program?

Managerial capacity is the ability of a water system to conduct its affairs in a manner enabling the system to achieve and maintain compliance with SDWA requirements. Managerial capacity refers to the system's institutional and administrative capabilities. Managerial capacity can be assessed through key issues and questions, including:

- Ownership accountability. Are the system owner(s) clearly identified? Can they be held accountable for the system?

- Staffing and organization. Are the system operator(s) and manager(s) clearly identified? Is the system properly organized and staffed? Do personnel understand the management aspects of regulatory requirements and system operations? Do they have adequate expertise to manage water system operations? Do personnel have the necessary licenses and certifications?

- Effective external linkages. Does the system interact well with customers, regulators, and other entities? Is the system aware of available external resources, such as technical and financial assistance?

Financial capacity is a water system's ability to acquire and manage sufficient financial resources to allow the system to achieve and maintain compliance with SDWA requirements. Financial capacity can be assessed through key issues and questions, including:

- Revenue sufficiency. Do revenues cover costs? Are water rates and charges adequate to cover the cost of water?

- Credit worthiness. Is the system financially healthy? Does it have access to capital through public or private sources?

- Fiscal management and controls. Are adequate books and records maintained? Are appropriate budgeting, accounting, and financial planning methods used? Does the system manage its revenues effectively?

Generally, water systems are not expected to require significantly increased technical, financial, or managerial capacity to comply with these new requirements.

8.7 Paperwork Reduction Act

The information collected as a result of this rule will allow the States and EPA to evaluate PWS compliance with the rule. For the first three years after promulgation of this rule, the major information requirements pertain to monitoring, and compliance reporting. Responses to the request for information are mandatory (Part 141). The information collected is not confidential.

EPA is required to estimate the burden on PWS for complying with the final rule. Burden means the total time, effort, or financial resources expended by persons to generate, maintain, retain, or disclose or provide information to or for a Federal agency. This includes the time needed to review instructions; develop, acquire, install, and utilize technology and systems for the purposes of collecting, validating, and verifying information, processing and maintaining information, and disclosing and providing information; adjust the existing ways to comply with any previously applicable instructions and requirements; train personnel to be able to respond to a collection of information; search data sources; complete and review the collection of information; and transmit or otherwise disclose the information. The Information Collection Rule for the Proposed Arsenic Rule estimated a total burden of 3.33 million hours for 3 µg/L, 3.23 million hours for 5 µg/L, 3.15 million hours for 10 µg/L, and 3.11 for 20 µg/L.

8.8 Protecting Children From Environmental Health Risks and Safety Risks

Executive Order (EO) 13045 (62 *FR* 19885, April 23, 1997) applies to any rule initiated after April 21, 1997, or proposed after April 21, 1998, that (1) is determined to be "economically significant" as defined under E.O. 12866 and (2) concerns an environmental health or safety risk that EPA has reason to believe may have a disproportionate effect on children. If the regulatory action meets both criteria, EPA must evaluate the environmental health or safety effects of the planned rule on children, and explain why the planned regulation is preferable to other potentially effective and reasonably feasible alternatives considered by EPA.

As described in Chapter 5 ("Benefits Analysis"), there is insufficient toxicological data to distinguish morbidity and mortality differences by age groups. No studies were located by ATSDR (1998) that focused exclusively on evaluating unusual susceptibility to arsenic. However, some members of the population are likely to be especially susceptible. For example, Chapter 5 describes several non-carcinogenic effects that may be of greater concern to children than adults, such as cardiovascular or reproductive effects. Similarly, arsenic has been suggested to pose significant problems in fetal development. This increased susceptibility may be due to a variety of factors. These factors include increased dose (intake per unit of body weight) in children, genetic predispositions, and dietary insufficiency (ATSDR, 1998), as well as pre-existing health conditions.

Because children have increased fluid and food intake in relation to their body weight (NAS, 1995), their dose (milligrams per kilogram of body weight per day - mg/kg/day) of arsenic will be, on average, greater than that of adults. For example, an intake of 1.2 liters per day in a 70 kg adult yields an overall water intake of 0.017 liters per kg of body weight. An infant who consumes 1 liter per day and weighs 10 kg is consuming 0.1 liter per kg of body weight, which is more than 5 times the water intake per kg of an adult. Any contaminant which is present in the water will be delivered at a correspondingly higher level, on a daily basis. Foy et al. noted that in studies of chronic exposure, children appear to be more severely affected, probably due to a higher exposure per body weight (1992 citation, reported in ATSDR, 1998). ATSDR (1998) identified a need for additional data on the exposure of children in their arsenic analysis.

8.9 Environmental Justice

Executive Order 12898 establishes a Federal policy for incorporating environmental justice into Federal agency missions by directing agencies to identify and address disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority and low-income populations. The Executive Order requires the Agency to consider environmental justice issues in the rulemaking and to consult with Environmental Justice (EJ) stakeholders.

The Agency has considered environmental justice related issues concerning the potential impacts of this regulation and has determined that there are no substantial disproportionate effects. Because the arsenic rule applies to all community water systems, the majority of the population, including minority and low-income populations will benefit from the additional health protection.

8.10 Health Risk Reduction and Cost Analysis

Section 1412(b)(3)(C) of the 1996 Amendments requires EPA to prepare a Health Risk Reduction and Cost Analysis (HRRCA) in support of any NPDWR that includes an MCL. According to these requirements, EPA must analyze each of the following when proposing a NPDWR that includes an MCL:

1. quantifiable and non-quantifiable health risk reduction benefits for which there is a factual basis in the rulemaking record to conclude that such benefits are likely to occur as the result of treatment to comply with each level;

2. quantifiable and non-quantifiable health risk reduction benefits for which there is a factual basis in the rulemaking record to conclude that such benefits are likely to occur from reductions in co-occurring contaminants that may be attributed solely to compliance with the MCL, excluding benefits resulting from compliance with other proposed or promulgated regulations;

3. quantifiable and non-quantifiable costs for which there is a factual basis in the rulemaking record to conclude that such costs are likely to occur solely as a result of compliance with the MCL, including monitoring, treatment, and other costs, and excluding costs resulting from compliance with other proposed or promulgated regulations;

4. the incremental costs and benefits associated with each alternative MCL considered;

5. the effects of the contaminant on the general population and on groups within the general population, such as infants, children, pregnant women, the elderly, individuals with a history of serious illness, or other sub-populations that are identified as likely to be at greater risk of adverse health effects due to exposure to contaminants in drinking water than the general population;

6. any increased health risk that may occur as the result of compliance, including risks associated with co-occurring contaminants; and

7. other relevant factors, including the quality and extent of the information, the uncertainties in the analysis, and factors with respect to the degree and nature of the risk.

This analysis summarizes EPA’s estimates of the costs and benefits associated with various arsenic levels. The summary tables below characterize aggregate costs and benefits, impacts on affected entities, and tradeoffs between risk reduction and compliance costs. This analysis also summarizes the effects of arsenic on the general population as well as any sensitive sub-populations and provides a discussion on the uncertainties in the analysis.

8.10.1 Quantifiable and Non-Quantifiable Health Risk Reduction Benefits

Arsenic ingestion has been linked to a multitude of health effects, both cancerous and non-cancerous. These health effects include cancer of the bladder, lungs, skin, kidney, nasal passages, liver, and prostate. Arsenic ingestion has also been attributed to cardiovascular, pulmonary, immunological, neurological, endocrine, and reproductive and developmental effects. A complete list of the arsenic related health effects reported in humans is shown in Chapter 5. Of all the health effects noted above, current research on arsenic exposure has only been able to define scientifically defensible risks for bladder cancer. That is, EPA has adequate data to perform a risk assessment on bladder cancer. Because there is currently a lack of strong evidence on the risks of other arsenic-related health effects, the Agency has based its assessment of the quantifiable health risk reduction benefits on the risks of arsenic induced bladder cancers. Avoided cases of lung cancer presented in Exhibit 8-34 were estimated based on a comparison of lung cancer incidence to bladder cancer indicidence.

The quantifiable health benefits of reducing arsenic exposures in drinking water are attributable to the reduced number of fatal and non-fatal bladder cancers. Exhibit 8-32 shows a range of mean bladder cancer risks for exposed populations at or above arsenic levels of 3, 5, 10, and 20 µg/L in CWSs. Exhibit 8-33 shows the corresponding health risk reductions (number of total bladder cancers avoided and the proportions of fatal and non-fatal bladder cancers avoided) at 3, 5, 10, and 20 µg/L. These ranges of total, fatal, and non-fatal bladder cancer cases are based on the range of risks shown in Exhibit 8-32.

Exhibit 8-32
Mean Bladder Cancer Risks, Exposed Population,
and Annual Cancer Cases Avoided in CWSs[1]

Arsenic Level (µg/L)	Mean Exposed Population Risk	Population Exposed	Total Bladder Cancer Cases Avoided per Year
3	$2.1 - 4.5 \times 10^{-5}$	34,599,915	22 - 52
5	$3.6 - 7.5 \times 10^{-5}$	21,347,435	16 - 45
10	$5.5 - 11.4 \times 10^{-5}$	8,530,370	9 - 26
20	$6.9 - 13.9 \times 10^{-5}$	3,579,085	4 - 15

[1]The bladder cancer risks presented in this table provide our “best” estimates at this time. Actual risks could be lower, given the various uncertainties discussed, or higher, as these estimates assume that the probability of illness from arsenic exposure in the U.S. is equal to the probability of death from arsenic exposure among the Taiwanese study group.

Exhibit 8-33
Annual Bladder Cancer Cases Avoided from Reducing Arsenic in CWSs[1]

Arsenic Level (µg/L)	Total Bladder Cancer Cases Avoided	Reduced Mortality Cases*	Reduced Morbidity Cases*
3	22 - 52	6 - 14	16 - 39
5	16 - 45	4 - 12	12 - 33
10	9 - 26	2 - 7	7 - 19
20	4 - 15	1 - 4	3 - 11

* The lower-end estimate of bladder cancer cases avoided is calculated using the lower-end risk estimate (see Exhibit 5-9) and assumes that the conditional probability of mortality among the Taiwanese study group was 100 percent. The upper-end estimate of bladder cancer cases avoided is calculated using the upper-end risk estimate (see Exhibit 5-9) and assumes that the conditional probability of mortality among the Taiwanese study group was 80 percent.
**Assuming 20-year mortality rate in the U.S. of 26 percent.

Health benefit estimates for lung cancer were also quantified based on the "what if?" scenario, where the risks of a fatal lung cancer case associated with arsenic are assumed to be 2-5 times that of a fatal bladder cancer case. More detail on lung cancer health benefits is provided in Chapter 5, "Benefits Analysis." Exhibit 8-34 shows the resulting annual lung cancer cases avoided as a result of the "what if?" scenario analysis.

Exhibit 8-34
Potential Annual Lung Cancer Cases Avoided from Reducing Arsenic in CWSs

Arsenic Level (µg/L)	Total Lung Cancer Cases Avoided	Reduced Mortality Cases*	Reduced Morbidity Cases*
3	8 - 80	7 - 70	1 - 10
5	6 - 68	5 - 60	1 - 8
10	3 - 40	3 - 35	0 - 5
20	2 - 23	1 - 20	0 - 3

The Agency has developed monetized estimates of the health benefits associated with the risk reductions from arsenic exposures. The approach used in this analysis for the measurement of health risk reduction benefits is the monetary value of a statistical life (VSL) applied to each fatal cancer avoided. For non-fatal cancers, willingness to pay (WTP) data to avoid chronic bronchitis is used as a surrogate to estimate the WTP to avoid non-fatal bladder cancers. A WTP central tendency estimate of $607,162 (May 1999$) is used to monetize the benefits of avoiding non-fatal cancers (this value was updated from the $536,000 value EPA updated to 1997$ from the Viscusi et al. 1991 study). The bladder cancer, lung cancer, and non-quantifiable health benefits are summarized in Exhibit 8-35. Total annual health benefits resulting from bladder cancer cases avoided range from $43.6 to $104.2 million at an MCL of 3 µg/L, $31.7 to $89.9 million at an MCL of 5 µg/L, $17.9 to $52.1 million at an MCL of 10 µg/L, and $7.9 to $29.8 million at an MCL of 20 µg/L. Potential annual health benefits resulting from lung cancer cases avoided range from $47.2 to $448.0 million at an MCL of 3 µg/L, $35.0 to $384.0 million at an MCL of 5 μg/L, $19.6 to $224.0 million at an MCL of 10 μg/L, and $8.8 to $128.0 million at an MCL of 20 μg/L.

Exhibit 8-35
Estimated Monetized Total Cancer Health Benefits and Non-Quantifiable Health Benefits from Reducing Arsenic in CWSs

<table>
<tr><th rowspan="2">Arsenic Level (μg/L)</th><th rowspan="2">Annual Bladder Cancer Health Benefits ($millions)[1,2]</th><th colspan="2">"What-if" Scenario and Potential Non-Quantifiable Health Benefits</th></tr>
<tr><th>"What-if" Scenario Annual Lung Cancer Health Benefits ($millions)[1,3]</th><th>Potential Non-Quantifiable Health Benefits</th></tr>
<tr><td>3</td><td>$43.6 - $104.2</td><td>$47.2 - $448.0</td><td rowspan="4">• Skin Cancer
• Kidney Cancer
• Cancer of the Nasal Passages
• Liver Cancer
• Prostate Cancer
• Cardiovascular Effects
• Pulmonary Effects
• Immunological Effects
• Neurological Effects
• Endocrine Effects
• Reproductive and Developmental Effects</td></tr>
<tr><td>5</td><td>$31.7 - $89.9</td><td>$35.0 - $384.0</td></tr>
<tr><td>10</td><td>$17.9 - $52.1</td><td>$19.6 - $224.0</td></tr>
<tr><td>20</td><td>$7.9 - $29.8</td><td>$8.8 - $128.0</td></tr>
</table>

1. May 1999 dollars.
2. The lower-end estimate is calculated using the lower-end number of bladder cancer cases avoided (see Exhibit 5-12) and assumes that the conditional probability of mortality among the Taiwanese study group was 100 percent. The upper-end estimate is calculated using the upper-end number of cancer cases avoided (see Exhibit 5-12) and assumes that the conditional probability of mortality among the Taiwanese study group was 80 percent.
3. These estimates are based on the "what if" scenario for lung cancer, where the risks of a fatal lung cancer case associated with arsenic are assumed to be 2-5 times that of a fatal bladder cancer case.

Reductions in arsenic exposures may also be associated with non-quantifiable benefits. EPA has identified several potential non-health non-quantifiable benefits associated with regulating arsenic in drinking water. These benefits may include any customer peace of mind from knowing that their drinking water has been treated for arsenic. To the extent that the Arsenic Rule can reduce households' perception of the health risks associated with arsenic in drinking water, household averting actions and costs to avoid these risks, such as buying bottled water or installing home treatment systems, could also be reduced.

8.10.2 Quantifiable and Non-Quantifiable Costs

The costs of reducing arsenic to various levels are summarized in Exhibit 8-36, which shows that, as expected, aggregate arsenic mitigation costs increase with decreasing arsenic levels. Total national costs at a 7 percent discount rate range are: $753.2 million per year at 3 μg/L; $442.2 million per year at 5 μg/L; $192.4 million per year at 10 μg/L; $73.7 million per year at 20 μg/L.

Exhibit 8-36
Summary of the Total Annual National Costs of Compliance
($ millions)

Discount Rate	CWS 3%	CWS 7%	NTNC* 3%	NTNC* 7%	TOTAL 3%	TOTAL 7%
MCL = 3 μg/L						
System Costs						
Treatment	$639.2	$746.4	--	--	$639.2	$746.4
Monitoring/ Administrative	$2.2	$3.0	$0.9	$1.1	$3.1	$4.1
State Costs	$1.6	$1.9	$0.6	$0.7	$2.2	$2.6
TOTAL COST	$643.1	$751.4	$1.5	$1.8	$644.6	$753.2
MCL =5 μg/L						
System Costs						
Treatment	$374.0	$436.0	--	--	$374.0	$436.0
Monitoring/ Administrative	$2.0	$2.8	$0.9	$1.1	$2.9	$3.9
State Costs	$1.3	$1.6	$0.6	$0.7	$2.0	$2.3
TOTAL COST	$377.3	$440.4	$1.6	$1.8	$378.9	$442.2
MCL = 10 μg/L						
System Costs						
Treatment	$160.4	$186.7	--	--	$160.4	$186.7
Monitoring/ Administrative	$1.8	$2.5	$1.0	$1.1	$2.8	$3.7
State Costs	$1.1	$1.3	$0.6	$0.7	$1.7	$2.1
TOTAL COST	$163.3	$190.5	$1.6	$1.9	$164.9	$192.4
MCL =20 μg/L						
System Costs						
Treatment	$58.9	$68.3	--	--	$58.9	$68.3
Monitoring/ Administrative	$1.7	$2.4	$1.0	$1.1	$2.7	$3.5
State Costs	$1.0	$1.2	$0.7	$0.7	$1.6	$1.9
TOTAL COST	$61.6	$71.8	$1.6	$1.9	$63.2	$73.7

*Costs include treatment, O&M, monitoring, and administrative costs to CWSs, monitoring and administrative costs to NTNCWSs, and State costs for administration of water programs.

Exhibit 8-37
Mean Annual Costs per Household in CWSs

SIZE CATEGORIES	MCL (μg/L)			
	3	5	10	20
<100	$368.13	$363.65	$357.17	$348.72
101-500	$258.68	$253.64	$246.38	$237.67
501-1,000	$106.07	$103.74	$98.35	$93.25
1,001-3,300	$63.61	$60.38	$56.51	$51.80
3,301-10,000	$44.28	$40.77	$37.04	$32.52
10,001-50,000	$36.39	$33.22	$29.13	$24.99
50,001-100,000	$29.52	$26.64	$22.80	$19.44
100,001-1,000,000	$23.47	$21.20	$18.32	$15.41
1,000,000 +	$2.70	$1.73	$0.89	$0.55
All categories	$43.73	$39.18	$33.05	$23.62

The cost impact of reducing arsenic in drinking water at the household level was also assessed. Exhibit 8-37 examines the cost per household for each system size category. As shown in the table, costs per household decrease as system size increases. However, costs per household do not vary significantly across arsenic levels. This is because costs do not vary significantly with removal efficiency; once a system installs a treatment technology to meet an MCL, costs based upon the removal efficiency that the treatment technology will be operated under remain relatively flat. Per household costs are, however, somewhat lower at less stringent arsenic levels. This is due to the assumption that some systems would blend water at these levels and treat only a portion of the flow in order to meet the target MCL.

Exhibit 8-38
Cost per Bladder Cancer Case Avoided for the Proposed Arsenic Rule
(CWSs Comply with MCL / NTNCs Monitor, in $ millions)

Arsenic Level (µg/L)	lower bound**	upper bound**
3% Discount Rate		
3	$ 29.4	$ 12.3
5	$ 23.8	$ 8.4
10	$ 18.3	$ 6.3
20	$ 15.9	$ 4.2
7% Discount Rate		
3	$ 34.4	$ 14.4
5	$ 27.7	$ 9.8
10	$ 21.4	$ 7.3
20	$ 18.6	$ 4.9

*Costs all treatment, O&M, monitoring, and administrative costs to CWSs, monitoring and administrative costs to NTNCWSs, and State costs for administration of water programs.
**Lower/upper bounds correspond to estimates of bladder cancer cases avoided.

Exhibit 8-38 illustrates the cost per bladder cancer case avoided, based on national cost estimates which include all the costs of treatment, O&M, monitoring and administrative costs to CWSs, monitoring and administrative costs to NTNCWSs, and all State costs for administration of water programs. At a 3 percent discount rate, cost per case ranges from approximately $29.4 million at an arsenic level of 3 µg/L (lower bound estimate of avoided bladder cancer cases) to $4.2 million at an MCL of 20 µg/L (upper bound of avoided bladder cancer cases). Similarly the range at a 7 percent discount rate is $34.3 million to $4.9 million.

References

Agency for Toxic Substances and Disease Registry. 1998. Toxicological Profile for Arsenic (Draft). U.S. Department of Health and Human Services.

Baker, Mary S., et al. 1989. Site specific treatment costs for cancer: an analysis of the medicare continuous history sample file. Cancer Care and Cost. DRGs and Beyond. Richard M. Scheffler and Neil C. Andrews, eds. Ann Arbor, MI: Health Administration Press Perspectives.

Brouwer, OF, et al. 1992. Increased neurotoxicity of arsenic in methylenetetrahydrofolate reductase deficiency. Clin Neurol Neurosurg. 94(4):307-10.

Buchet, JP and Lauwerys, R. 1987. Study of factors influencing the in vio methylation of inorganic arsenic in rats. Toxicol Appl Pharmacol. 91: 65-74.

Clifford, D., G. Ghurye and A. Tripp (1998). "Arsenic Removal by Ion Exchange With and Without Brine Reuse," AWWA Inorganic Contaminants Workshop, San Antonio, TX, February 23-24, 1998.

Dallaire, L, and Beliveau, R. 1992. Phosphate transport by capillaries of the blood-brain barrier. J Biol Chem. 267 (31): 22323-7.

Dong, JT and Luo, XM. 1993. Arsenic-induced DNA-strand breaks associated with DNA-protein crosslinks in human fetal lung fibroblasts. Mutat Res 302(2):97-102.

Edelman, GM. 1992. Morphoregulation. Dev Dynamics. 193:2-10.

EOA, IRIS web site. Extracted 8199.

EPA. 1995. Community Water System Survey.

EPA, 1997a. Information Collection Request for the Public Water System Supervision Program.

EPA. 1997b. Community Water System Survey, Volume II: Detailed Survey Result Tables and Methodology Report. Office of Water, Washington, D.C. EPA/815-R-97-001a and -001b.

EPA. 1997c. The Benefits and Costs of the Clean Air Act, 1970-1990. Clean Air Act §812 report prepared for U.S. Congress by U.S. EPA Office of Air and Radiation. October. EPA 410-R-97-002.

EPA. 1998a. An Assessment of the Vulnerability of Non-Community Water Systems to SDWA Cost Increases. Washington, D.C.

EPA. 1998b. Cost of Illness Handbook. Washington, D.C.

EPA. 1998c. National-Level Affordability Criteria Under the 1996 Amendments to the Safe Drinking Water Act, Draft. Washington, D.C.

EPA. 1999a. Drinking Water Baseline Handbook, Draft 1st Edition. Washington, D.C.

EPA, 1999b Geometries and Characteristics of Public Water Systems. Prepared for Office of Ground Water and Drinking Water by Science Applications International Corporation(SAIC) EPA Contract No. 68-C6-0059.

EPA. 1999c. Arsenic Occurrence in Public Drinking Water Supplies. Washington, D.C.

Federal Register. 1998. Aug. 6.

Freeman, HC, et al. 1979. Clearance of arsenic ingested by man from arsenic contaminated fish. Bull Environ Contam Toxicol. 22(1-2):224-9.

Geubel, AP, et al. 1988. Abnormal methylation capacity in human liver cirrhosis. Int J Clin Pharmacol Res. 8:117-22.

Gunn, TM, et al. 1992. Further genetic studies of the cause of exancephaly in SELH mice. Teratology. 45:679-86.

International Consultants, Inc. (ICI) and Malcolm Pirnie, Inc. (MPI) (1999). Technologies and Costs for the Removal of Arsenic from Drinking Water, Prepared for the United States Environmental Protection Agency, Office of Ground Water and Drinking Water, Standards and Risk Management Division, Targeting and Analysis Branch, April 1999.

Jha, AN, et al. 1992. Genotoxic effects of sodium arsenite on human cells. Mutat Res. 1992 284:(2):215-21.

Kapadia, Amit 1999a. E-mail from Amit Kapadia, USEPA to Michael Muller, Abt Associates, July 1.

Kapadia, Amit 1999b. Telephone conversation between Amit Kapadia, USEPA and Michael Muller, Abt Associates, July.

Leonard, A and Lauwerys, RR. 1980. Carcinogenicity, teratogenicity and mutagenicity of arsenic. Mutat Res. 75(1):49-62.

Li, W and Chou, IN. 1992. Effects of sodium arsenite on the cytoskeleton and cellular glutathione levels in cultured cells. Toxicol Appl Pharmacol 114(1): 132-9.

Morris-Kay, GM, et al. 1994. Normal neurulation in mammals. In Ciba Foundation Symposium, neural tube defects. New York: John Wiley & Sons, 51-69.

Mottet, NK and Ferm, VH. 1983. The congenital teratogenicity and perinatal toxicity of metals. In reproduction and development toxicity of metals. Clarkson TW, Nordberg GF, and Sager, PR, eds. New York: Plenum Press, 93-125.

National Academy of Sciences. 1995. Risk Assessment in the Federal Government.

National Cancer Institute. 1999.

National Research Council. 1999. Arsenic in Drinking Water.

Petres, J, et al. 1977. Effects of arsenic cell metabolism and cell proliferation: cytogenetic and biochemical studies. Environ. Health Perspect. 19:223-7.

Scheonwolf, GC and Smith, JL. 1990. Mechanisms of neurulation: traditional viewpoint and recent advances. Development. 109:243-270.

SDWIS, 1998. December 1998 freeze.

Smith, Ben 1999a. Facsimile from Ben Smith, USEPA to Michael Muller, Abt Associates, June 30.

Somogyi, A and Beck, H. 1991. Nurturing and breast-feeding exposure to chemicals in breast milk. International Workshop on the Impact of the Environment on Reproductive Health, Copenhagen, Denmark, September 30-October 4, 1991. Environ Health Perspect 101 (suppl.2): 45-52.

Subramanian, K.S., T. Viraraghavan, T. Phommavong and S. Tanjore (1997). "Manganese Greensand for Removal of Arsenic in Drinking Water," Water Quality Research Journal Canada, 32:3:551-561.

Taubeneck, MW, et al. 1994. Altered material zinc metabolism following exposure to diverse developmental toxicants. Reprod Toxicol 8(1):25-40.

Tsai, SM, et al. 1999. Mortality for certain diseases in areas with high levels of arsenic in drinking water. Arch Environ Health. 54(3):186-93.

Vahter, M. and Marafante, E. 1987. Effects of low dietary intake methionine, choline, or proteins on the biotransformation of arsenite in the rabbit. Toxiol Lett. 37: 41-46.

Variance Technology Findings for Contaminants Regulated before 1996.

Viscusi, K., et al. 1991. Pricing Environmental Health Risks: Survey Assessments of Risk-Risk and Risk-dollar Tradeoffs. Journal of Environmental Economics and Management. 201:32-57.

Appendix A: Decision Tree and Decision Matrix

A.1 Introduction

The purpose of this appendix is to present the rationale behind the development of the decision tree and associated decision matrix. It includes an overview of the decision tree structure and major factors impacting the decision- making process. The following list outlines the contents of this appendix:

A.2 BACKGROUND - Presents a brief history of the arsenic regulation and the statutory requirements impacting EPA and the decision-making process.

A.3 DECISION TREE OVERVIEW - Outlines the decision tree and presents major factors affecting the decision-making process.

A.4 MAJOR FACTORS AFFECTING THE DECISION TREE - Presents the rationale for selecting parameters which impact the decision tree, including MCL, population, water type, region, and co-occurrence of solutes.

A.5 ADDITIONAL FACTORS AFFECTING THE DECISION TREE - Presents other parameters in the process which impact the decision tree, including: corrosion control, pre-oxidation, regionalization, and alternative technologies.

A.6. ARSENIC RULE-MAKING DECISION MATRIX - Complete copy of the decision matrix developed for the arsenic rule-making process. These are provided in Exhibits A-2 through A-17.

A.7. REFERENCES.

A.2 Background

In 1998 and 1999, EPA conducted technology and cost evaluations for the removal of arsenic from drinking water. These evaluations looked into the effectiveness of various removal technologies and the capital and operations and maintenance (O&M) costs associated with each process. The following were evaluated and determined effective to varying degrees:

- Coagulation/Filtration (C/F);
- Modified Coagulation/Filtration (modifications to existing C/F plants);
- Direct Filtration (DF);
- Coagulation Assisted Microfiltration (CMF);
- Lime Softening (LS);
- Modified Lime Softening (modifications to existing LS plants);

- Activated Alumina (AA);
- Ion Exchange (IX);
- Ultrafiltration (UF);
- Nanofiltration (NF);
- Reverse Osmosis (RO);
- Greensand Filtration (GF); and
- Point-of-Entry (POE) and Point-of-Use (POU) Treatment Options.

The technology and cost evaluation yielded a document entitled *Technologies and Costs for the Removal of Arsenic From Drinking Water* (ICI and MPI, 1999). The document includes detailed evaluations of the above technologies, capital and O&M cost estimates for each of the listed technologies, as well as other technologies that were considered ineffective or unproven.

EPA used the information contained in the technologies and costs (T&C) document to develop a regulatory decision tree. The decision tree was then used to fashion a decision matrix which contains the probability that a given system will choose a treatment technology based on the percent removal required to meet the proposed MCL. The decision matrix, unit cost curves for treatment and waste disposal (illustrated in the T&C), treatment-in-place data and occurrence estimates will be used to develop national cost of compliance estimates.

A.3 Decision Tree Overview

The decision tree is a flow chart that details the thought process involved in estimating which treatments will be installed to comply with the four MCL options. The decision tree was developed under the overriding assumption that systems would attempt to comply with the proposed MCL by choosing the lowest cost approach. However, it was also recognized that some systems may not be able to choose the lowest cost technology, because they face certain constraints. Therefore, the "branches" of the decision tree represent constraining factors that must be taken into consideration when estimating which treatment technology a system will select. The following questions were used to define the branches of the decision tree. A detailed explanation of the rationale behind each question is presented in the next section.

1. What is the target MCL?

2. What is the influent arsenic concentration of the system?

3. What is the population of the system?

4. In what region of the country is the system located?

5. Does the system utilize ground or surface water?

6. Does the system currently have some type of treatment in place?

7. Are there any co-occurrence issues that preclude the use of a particular treatment technology?

8. What disposal options are available for the treatment technology selected?

Even though these eight questions represent major decisions within the decision tree structure and each question must be answered to complete a branch of the tree, the tree was structured to limit the number of branches that must be considered during the development of the decision matrix. By first selecting the target MCL and influent arsenic concentration, some branches of the tree are eliminated early in the process. For example, if the target MCL is 20 μg/L and the influent arsenic levels are between 10 and 20 μg/L, no removal is necessary, and therefore the probability of choosing any treatment technology is zero. Similar logic was applied to other decisions factors.

A.4 Major Factors Affecting the Decision Tree

This section explains the rationale behind selecting each particular decision factor. Specifically, this section will discuss the following:

- the MCL target,
- influent arsenic concentration,
- population,
- region where the system is located,
- source water,
- whether a system has existing treatment in place,
- co-occurrence of solutes, and
- waste disposal issues.

A.4.1 MCL Target

The MCL target is the single most important factor in development of the decision tree because it is essential for determining all other branches of the tree. The decision tree is structured such that selection of the target MCL is the first step in the decision process. Four MCL scenarios will be analyzed as part of the regulatory development process (3 μg/L, 5 μg/L, 10 μg/L, and 20 μg/L).

A.4.2 Influent Arsenic Concentration

When coupled with the MCL target, the influent arsenic concentration was of major importance in developing the decision tree. In developing the decision tree, influent arsenic concentrations were grouped into four categories: less than 10 μg/L, 10 to 20 μg/L, 20 to 30 μg/L, and 30 to 50 μg/L. Given the MCL under consideration, the influent arsenic concentration determines what percent removal of arsenic is needed, if any, and lays the groundwork for remaining decisions in the tree. Percent removal is critical for determining what additional technologies may be feasible. For example, if a surface water plant has an influent arsenic level of 50 μg/L, and the target MCL is 2

μg/L, then 96 percent removal is required.[1] Research indicates that lime softening is only capable of achieving approximately 80 percent removal; thus, lime softening would not be a viable treatment option in this branch of the decision tree. Likewise, in the decision matrix, the probability of choosing lime softening as a treatment technology would be zero whenever the percent removal is over 80 percent.

A.4.3 System Size

System size, or population, also plays a significant role in determining the treatment options available to a system, as well as the affordability of a particular technology for a system. EPA established nine size categories to be used in the decision tree and RIA process:

1. 25 to 100;
2. 101-500;
3. 501-1,000;
4. 1,001-3,300;
5. 3,301-10,000;
6. 10,001-50,000;
7. 50,001-100,000;
8. 100,001-1,000,000; and
9. greater than 1,000,000.

In developing the decision tree EPA grouped size categories one through three (25 to 1,000 people) and four though eight (1,001 to 1,000,000 people) because POE and POU treatment options are considered viable treatment alternatives only for the three smallest categories. With these groupings, the available technologies are constant for each of the size categories within each group. However, the probability of choosing a given technology is still assigned dependent on system size category. Therefore, in the development of the decision matrix, the probabilities that certain technologies are chosen change for each of the size categories. Hence, the decision matrix accommodates each of the eight size categories (one through eight) individually. Systems within the ninth size category (greater than 1,000,000) will be addressed on a case-by-case basis by EPA, and will fall outside the scope of the decision tree process.

A.4.4 Region

The region of the nation that a system resides in does not effect the treatment options available. Therefore, the decision tree is structured in such a way that, regardless of the region, the branches are identical, and in fact refer to the same pages within the decision tree. However, the number of systems that may select a particular option as defined in the decision matrix, is region-specific.

EPA has decided that the nation can be divided into three regions for the purpose of the decision

[1]Required removal percentages in the decision tree are based on worst cast scenarios and therefore correspond with the upper bound of the arsenic concentration range for each category.

making process: 1) Southwest Region; 2) Northwest Region; and 3) East Region. The regions were selected based upon availability of water (i.e., scarcity of water) and availability of land. In the Southwest Region, for example, water may be scarce and treatment technologies that generate large volumes of reject water, such as RO, may not be appropriate. In the East Region, water scarcity is much less a concern than the availability of land. Technologies or disposal options that require significant amounts of land are less likely to be utilized in the East Region. The Northwest Region, by comparison, is less affected by the scarcity of water or land availability than either of the other two regions.

A.4.5 Source Water

The source of the system's raw water, either ground water or surface water, plays a major role in determining the technologies that may already be in use by a system and what treatment options are available if a system needs to install a new treatment facility.

For example, greensand filtration is affected by the level of iron in the raw water. Influent levels greater than 300 mg/L (ppm) are conducive to removal of arsenic by greensand filtration. Surface waters typically have low iron content, whereas ground waters often have levels in excess of 300 mg/L (Subramanian, et al., 1997). Accordingly, greensand filtration was not considered a viable removal technology for surface water systems.

To determine the types of treatment that are currently being utilized throughout the country, EPA reviewed the Community Water Systems Survey (CWSS). EPA determined there are few surface water systems utilizing RO, IX or AA. As a result, when approximating the treatment in place options, RO, IX, and AA were omitted for surface water systems.

Arsenic removal is significantly more efficient when arsenic is present as arsenate (As^{5+}). Research has demonstrated many of the technologies considered perform poorly when arsenite (As^{3+}) is the predominant form (ICI and MPI, 1999). Arsenite can be easily oxidized to arsenate using conventional oxidation methods, such as chlorination and potassium permanganate addition. Ground waters typically contain higher levels of As^{3+}, whereas As^{5+} is the dominant species in surface waters. As a result, ground waters are more likely to install pre-oxidation and use higher oxidant doses, whereas surface waters may be able to get by with little or no pre-oxidation capacity.

A.4.6 Systems with Treatment In-Place

If a system currently has treatment in-place it will significantly impact the decision tree. Many existing treatment facilities will be able to achieve the necessary removal with little or no modification, particularly at high MCLs. At the lower MCLs (2 and 5 μg/L), existing facilities may be able to add polishing steps or make some modifications to the existing system to achieve the required removal level. Table 1 outlines the treatment technologies included in the decision tree, the percent removal assumed capable without modification or polishing, and the maximum percent removal.

A.4.7 Systems without Treatment In-Place

Many factors affect the decision tree when considering the addition of a treatment option to systems with no current treatment in place. Source water type and quality, system size, required arsenic removal, and removal achievable by a particular technology are all major considerations. Many of these considerations have been discussed earlier in Section 4, however, source water quality, i.e., co-occurrence of solutes, is discussed in Section 4.8.

For ground water systems (any size) without treatment in-place, the most suitable treatment technologies are IX, AA and RO, though CF and LS may be used. CF and LS are best suited for large surface water systems without treatment in-place while IX, AA and RO are best suited for small surface water systems without treatment in-place. In either case, RO is not a suitable treatment technology in regions where water is scarce. Modified CF and LS are for those surface water systems that already have CF or LS in-place.

The SDWA identifies POE and POU treatment units as potentially affordable technologies, but stipulates that POE and POU treatment systems "shall be owned, controlled and maintained by the public water system, or by a person under contract with the public water system to ensure proper operation and compliance with the maximum contaminant level or treatment technique and equipped with mechanical warnings to ensure that customers are automatically notified of operational problems."

Preliminary affordability determinations have shown that POE and POU technologies will only be considered viable for small systems. These determinations have shown the cost breakpoint to be in the area of 200 persons served. This estimate does not account for waste disposal costs, which would make central treatment estimates more expensive, thus increasing the breakpoint. As a result, POE and POU units are only included in the decision tree for systems with populations fewer than 1,000 individuals.

Exhibit A-1
Treatment Technologies for Systems with Treatment In-Place and Percent Removals Assumed and Achievable

Treatment Technology	Percent Removal of In-Place System	Maximum Percent Removal[1]
Coagulation/Filtration[2]	50	95
Lime Softening[2]	50	80
Coagulation Assisted Microfiltration	NA	90
Ion Exchange	95	>95
Activated Alumina	95	>95
Reverse Osmosis	95	>95
Greensand Filtration[3]	90	90
POE Activated Alumina	NA	>95
POU Ion Exchange	NA	>95

1 - For Percent Removals of In-Place Systems that are very close to Maximum Percent Removals (e.g., 95% and > 95%) polishing steps may be required.
2 - Maximum Percent Removal involves modification to existing system in the form of additional chemical feed systems, pumping, piping, etc.
3 - EPA is currently evaluating the removals achievable by this process. The final decision matrix may reflect significantly lower removals, e.g., 50%.
NA - Not Applicable

A.4.8 Co-Occurrence of Solutes

There are a number of solutes and water quality parameters that may effect the viability of a particular treatment option. Total dissolved solids (TDS), silica, sulfate and iron can all be major detractors/benefactors for the use of a particular technology. The decision tree simply cannot account for each individual situation where the influent water quality plays a role in selecting the treatment option. Utilities are encouraged to read the T&C document (ICI and MPI, 1999) to gather additional information on parameters which impact the performance of a particular technology.

The decision tree uses influent sulfate and iron levels as decision factors in selecting treatment technologies. Sulfate has been shown to decrease the effectiveness of ion exchange processes for arsenic removal; therefore, these processes are not generally recommended where influent sulfate levels exceed 120 mg/L (Clifford, et al., 1998). Iron, on the other hand, significantly improves the effectiveness of greensand filtration (Subramanian, et al., 1997). Greensand filtration is best suited for ground waters (which typically contain higher levels of iron than surface waters) with high influent levels of iron (300 mg/L).

The decision tree has been structured to accommodate the impact of sulfate and iron on treatment effectiveness. For ground water sources, both sulfate and iron levels are considered. Ion exchange is not considered a feasible treatment option when sulfate levels exceed 120 mg/L, and greensand filtration is not considered viable when the iron level falls below 300 mg/L. For surface waters in which high iron levels are rare, only sulfate has been considered. For purposes of approximating national cost, greensand filtration is not considered a treatment option for surface water systems. Ion exchange is not considered a feasible treatment option when the sulfate level exceeds 120 mg/L. Therefore, in the development of the decision matrix, the probability that a system will choose a particular technology is assumed with an eye on the regional levels of iron and sulfate.

A.4.9 Waste Disposal

Waste handling and disposal options are specific to the treatment technology selected and the availability of disposal options does not vary by system size in the decision tree. However, the probability that a system will utilize a particular option does vary with system size. For example, evaporation ponds may not be suitable for large systems in the Northwest Region where climatic conditions do not facilitate evaporation. Mechanical dewatering devices can be expensive and may require significant operator attention and may not be suitable for small systems.

A.4.9.1 Mechanical Dewatering

Mechanical dewatering processes include centrifuges, vacuum-assisted dewatering beds, belt filter presses, and plate and frame filter presses. Such processes generally have high capital, as well as high O&M costs, compared to similar capacity non-mechanical dewatering processes (e.g., storage lagoons). Due to the high costs, such processes are generally not suitable for application with very small water systems.

Filter presses have been used in industrial processes for years and have been increasing in the water treatment industry over the past several years. The devices have been successfully applied to both lime softening process sludge and coagulation/filtration process sludge. Filter presses require little land, have high capital costs, and are labor intensive.

Centrifuges have also been used in the water industry for years. Centrifugation is a continuous process requiring minimal time to achieve the optimal coagulation/filtration. Centrifuges have low land requirements and high capital costs. They are more labor intensive than non-mechanical alternatives, but less intensive than filter presses. Again, due to the capital and O&M requirements, centrifuges are more suitable for larger water systems.

A.4.9.2 Evaporation Ponds and Drying Beds

Evaporation ponds and drying beds are non-mechanical dewatering technologies wherein favorable climatic conditions are used to dewater waste brines generated by treatment processes such as reverse osmosis and ion exchange. Ponds and drying beds are not generally suitable for lime softening or coagulation/filtration. Evaporation is an extremely land intensive waste handling option requiring shallow basins with large surface areas which can be an important consideration in densely populated regions. Evaporation ponds and drying beds have few operation and maintenance requirements but are only feasible in regions with high temperatures, low humidity, and low precipitation.

A.4.9.3 Storage Lagoons

Lagoons are the most common, and often least expensive, method to thicken or dewater treatment sludge, however, they are land intensive. Storage lagoons are best suited for dewatering lime softening process sludge, though they have been applied with some success to coagulation/filtration process sludge. Coagulation/filtration process sludge do not typically dewater well in storage lagoons. Thickened coagulation/filtration process sludge can be difficult to remove from lagoons and often require dredging or vacuum pumping by knowledgeable experts.

Since lagooning is a land intensive process, it has limited applicability in densely populated regions, or regions with limited land availability. Lagoons are best suited for areas with favorable climatic conditions, i.e., high temperatures, low humidity, and low precipitation. In fact, in northern climates, winter freezing can dehydrate coagulation/filtration sludge.

A.4.9.4 Direct Discharge

Direct discharge to a surface water body is a common method of disposal for water treatment byproducts. No pretreatment or concentration of the byproduct stream is necessary prior to discharge, and the receiving water dilutes the waste concentration and gradually incorporates the sludge or brine. The primary cost associated with direct discharge is that of the piping. Direct discharge requires little oversight and operator experience and maintenance are minimal. This method has been used to successfully dispose of lime softening and coagulation/filtration process sludge materials, as well as brine streams generated at reverse osmosis and ion exchange water plants.

A.4.9.5 POTW Discharge

Indirect discharge (POTW discharge) is a commonly used method of disposal for filter backwash and brine waste streams. Coagulation/filtration and lime softening sludge materials have also been successfully disposed of in this manner. The primary cost associated with POTW discharge is that of the piping. Additional costs associated with POTW discharge may include lift stations, additional piping for access to the sewer system, and any cost incurred by the POTW in accommodating the increased demands on the POTW.

A.4.9.6 Dewatered Sludge Land Application

Dewatered sludge can be disposed of by spreading the material over an approved land surface. Land application is limited by the availability of land. In areas where grassland, farmland, or forested land is unavailable, transportation can significantly affect the cost effectiveness of this disposal option. Land application can be a means of final disposing of lime softening sludge, and to a lesser degree, coagulation/filtration sludge. Lime softening sludge can be used to neutralize soil pH while coagulation/filtration sludge offer no benefit to soil chemistry and are generally used as fill material.

A.4.9.7 Sanitary Landfill Disposal

Two forms of sanitary landfill are commonly used for disposal of water treatment byproducts: monofills and commercial nonhazardous waste landfills. In some parts of the country, decreasing landfill availability, rising costs, and increasing regulations are making landfill disposal more expensive. Costs associated with the development of monofills are generally less than those associated with commercial nonhazardous water landfill.

A.5 Additional Factors Affecting the Decision Tree

A.5.1 Pre-Oxidation

As mentioned above, inorganic arsenic occurs in two primary valence states, arsenite (As III) and arsenate (As V). As(III) is dominant in ground waters while surface waters more typically contain As(V). As(III) is easily oxidized to As(V) by conventional oxidation technologies such as chlorination and potassium permanganate addition. Each of the treatment technologies considered in the decision tree remove As(V) more readily than As(III) and as a result, pre-oxidation may be necessary depending upon source water conditions.

Pre-oxidation is included in the decision tree for all treatment technologies. Systems without treatment in-place may already be chlorinating which may meet pre-oxidation requirements. For those systems, pre-oxidation may or may not need to be installed. Similarly, systems with treatment in-place may have pre-oxidation in-place which could meet the pre-oxidation requirements. For single-house (POE) or single tap (POU) treatment options, centralized pre-oxidation is required.

A.5.2 Corrosion Control

Many of the treatment technologies considered in the decision tree (e.g., LS, AA, IX, and RO) remove hardness and alkalinity. Removal of hardness and alkalinity can reduce the pH of finished water and lead to corrosion problems within the system. Hardness and alkalinity, at the appropriate levels, act as buffers against corrosion in the treatment plant and distribution system. At these levels, alkalinity and hardness form protective coatings (metal hydroxides), control pH and enhance the buffer effect against corrosion. Corrosion control is included in the decision tree for all new constructions, that is, systems without existing treatment plants. It was assumed that existing plants had adequate corrosion control in-place.

A.5.3 Regionalization

The term regionalization is used to define the process of purchasing water or transporting water from one community to another. Numerous operational and other factors including

1) the availability of water,
2) water quality,
3) geography, and
4) economic factors influence the decision to implement regionalization.

Water quality also plays a role in the decision-making process. For example, if a community's source water is contaminated, it may be less expensive for the community to purchase water from another community than to treat its own water source. Regionalization is considered an option only for small systems (<1mgd) in the decision tree.

A.5.4 Alternative Technologies

Technologies and Costs for the Removal of Arsenic from Drinking Water (ICI and MPI, 1999) evaluated four arsenic removal technologies that were not included in the decision tree:

1) Sulfur-Modified Iron,
2) Granular Ferric Hydroxide,
3) Iron Filings, and
4) Iron Oxide Coated Sand.

The technologies were not included in the decision tree for reasons which are summarized below.

A.5.4.1 Sulfur-Modified Iron

A patented Sulfur-Modified Iron (SMI) process for arsenic removal has recently been developed. During this process, powdered iron, powdered sulfur, and the oxidizing agent (H_2O_2 in preliminary tests) are thoroughly mixed and added to the water to be treated. The oxidizing agent serves to convert As(III) to As(V). Arsenic removal utilizing the SMI process seems to be dependent on the iron to arsenic level as well as pH. Flow distribution problems were evident, as several columns became partially plugged during operation.

All experimentation on the SMI process has been at the bench-scale level, and involves only batch processes. The literature is unclear about removal efficiency since results varied from less than 10 to 99 percent, depending on conditions. It appears that O&M for such a system would be expensive and would require a highly trained operator. Finally, by the admission of the researchers, disposal costs might outweigh the increased adsorption capacity.

A.5.4.2 Granular Ferric Hydroxide

A new removal technique for arsenate is adsorption by granular ferric hydroxide (GFH) in fixed bed reactors. Although the competition of sulfate on arsenate adsorption was not very strong, phosphate competed strongly with arsenate which reduced arsenate removal with GFH.

Currently, GFH media costs approximately $4,000 per ton. In addition to the high cost of the media, the direct deposition of spent GFH as hazardous waste is favored

A.5.4.3 Iron Filings

The Iron Filings process is essentially a filter technology, much like greensand filtration, wherein the source water is filtered through a bed of sand and iron filings. Unlike some technologies (i.e. ion exchange), sulfate is actually introduced in this process to encourage arsenopyrite precipitation.

While this process seems to be quite effective, its use as a drinking water treatment technology appears to be limited. There is no indication that this technology can reduce arsenic levels below approximately 25 ppb. This technology also suffers from a study design which failed to test its effectiveness at influent levels of concern in drinking water. Since the study design called for such high influent levels - 470 to 20,000 ppb - there is no data to indicate how the technology performs at normal source water arsenic levels, which most certainly are below the 470 ppb level used in experimentation. This technology needs to be further evaluated before it should be recommended as an approved arsenic removal technology for drinking water.

A.5.4.4 Iron Oxide Coated Sand

Iron oxide coated sand (IOCS) is a rare process that has shown some tendency for arsenic removal. IOCS consists of sand grains coated with ferric hydroxide which are used in fixed bed reactors to remove various dissolved metal species. Factors such as pH, arsenic oxidation state, competing ions, EBCT, and regeneration time have significant effects on the removals achieved with IOCS. Like other processes, the media must be regenerated upon exhaustion. IOCS has only limited experience having only been tested at bench-scale. High levels of arsenite could reduce IOCS effectiveness because the bonding is strong and may permanently damage the media. Natural organic matter may also be problematic for arsenic removal. IOCS also takes a considerable amount of time to produce in a laboratory setting. At full-scale this would likely result in high capital cost.

A.6 Arsenic Rule Making Decision Matrix

The actual decision tree is illustrated as a flow chart and occupies over 300 written pages. Rather than include the decision tree as part of this appendix, the decision matrix is presented. The decision matrix contains the actual assumptions regarding compliance decisions that were used to estimate system compliance costs. The decision tree is presented in Exhibits A-2 to A-16. Each exhibit provides the decision matrix for a particular source water and size category pair (e.g. Exhibit A-2 contains the decision matrix for ground water systems serving fewer than 100 people). The first column described the treatment technology train associated with the row. The next three columns present three different decision probabilities for each technology treatment train, depending on the required percentage reduction in influent arsenic (e.g. in the cost analysis, a system which needed to remove between 50 and 90 percent of the influent arsenic would have a seven percent chance of choosing treatment technology train 24, Reverse Osmosis POU with pre-corrosion control).

Exhibit A-2
Probability Decision Tree: Ground Water Systems Serving 100 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	>90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	3.0	3.0	1.0
4	Modify Coagulation/Filtration and pre-oxidation	2.0	2.0	1.0
5	Anion Exchange (25 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	2.0	2.0	17.0
6	Anion Exchange (150 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	2.0	2.0	17.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	60.0	70.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	0.0	0.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	0.0	0.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backwash stream	18.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	18.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	18.0
23	POE Activated Alumina and corrosion control and pre-oxidation	4.0	7.0	8.0
24	POU Reverse Osmosis and pre-oxidation	4.0	7.0	10.0
25	POU Activated Alumina and pre-oxidation	5.0	7.0	10.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-3
Probability Compliance Decision Tree: Ground Water Systems Serving 101-500 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL		
		<50%	50-90%	>90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	3.0	3.0	1.0
4	Modify Coagulation/Filtration and pre-oxidation	4.0	4.0	2.0
5	Anion Exchange (25 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	24.0	18.0	17.0
6	Anion Exchange (150 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	24.0	18.0	17.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	0.0	0.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	0.0	0.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backwash stream	18.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	7.0	19.0	18.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	6.0	19.0	18.0
23	POE Activated Alumina and corrosion control and pre-oxidation	4.0	6.0	9.0
24	POU Reverse Osmosis and pre-oxidation	5.0	6.0	9.0
25	POU Activated Alumina and pre-oxidation	5.0	7.0	9.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-4
Probability Compliance Decision Tree: Ground Water Systems Serving 501-1,000 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	>90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	2.0	2.0	1.0
4	Modify Coagulation/Filtration and pre-oxidation	2.0	2.0	1.0
5	Anion Exchange (25 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	24.0	18.0	17.0
6	Anion Exchange (150 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	0.0	3.0	13.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	0.0	0.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	0.0	0.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backwash stream	18.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	24.0	18.0	17.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	19.0	13.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	15.0	19.0	19.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	15.0	19.0	19.0
23	POE Activated Alumina and corrosion control and pre-oxidation	0.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	0.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	0.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-5
Probability Compliance Decision Tree: Ground Water Systems Serving 1,001-3,300 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	>90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	3.0	3.0	1.0
4	Modify Coagulation/Filtration and pre-oxidation	3.0	3.0	1.0
5	Anion Exchange (25 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	24.0	18.0	17.0
6	Anion Exchange (150 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	13.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	8.0	10.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	8.0	10.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backwash stream	18.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	24.0	18.0	17.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	13.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	6.0	19.0	19.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	6.0	19.0	19.0
23	POE Activated Alumina and corrosion control and pre-oxidation	0.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	0.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	0.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-6
Probability Compliance Decision Tree: Ground Water Systems Serving 3,301-10,000 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	≥90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	3.0	3.0	1.0
4	Modify Coagulation/Filtration and pre-oxidation	8.0	8.0	4.0
5	Anion Exchange (25 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	24.0	18.0	17.0
6	Anion Exchange (150 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	12.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	2.0	8.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	3.0	7.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backwash stream	18.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	24.0	18.0	17.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	11.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	9.0	19.0	19.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	9.0	19.0	19.0
23	POE Activated Alumina and corrosion control and pre-oxidation	0.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	0.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	0.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-7
Probability Compliance Decision Tree: Ground Water Systems Serving 10,001-50,000 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	≥90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	5.0	5.0	2.0
4	Modify Coagulation/Filtration and pre-oxidation	4.0	4.0	2.0
5	Anion Exchange (25 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	24.0	18.0	17.0
6	Anion Exchange (150 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	12.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	22.0	28.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	21.0	27.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backwash stream	0.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	24.0	18.0	17.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	12.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	19.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	19.0
23	POE Activated Alumina and corrosion control and pre-oxidation	0.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	0.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	0.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-8
Probability Compliance Decision Tree: Ground Water Systems Serving 50,001-100,000 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL		
		<50%	50-90%	>90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	3.0	3.0	1.0
4	Modify Coagulation/Filtration and pre-oxidation	4.0	4.0	2.0
5	Anion Exchange (25 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	23.0	18.0	17.0
6	Anion Exchange (150 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	12.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	24.0	29.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	23.0	28.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backwash stream	0.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	23.0	18.0	17.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	13.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	19.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	19.0
23	POE Activated Alumina and corrosion control and pre-oxidation	0.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	0.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	0.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-9
Probability Compliance Decision Tree: Ground Water Systems Serving 100,001-1,000,000 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	≥90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	10.0	10.0	5.0
4	Modify Coagulation/Filtration and pre-oxidation	5.0	5.0	2.0
5	Anion Exchange (25 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	17.0
6	Anion Exchange (150 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	10.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	43.0	43.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	42.0	42.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backw ash stream	0.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	17.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	11.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	19.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	19.0
23	POE Activated Alumina and corrosion control and pre-oxidation	0.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	0.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	0.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-10
Probability Decision Tree: Surface Water Systems Serving 100 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	>90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	4.0	4.0	2.0
4	Modify Coagulation/Filtration and pre-oxidation	22.0	22.0	11.0
5	Anion Exchange (25 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	2.0	2.0	17.0
6	Anion Exchange (150 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	2.0	2.0	17.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	56.0	46.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	0.0	0.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	0.0	0.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backw ash stream	0.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	3.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	3.0
23	POE Activated Alumina and corrosion control and pre-oxidation	5.0	8.0	15.0
24	POU Reverse Osmosis and pre-oxidation	5.0	8.0	16.0
25	POU Activated Alumina and pre-oxidation	4.0	8.0	16.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-11
Probability Decision Tree: Surface Water Systems Serving 101-500 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	>90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	9.0	9.0	4.0
4	Modify Coagulation/Filtration and pre-oxidation	53.0	53.0	26.0
5	Anion Exchange (25 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	15.0	17.0	16.0
6	Anion Exchange (150 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	14.0	17.0	16.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	0.0	0.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	0.0	0.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backw ash stream	0.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	2.0	19.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	2.0	19.0
23	POE Activated Alumina and corrosion control and pre-oxidation	3.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	3.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	3.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-12
Probability Decision Tree: Surface Water Systems Serving 501-1,000 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	>90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	19.0	19.0	8.0
4	Modify Coagulation/Filtration and pre-oxidation	73.0	73.0	36.0
5	Anion Exchange (25 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	8.0	8.0	16.0
6	Anion Exchange (150 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	0.0	0.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-watering/non-hazardous landfill waste disposal and pre-oxidation	0.0	0.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backwash stream	0.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	16.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW waste disposal and corrosion control and pre-oxidation	0.0	0.0	12.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	12.0
23	POE Activated Alumina and corrosion control and pre-oxidation	0.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	0.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	0.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-13
Probability Decision Tree: Surface Water Systems Serving 1,001-3,300 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	≥90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	16.0	16.0	8.0
4	Modify Coagulation/Filtration and pre-oxidation	76.0	76.0	35.0
5	Anion Exchange (25 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	8.0	8.0	16.0
6	Anion Exchange (150 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	0.0	0.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	0.0	0.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backw ash stream	0.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	16.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	13.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	12.0
23	POE Activated Alumina and corrosion control and pre-oxidation	0.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	0.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	0.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-14
Probability Decision Tree: Surface Water Systems Serving 3,301-10,000 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL		
		<50%	50-90%	≥90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	7.0	7.0	3.0
4	Modify Coagulation/Filtration and pre-oxidation	85.0	85.0	42.0
5	Anion Exchange (25 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	8.0	8.0	16.0
6	Anion Exchange (150 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	0.0	0.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	0.0	0.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backw ash stream	0.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	16.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	12.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	11.0
23	POE Activated Alumina and corrosion control and pre-oxidation	0.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	0.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	0.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-15
Probability Decision Tree: Surface Water Systems Serving 10,001-50,000 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	>90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	8.0	8.0	4.0
4	Modify Coagulation/Filtration and pre-oxidation	92.0	92.0	48.0
5	Anion Exchange (25 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	16.0
6	Anion Exchange (150 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	0.0	0.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	0.0	0.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backw ash stream	0.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	16.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	8.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	8.0
23	POE Activated Alumina and corrosion control and pre-oxidation	0.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	0.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	0.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-16
Probability Decision Tree: Surface Water Systems Serving 50,001-100,000 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	>90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	5.0	5.0	2.0
4	Modify Coagulation/Filtration and pre-oxidation	85.0	85.0	42.0
5	Anion Exchange (25 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	16.0
6	Anion Exchange (150 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	5.0	5.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	5.0	5.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backw ash stream	0.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	16.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	12.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	12.0
23	POE Activated Alumina and corrosion control and pre-oxidation	0.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	0.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	0.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Exhibit A-17
Probability Decision Tree: Surface Water Systems Serving 100,001-1,000,000 People

No.	Treatment Technology Train	Percent of Treatment Required to Achieve MCL <50%	50-90%	>90%
1	Regionalization	0.0	0.0	0.0
2	Alternate Source	0.0	0.0	0.0
3	Modify Lime Softening and pre-oxidation	5.0	5.0	2.0
4	Modify Coagulation/Filtration and pre-oxidation	94.0	94.0	47.0
5	Anion Exchange (25 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	16.0
6	Anion Exchange (150 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
7	Anion Exchange (25 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
8	Anion Exchange (150 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
9	Activated Alumina (2,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
10	Activated Alumina (10,000 BV) and non-hazardous landfill (for spent media) and pre-oxidation	0.0	0.0	0.0
11	Reverse Osmosis and direct discharge w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
12	Reverse Osmosis and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	0.0
13	Reverse Osmosis and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
14	Coagulation Assisted Microfiltration and mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	1.0	1.0	0.0
15	Coagulation Assisted Microfiltration and non-mechanical de-w atering/non-hazardous landfill w aste disposal and pre-oxidation	0.0	0.0	0.0
16	Oxidation Filtration (Greensand) and POTW for backw ash stream	0.0	0.0	0.0
17	Anion Exchange (25 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	16.0
18	Anion Exchange (150 mg/l SO4) and chemical precipitation/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	0.0
19	Activated Alumina (2,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
20	Activated Alumina (10,000 BV) and POTW/non-hazardous landfill and pre-oxidation	0.0	0.0	0.0
21	Anion Exchange (90 mg/l SO4) and POTW w aste disposal and corrosion control and pre-oxidation	0.0	0.0	10.0
22	Anion Exchange (90 mg/l SO4) and evaporation pond/non-hazardous landfill and corrosion control and pre-oxidation	0.0	0.0	9.0
23	POE Activated Alumina and corrosion control and pre-oxidation	0.0	0.0	0.0
24	POU Reverse Osmosis and pre-oxidation	0.0	0.0	0.0
25	POU Activated Alumina and pre-oxidation	0.0	0.0	0.0
	Sum of Probabilities:	**100.00**	**100.00**	**100.00**

Appendix B: Bladder Cancer Risk Analysis

B.1 Community Water Systems

In order to calculate the number of bladder cancer cases avoided due to each regulatory option, EPA developed a Monte-Carlo based risk model. This model is summarized in Chapter 5. This appendix provides a more detailed description of the risk analysis, including the assumptions and calculations used in the analysis.

The following sections explain how we calculated risk reductions for populations exposed to arsenic concentrations of 3 μg/L and above in CWSs. First, the data used in the analysis will be presented. Second, the calculations used in the analysis will be explained. Finally, the results of the analysis will be explained.

B.1.1 Data Inputs

The inputs into a Monte-Carlo analysis can be separated into two categories, those data that describe variation across a population, and those data that describe uncertainty in the underlying population values. In the CWS risk analysis, two data inputs have elements of uncertainty, water consumption and the risk distributions (lifetime risk at 50 μg/L, assuming consumption of 2 L per day, and 70 kg body weight). In order to best understand the results of the analysis, it is important to separate out the effects of variation and uncertainty.

This is accomplished in the following manner. Two different distributions for water consumption are used. As described in the next section, one includes "total water consumption" and one includes "community water consumption." The former captures the upper bound of water consumption, and the latter captures the lower bound. Likewise, two different distributions for lifetime risk are used. As described below, the first captures the lower bound of lifetime risk (mean 0.731/1,000 people, 95% upper confidence limit 0.807/1,000 people) and the second captures the upper bound of lifetime risk (mean 1.237/1,000 people, 95% upper confidence limit 1.548/1,000 people). Therefore, throughout the analysis, two scenarios are carried out. The "Lower Bound" scenario uses the lower bound water consumption and lifetime risk assumptions. The "Upper Bound" scenario uses upper bound water consumption and lifetime risk assumptions. The range of results within one scenario represent the variation within the population. The difference in results between the two scenarios captures the uncertainty in the risk analysis.

B.1.1.1 Water Consumption

EPA recently updated its estimates of personal (per capita) daily average estimates of water consumption (*Estimated per Capita Water Consumption in the United States*, external review draft, EPA 1999). The estimates used data from the combined 1994, 1995, and 1996 Continuing Survey of Food Intakes by Individuals (CSFII), conducted by the U.S. Department of Agriculture

(USDA). The CSFII is a complex, multistage area probability sample of the entire U.S. and is conducted to survey the food and beverage intake of the U.S. Estimates of water consumed include “Community Water” and “Total Water.” Community Water includes water consumed directly as a beverage as well as water added to foods and beverages during final preparation at home or by food service establishments such as school cafeterias and restaurants. “Total” includes Community Water plus bottled water (see Exhibit B-1).

Exhibit B-1
Source of Water Consumed

Source	Direct (drinking)	Indirect (from food and beverages)	Bottled water
Community Water	X	X	
Total Water	X	X	X

Water consumption estimates for selected subpopulations in the U.S. are described in the analysis, including per capita water consumption by source for gender, region, age categories, economic status, race, and residential status and separately for pregnant women, lactating women, and women in childbearing years. The water consumption estimates by age and sex were used in the computation of bladder cancer cases avoided, and are shown in Exhibits B-2 through B-21.

Exhibit B-2
Water Consumption (ml) Male Less Than 1 Year Old (Lower Bound)

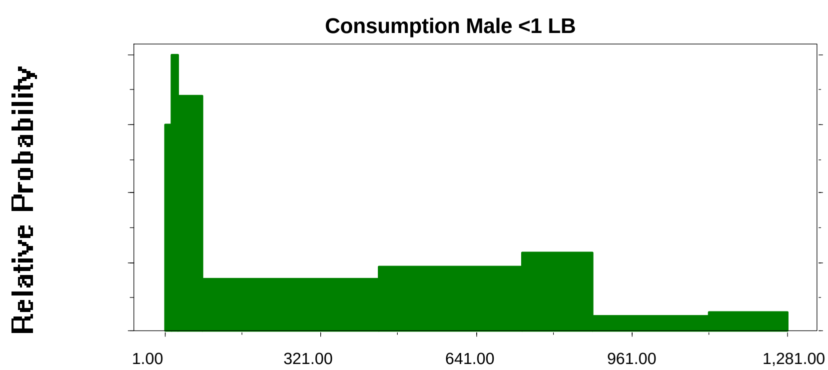


Exhibit B-3
Water Consumption (ml) Male 1-10 Years Old (Lower Bound)

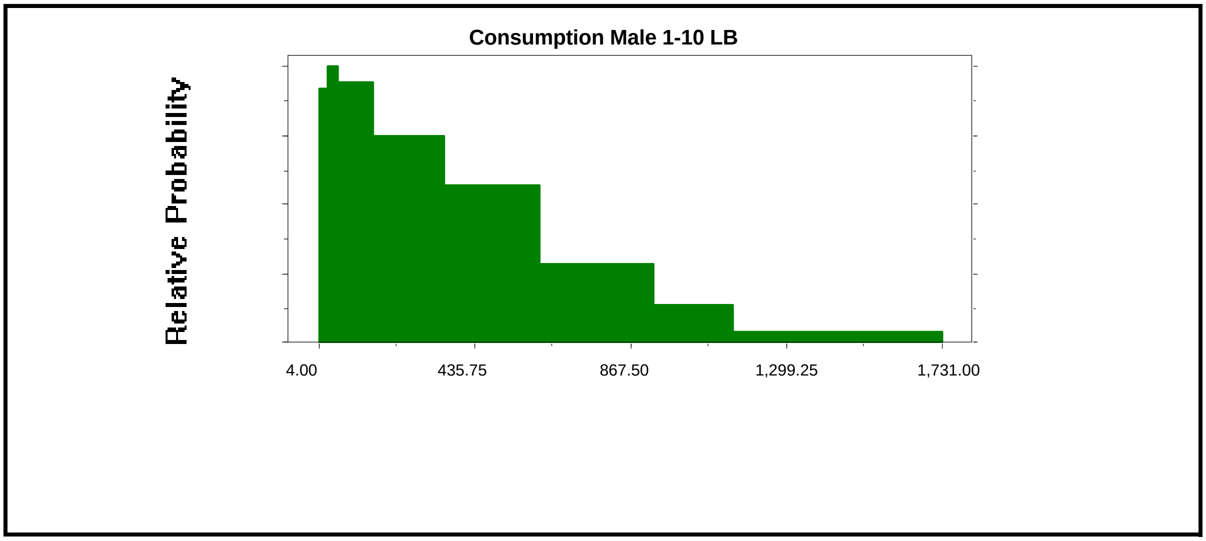


Exhibit B-4
Water Consumption (ml) Male 11-19 Years Old (Lower Bound)

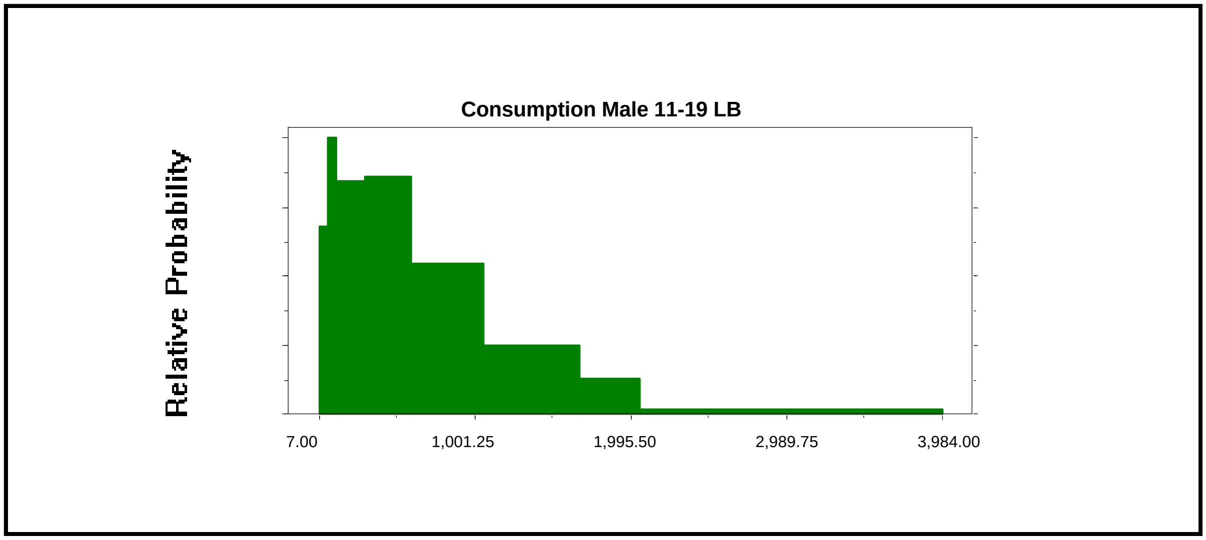


Exhibit B-5
Water Consumption (ml) Male 20-64 Years Old (Lower Bound)

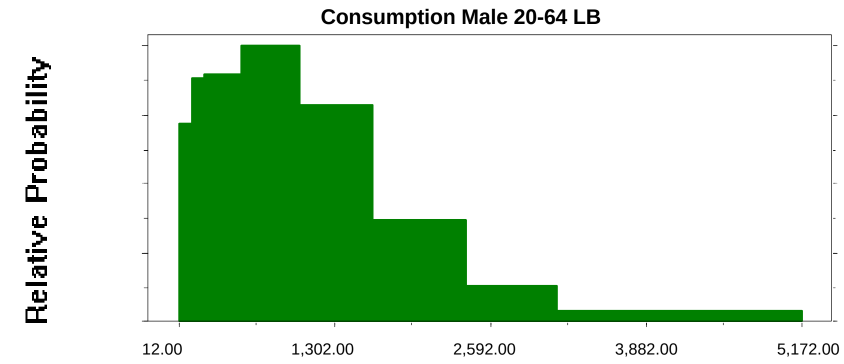


Exhibit B-6
Water Consumption (ml) Male Over 64 Years Old (Lower Bound)

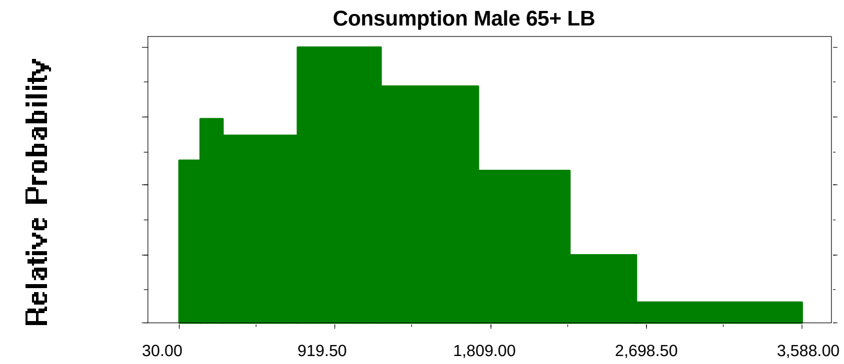


Exhibit B-7
Water Consumption (ml) Male Under 1 Year Old (Upper Bound)

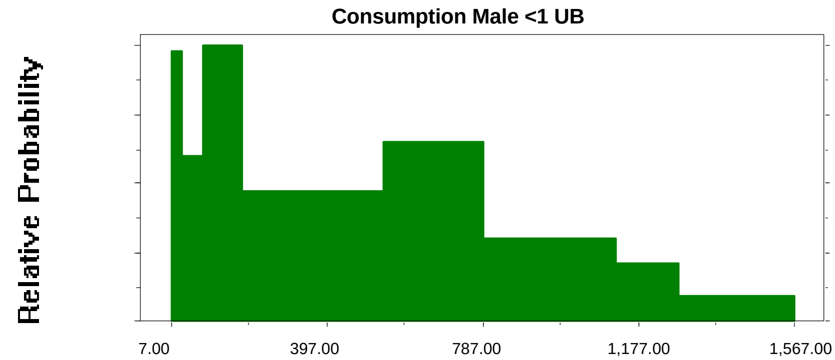


Exhibit B-8
Water Consumption (ml) Male 1-10 Years Old (Upper Bound)

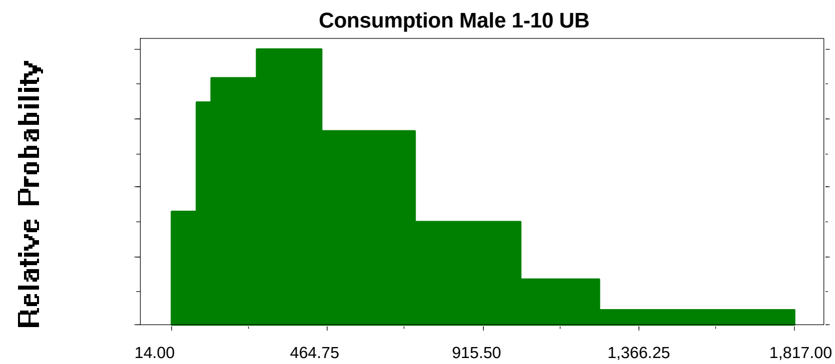


Exhibit B-11
Water Consumption (ml) Male Over 64 Years Old (Upper Bound)

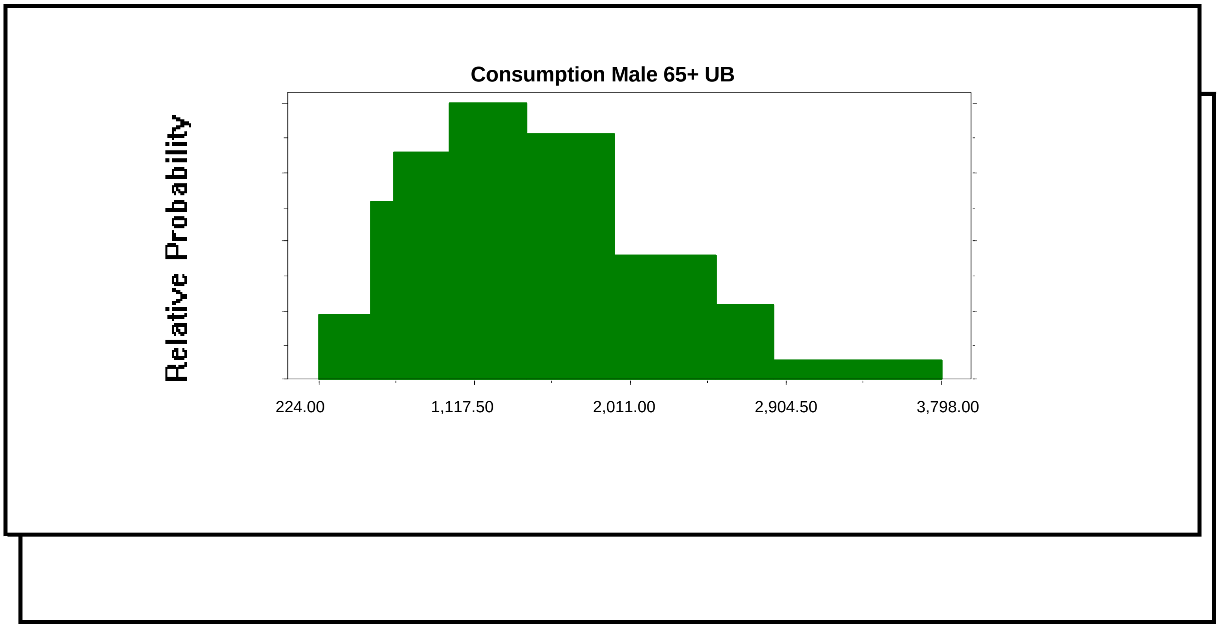


Exhibit B-10
Water Consumption (ml) Male 20-64 Years Old (Upper Bound)

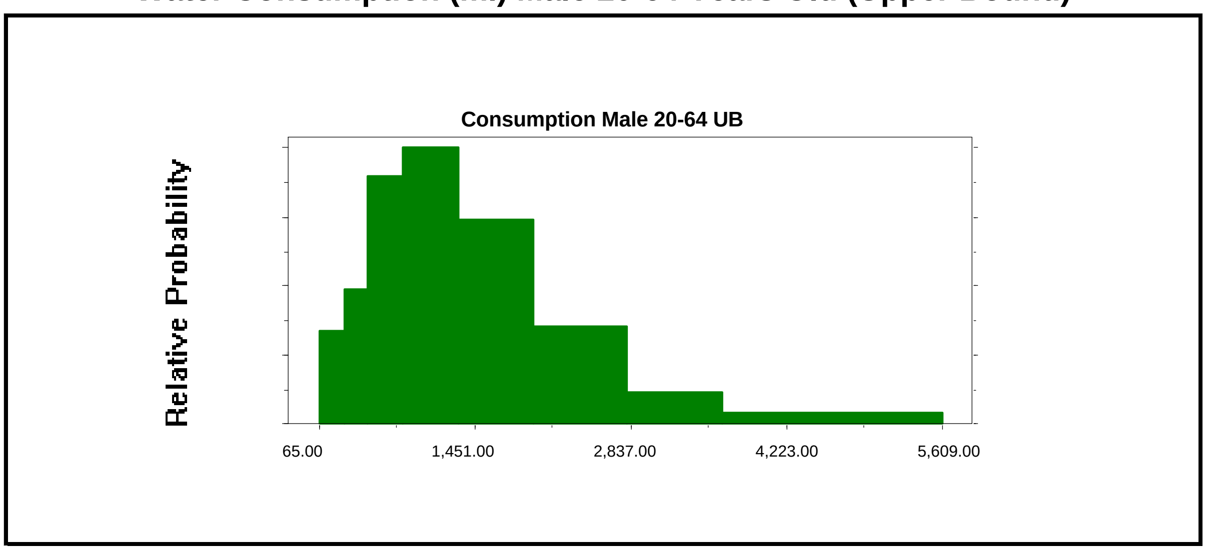


Exhibit B-12
Water Consumption (ml) Female Under 1 Year Old (Lower Bound)

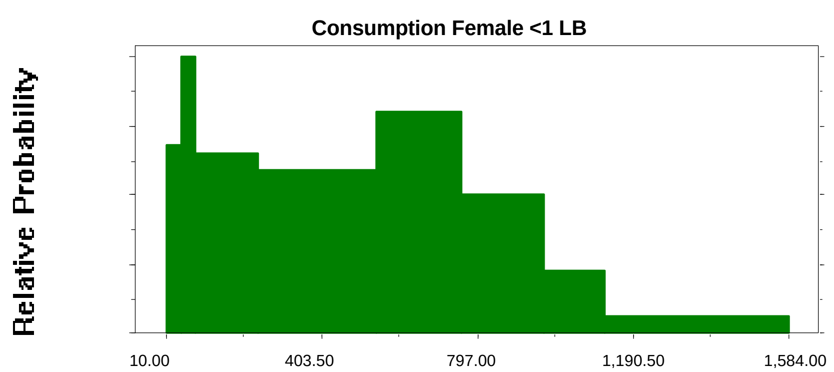


Exhibit B-13
Water Consumption (ml) Female 1-10 Years Old (Lower Bound)

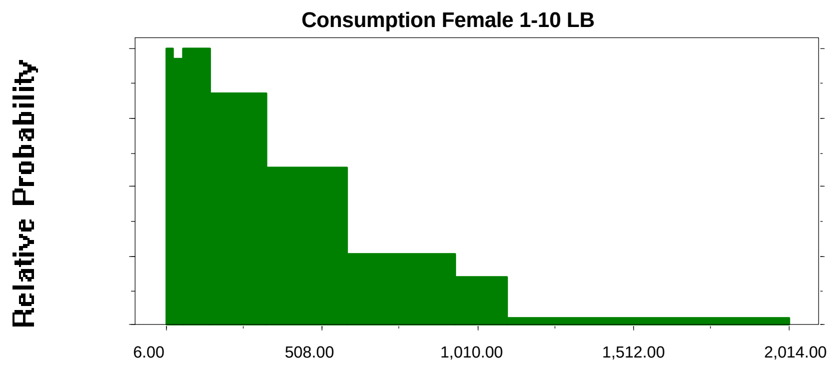


Exhibit B-14
Water Consumption (ml) Female 11-19 Years Old (Lower Bound)

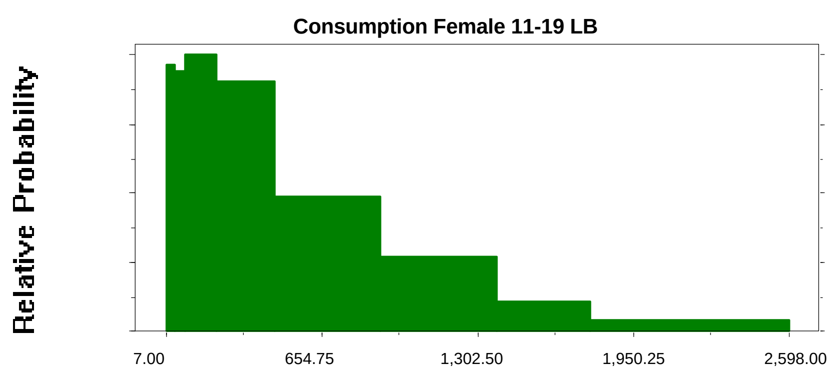


Exhibit B-15
Water Consumption (ml) Female 20-64 Years Old (Lower Bound)

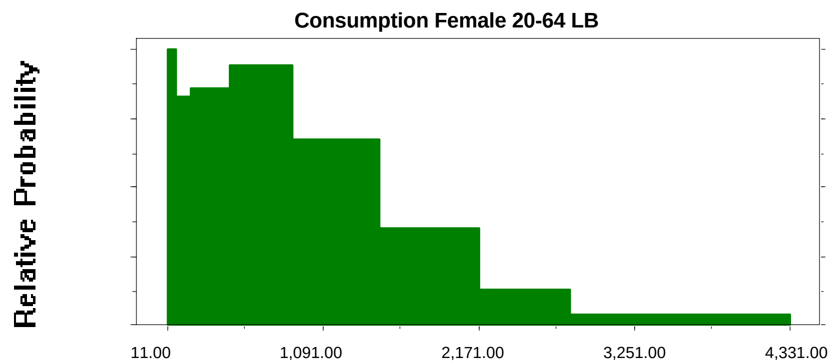


Exhibit B-16
Water Consumption (ml) Female Over 64 Years Old (Lower Bound)

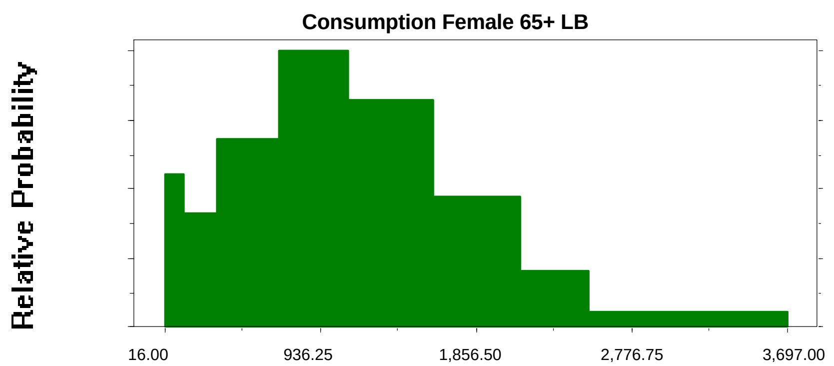


Exhibit B-17
Water Consumption (ml) Female Under 1 Year Old (Upper Bound)

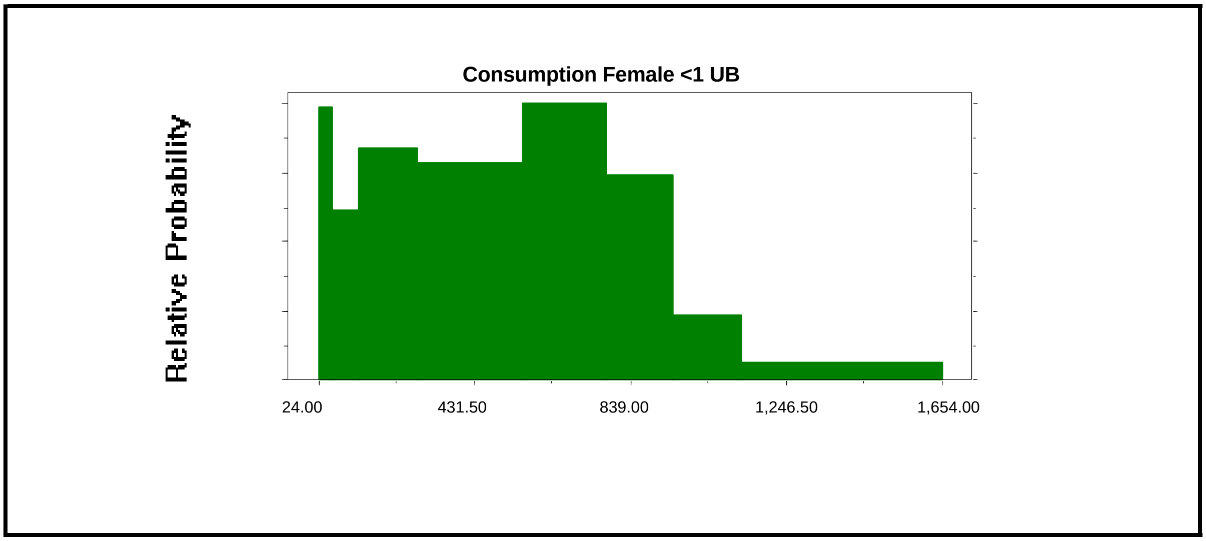


Exhibit B-18
Water Consumption (ml) Female 1-10 Years Old (Upper Bound)

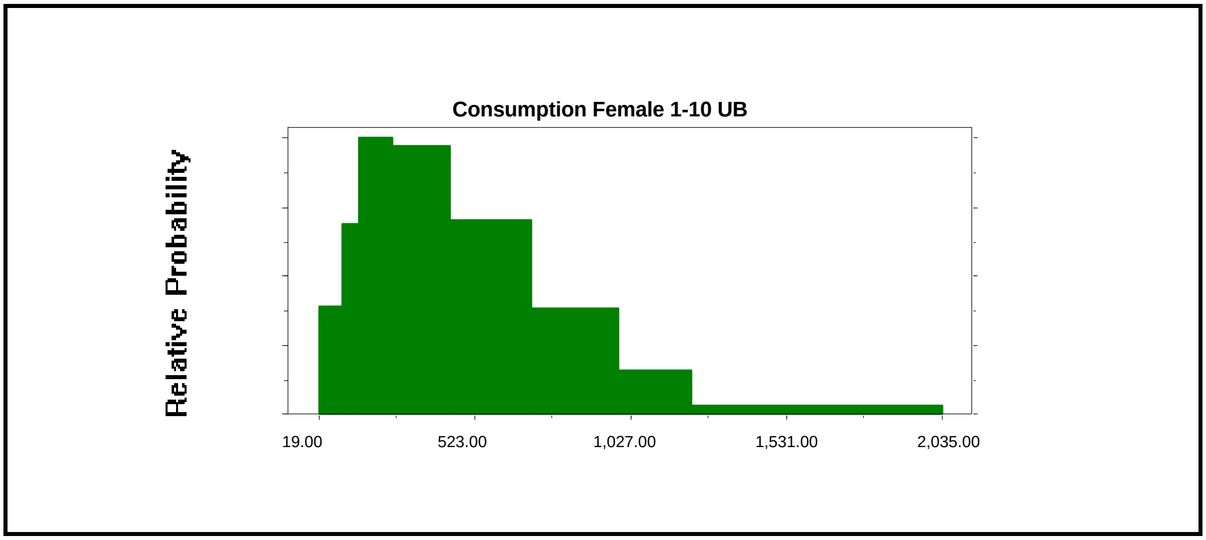


Exhibit B-19
Water Consumption (ml) Female 11-19 Years Old (Upper Bound)

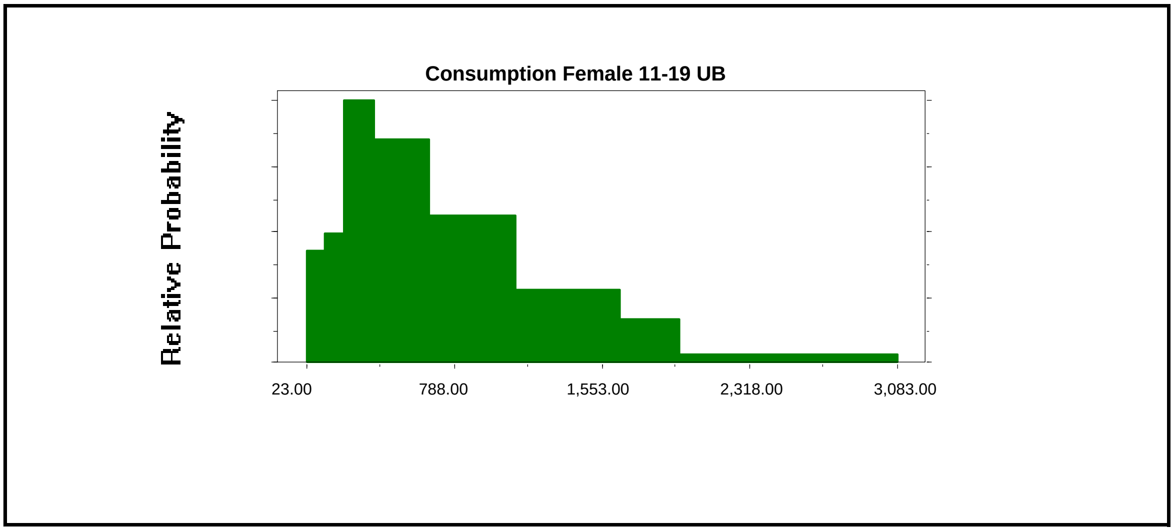


Exhibit B-20
Water Consumption (ml) Female 20-64 Years Old (Upper Bound)

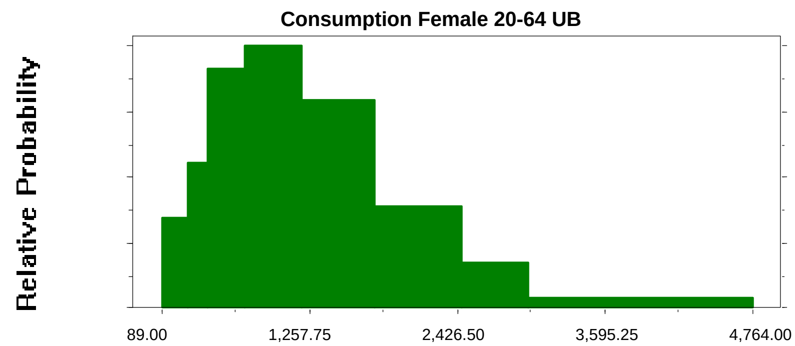
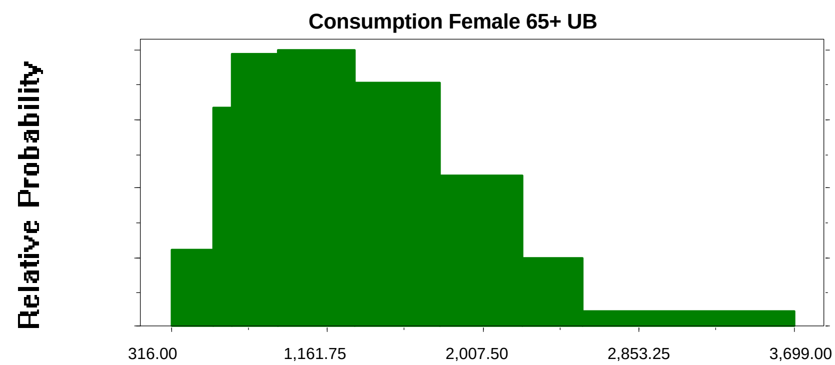


Exhibit B-21
Water Consumption (ml) Female Over 64 Years Old (Upper Bound)



B.1.1.2 Body Weight

In this analysis, EPA used body weight data from the U.S. census (DOC, 1999). The body weight data included a mean and a distribution of weight for male and females on a year-to-year basis throughout a lifetime (70 years). These data were used to develop statistical distributions of body weight for each sex and age category included in the water consumption study discussed above. The body weight distributions are provided in Exhibits B-22 through B-31.

Exhibit B-22
Body Weight (kg) Male Less Than 1 Year Old

Normal distribution with parameters:

Mean	9.4
Standard Dev.	1.3

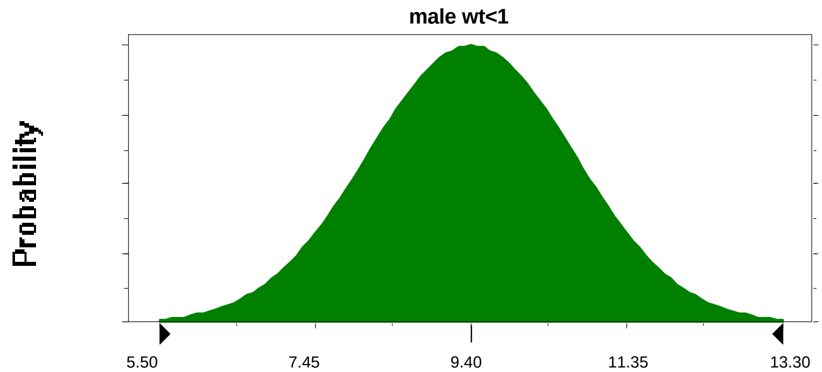


Exhibit B-23
Body Weight (kg) Male 1-10 Years Old

Normal distribution with parameters:

Mean	22.1
Standard Dev.	1.4

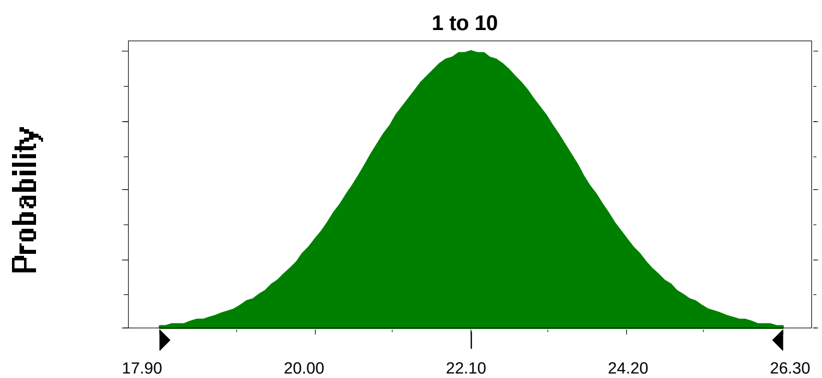


Exhibit B-24
Body Weight (kg) Male 11-19 Years Old

Normal distribution with parameters:

Mean	58.5
Standard Dev.	3.8

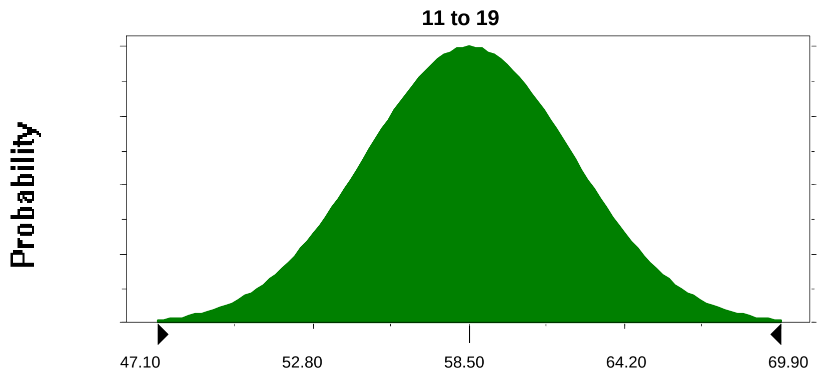


Exhibit B-25
Body Weight (kg) Male 20-64 Years Old

Normal distribution with parameters:

Mean	79.1
Standard Dev.	6.3

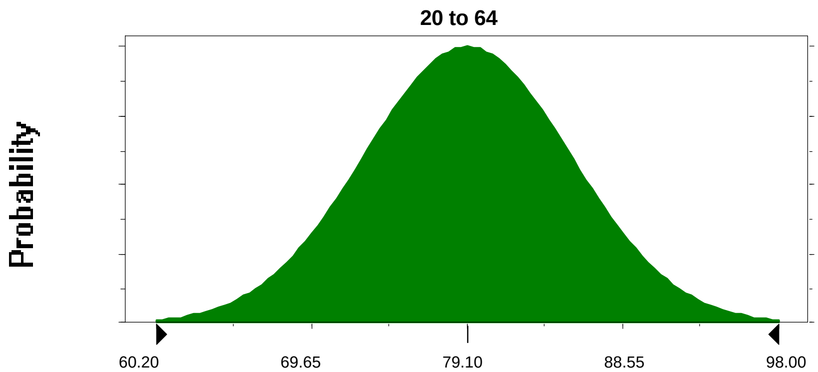


Exhibit B-26
Body Weight (kg) Male Over 64 Years Old

Normal distribution with parameters:

Mean	74.8
Standard Dev.	12.8

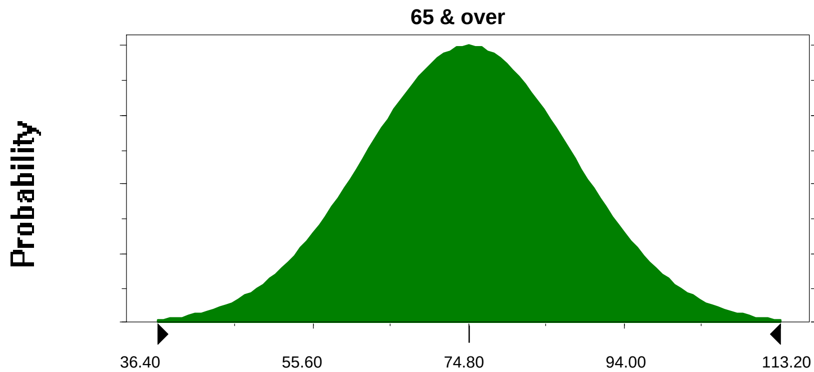


Exhibit B-27
Body Weight (kg) Female Under 1 Year Old

Normal distribution with parameters:

Mean	8.8
Standard Dev.	1.2

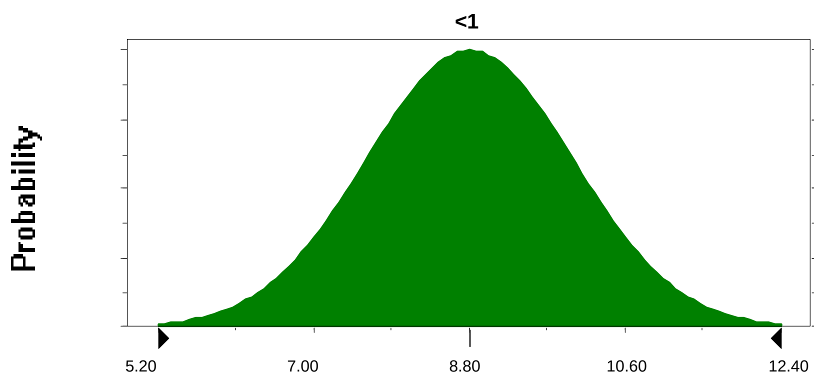


Exhibit B-28
Body Weight (kg) Female 1-10 Years Old

Normal distribution with parameters:

Mean	21.6
Standard Dev.	1.5

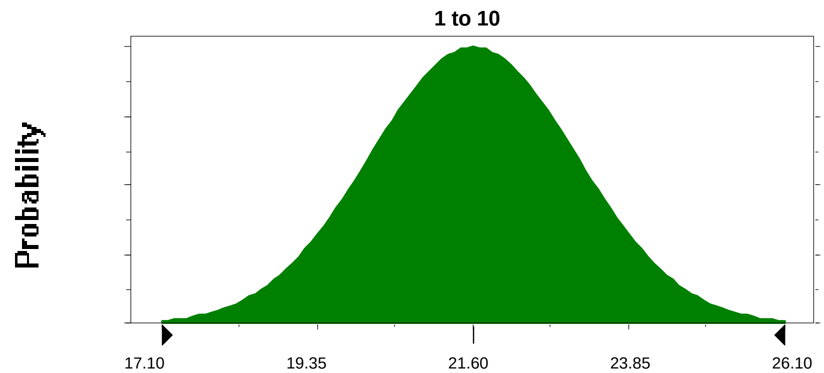


Exhibit B-29
Body Weight (kg) Female 11-19 Years Old

Normal distribution with parameters:

Mean	53.8
Standard Dev.	3.6

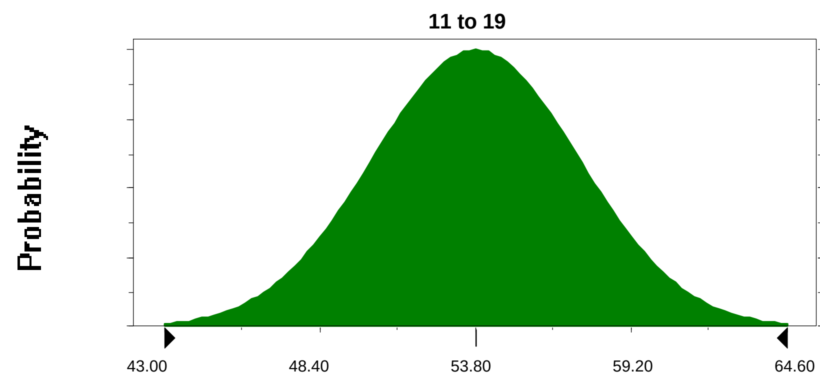


Exhibit B-30
Body Weight (kg) Female 20-64 Years Old

Normal distribution with parameters:

Mean	65.8
Standard Dev.	7

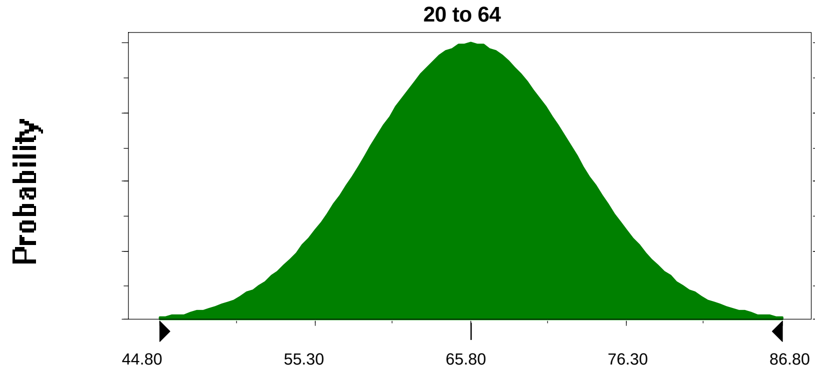
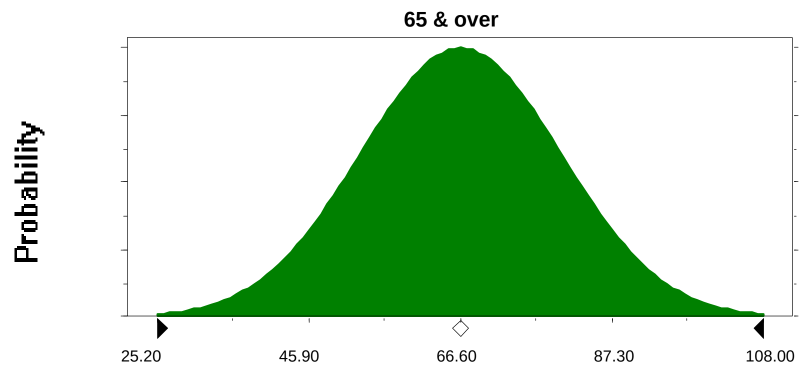


Exhibit B-31
Body Weight (kg) Female Over 64 Years Old

Normal distribution with parameters:

Mean	66.6
Standard Dev.	13.8



B.1.1.3 Lifetime Risk of Bladder Cancer

In its 1999 report, *Arsenic in Drinking Water*, the National Research Council (NRC) analyzed bladder cancer risks using data from Taiwan. In addition, NRC examined evidence from human epidemiological studies in Chile and Argentina, and concluded that risks of bladder and lung cancer were comparable to those "in Taiwan at comparable levels of exposure (NRC 1999, page 7)." The NRC also examined the implications of applying different mathematical procedures to the newly available Taiwanese data for the purpose of characterizing bladder cancer risk.

These risk distributions are based on bladder cancer mortality data in Taiwan, in a section of Taiwan where arsenic concentrations in the water are very high by comparison to those in the U.S. It is also an area of very low incomes and poor diets, and the availability and quality of medical care is not of high quality, by U.S. standards. In its estimate of bladder cancer risk, the Agency assumed, that within the Taiwanese study area, the risk of contracting bladder cancer was relatively close to the risk of dying from bladder cancer (that is, that the bladder cancer morbidity rate was equal to the bladder cancer mortality rate).[1]

In the NRC report, two tables are provided which provide six lifetime risk distributions at the current MCL of 50 ug/L, which EPA's senior scientist feel are appropriate to use in this risk analysis. Table 10-11 of the report shows three risk estimates based on the Taiwanese male bladder cancer data, using a Poisson regression model (the models differ based on assumptions regarding the availability of baseline data about the exposed population). The means of the risk distributions are 0.731, 0.911, and 1.049 per 1,000 people. Table 10-12 of the report presents excess lifetime risk estimates at the current MCL of 50 ug/L for bladder cancer in males calculated using EPA's 1996 proposed revisions to the cancer guidelines (EPA 1996) (the models differ based on assumptions regarding the availability of baseline data about the exposed population). The means of these distributions are: 1.237, 1.129, and 1.111 cases per 1,000 people.

EPA has no means by which to choose one of these lifetime risk estimates over the other, therefore, as mentioned above, the Agency has chosen to estimate the range of uncertainty concerning the lifetime risk estimates. This was done by using the lowest lifetime risk estimate in the "Lower Bound" scenario, and using the highest lifetime risk estimate in the "Upper Bound" scenario. These risk estimates are shown in Exhibits B-32 And B-33 respectively.

---

[1] We do not have data on the rates of survival for bladder cancer in the Taiwanese villages in the study and at the time of data collection. We do know that the relative survival rates for bladder cancer in developing countries overall ranged from 23.5% to 66.1 % in 1982-1992 ("Cancer Survival in Developing Countries," International Agency for Research on Cancer, World Health Organization, Publication No. 145, 1998). The age-adjusted annual incidence rates of bladder cancer in Taiwan in 1996 for males and females, respectively, were 7.36 and 3.09 per 100,000, with corresponding annual mortality rates of 3.21 and 1.44 per 100,000 (correspondence from Chen to Herman Gibb, January 3, 2000).

Exhibit B-32
Lifetime Bladder Cancer Risk at 50 μg/L per 1,000 people (Lower Bound)

Normal distribution with parameters:

Mean	0.731
Standard Dev.	0.0388

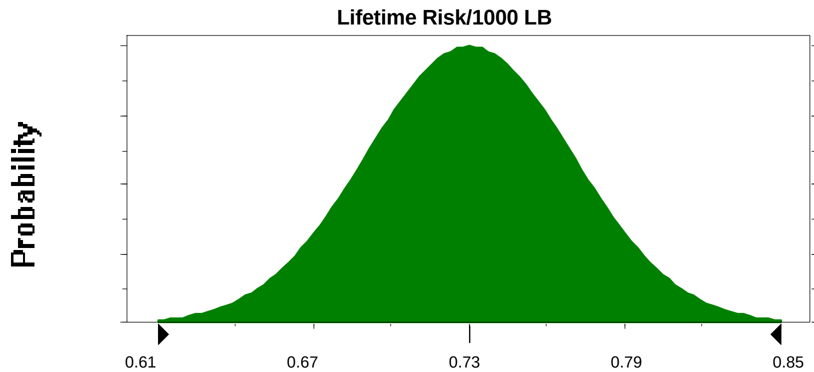
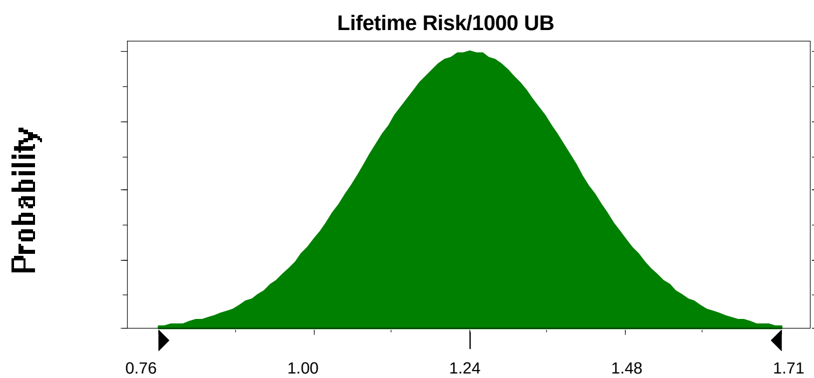


Exhibit B-33
Lifetime Bladder Cancer Risk at 50 μg/L per 1,000 People (Upper Bound)

Normal distribution with parameters:

Mean	1.237
Standard Dev.	0.159



B.1.1.4 Arsenic Occurrence Estimates

EPA used statistical techniques to assess the national distribution of mean arsenic concentrations in water systems. A detailed explanation of the occurrence data used in the risk analysis can be found in the *Occurrence and Exposure Document for the Arsenic in Drinking Water Rule* (EPA, 1999). For each MCL under consideration, the Post-Compliance Exposure Distribution at different concentrations (µg/L) is provided in Exhibits B-34 to B-38 for ground water and Exhibits B-39 to B-43 for surface water. Two important caveats should be mentioned. First, the risk analysis only applies to persons exposed to arsenic concentrations at or above 3 µg/L. This represents the feasible range (at concentrations below this level, arsenic concentrations can not be accurately measured). Second, for each MCL, it is assumed that all systems will provide finished water with a maximum concentration equal to 80 percent of the MCL. This assumption is consistent with industry practice, and the same assumption was made in the calculation of the proposed rule's costs.

Exhibit B-34
Post-Compliance Exposure Distribution (µg/L) at MCL= 50 µg/L
(Ground Water)

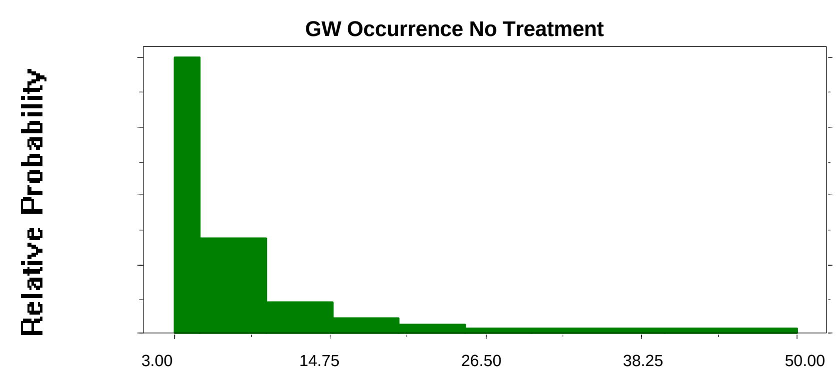


Exhibit B-35
Post-Compliance Exposure Distribution (μg/L) at MCL= 20 μg/L
(Ground Water)

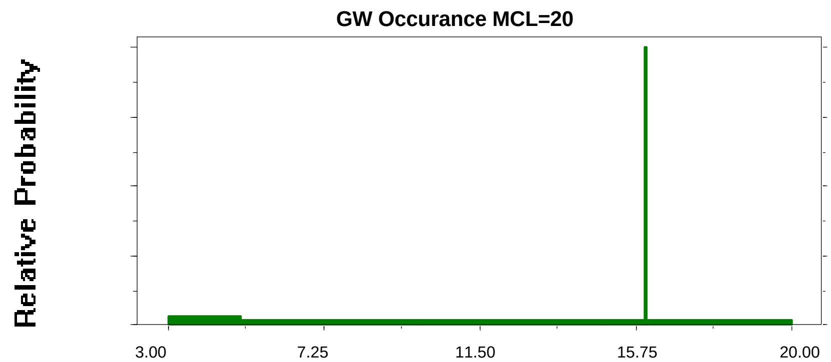


Exhibit B-36
Post-Compliance Exposure Distribution (μg/L) at MCL= 10 μg/L
(Ground Water)

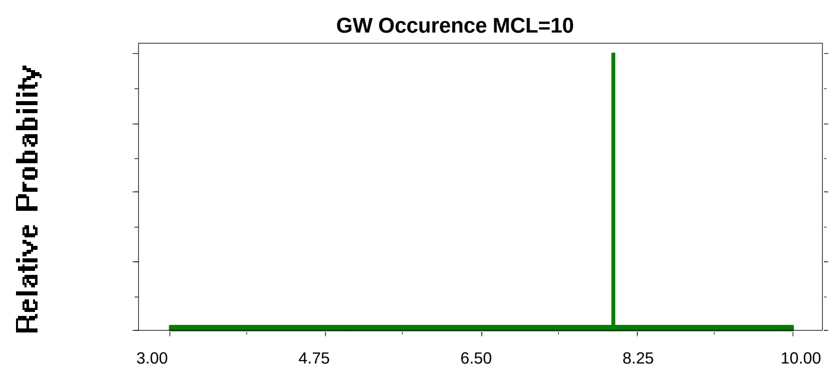


Exhibit B-37
Post-Compliance Exposure Distribution (μg/L) at MCL= 5 μg/L
(Ground Water)

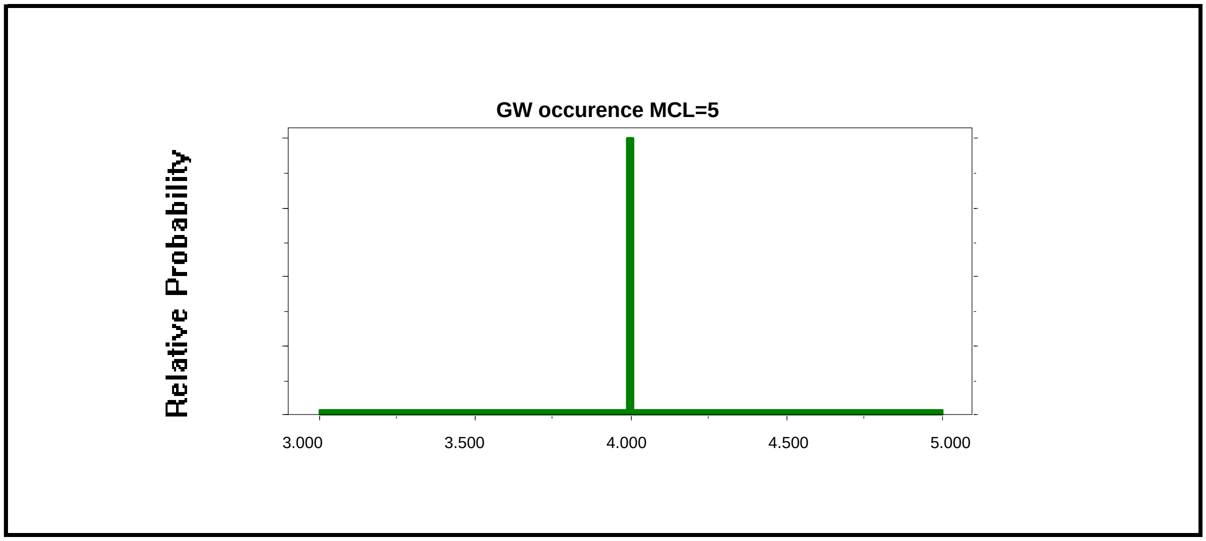


Exhibit B-38
Post-Compliance Exposure Distribution (μg/L) at MCL= 3 μg/L
(Ground Water)

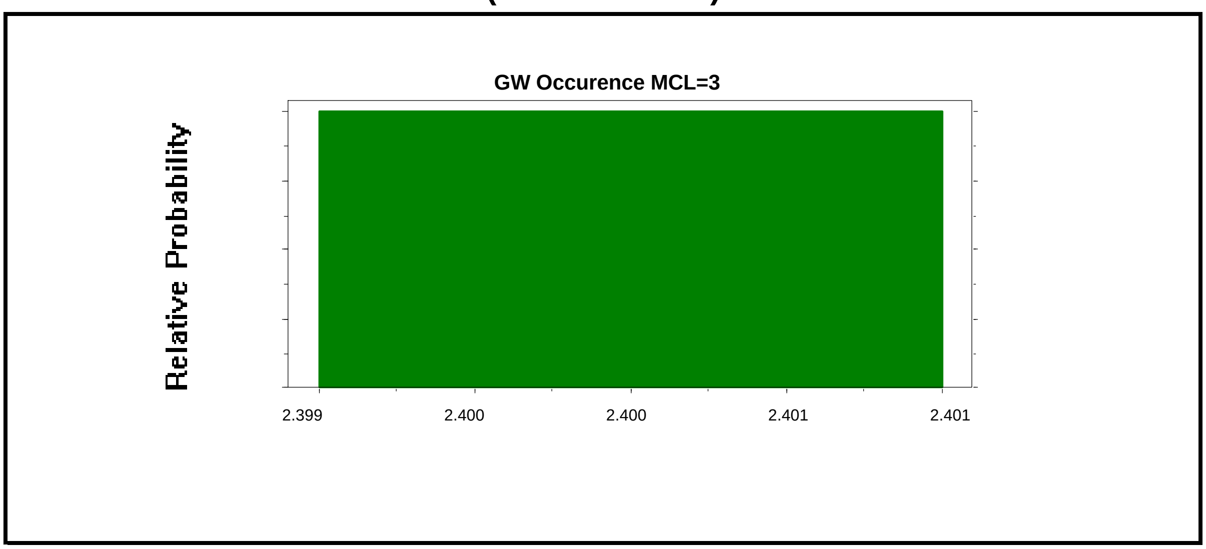


Exhibit B-39
Post-Compliance Exposure Distribution (μg/L) at MCL= 50 μg/L
(Surface Water)

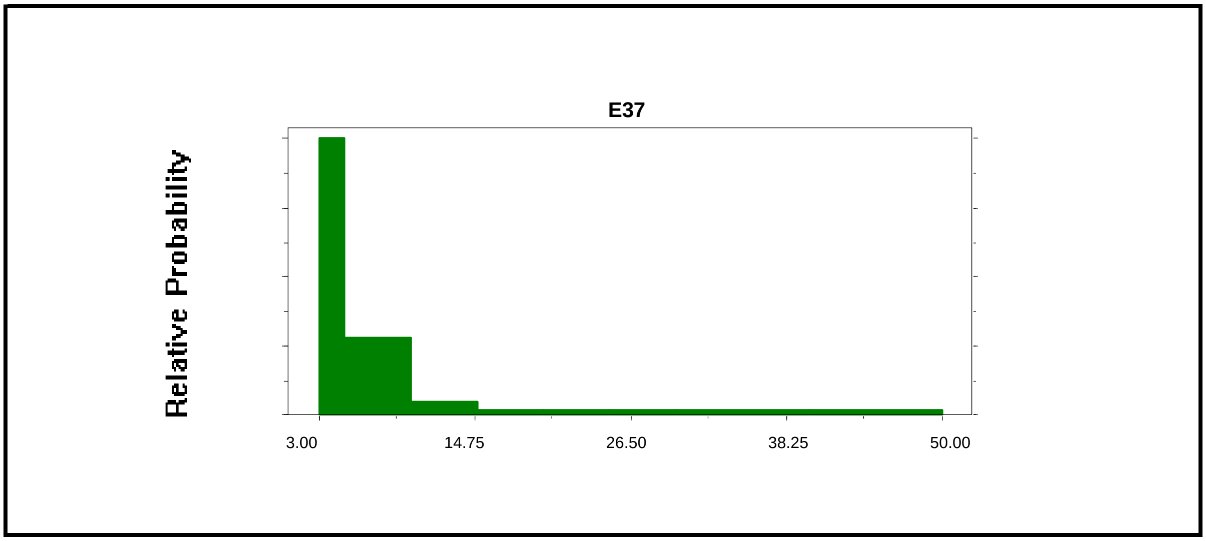


Exhibit B-40
Post-Compliance Exposure Distribution (μg/L) at MCL= 20 μg/L
(Surface Water)

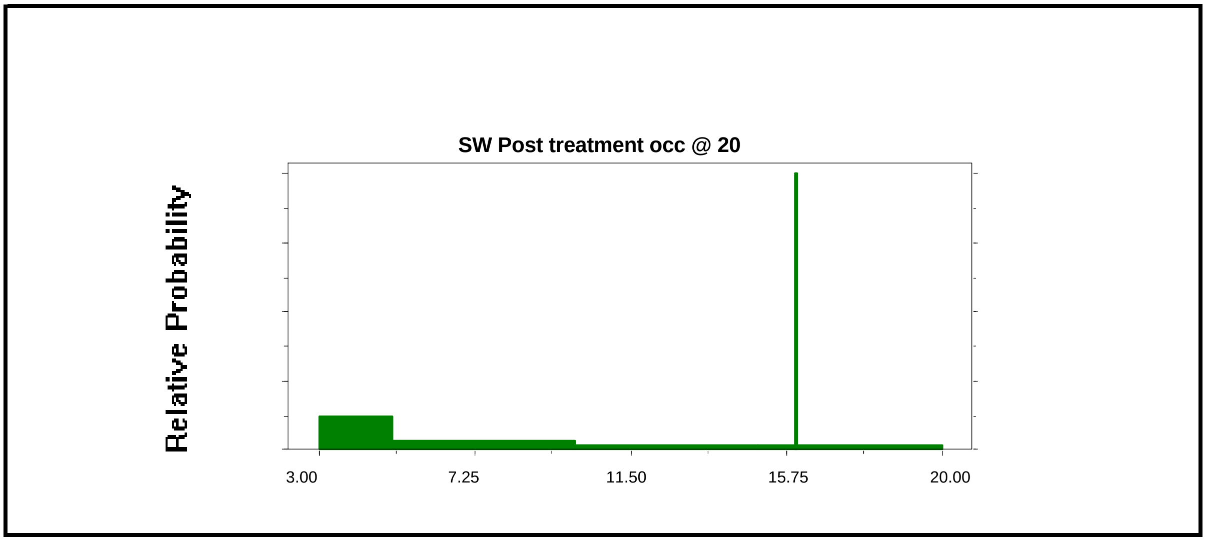


Exhibit B-41
Post-Compliance Exposure Distribution (μg/L) at MCL= 10 μg/L
(Surface Water)

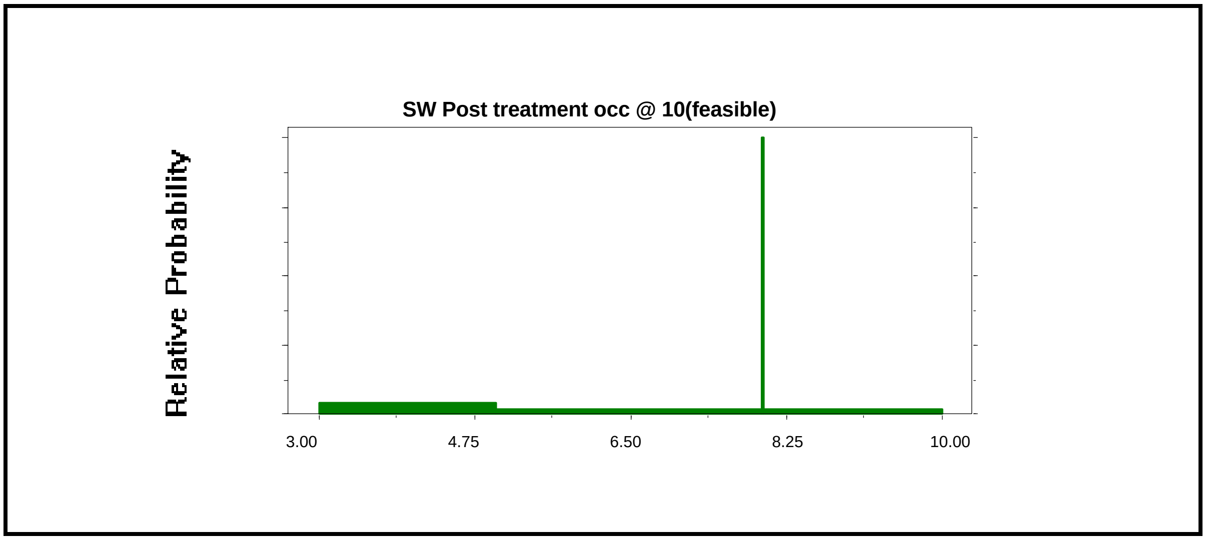


Exhibit B-42
Post-Compliance Exposure Distribution (μg/L) at MCL= 5 μg/L
(Surface Water)

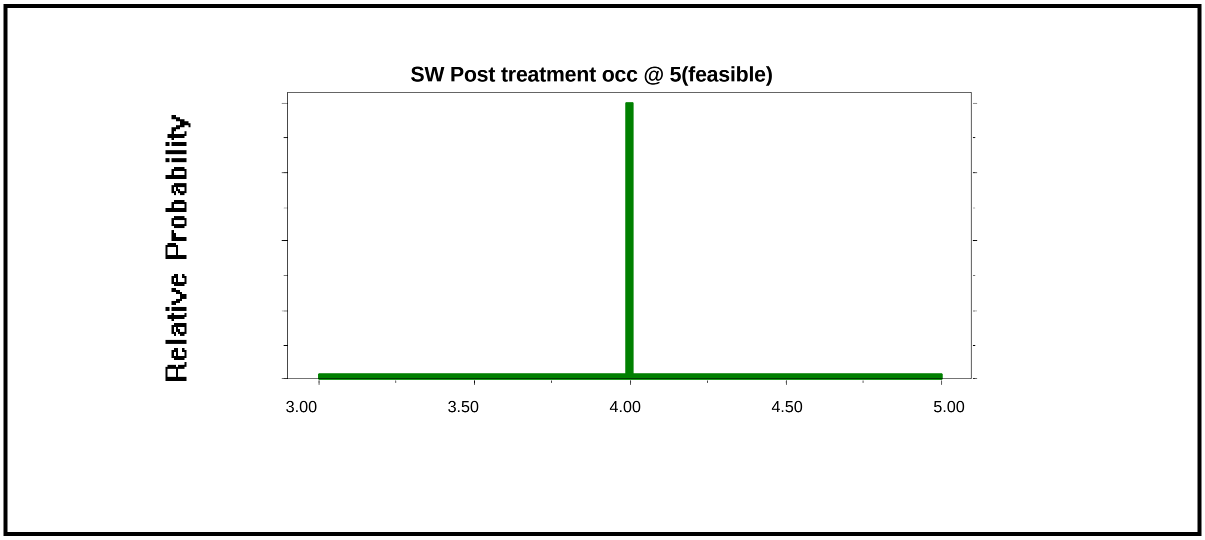
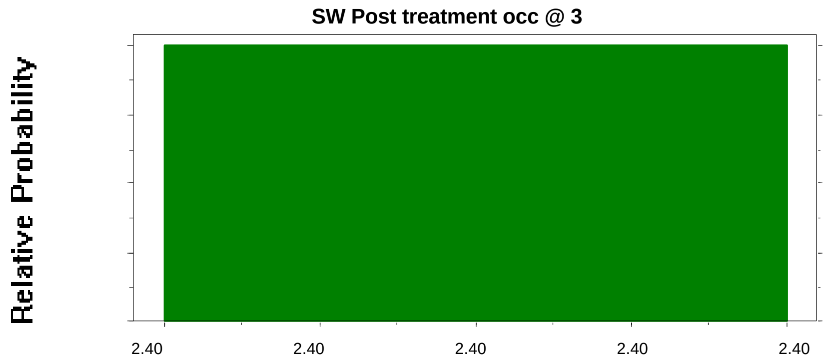


Exhibit B-43
Post-Compliance Exposure Distribution (μg/L) at MCL= 3 μg/L
(Surface Water)



B.1.1.5 CWS Population Affected

As mentioned above, the target population for the CWS risk analysis is people exposed to arsenic at levels at or above 3 μg/L, as this is considered the feasible level. Exhibit B-44 provides the population served by both surface water and ground water CWSs. In addition, the percentage of people served that are exposed at arsenic levels above 3 μg/L is provided. Ground water systems with finished water concentration above the minimum feasible level serve 16.5 million people, while surface water systems with finished water above 3 μg/L serve 10.1 million people, for a total exposed population of 26.7 million people. Systems serving over1 million people were identified from a system-by-system data collection.

Exhibit B-44
Total Population Served by Water Systems
By Source Water, System Type and Service Population Category

Service Population Category	Community	
	Groundwater	Surface Water
< 100	859,777	61,450
101–500	3,741,017	570,448
501–1,000	3,457,163	921,449
1,001–3,300	10,631,422	4,797,855
3,301–10,000	14,095,015	10,995,980
10,001–50,000	25,004,779	36,819,575
50,001–100,000	8,609,455	20,500,370
100,001-1,000,000	14,575,556	65,375,183
> 1,000,000	2,855,494	28,658,586
Total Population Served	**83,829,678**	**168,700,896**
Percentage of Population Over 3μg/L	19.70%	6.01%
Population Served Over 3μg/L By Source Type	16,514,447	10,138,923
Total Population Served Over 3μg/L	26,653,370	
SOURCE PERCENTAGE (Percentage of Total Population Served Over 3μg/L)	62%	38%

Source: Safe Drinking Water Information System (SDWIS), December 1998 freeze.

In addition, since the daily water consumption and body weight associated with each age category varies by sex, it is necessary to know the percentage of the population made up by each sex. In this risk analysis, it is assumed that 51.9 percent of the population is female, and 48.1 percent is male (DOC, 1999).

B.1.2 CWS Risk Model

The CWS risk analysis is a Monte-Carlo based simulation model. This section will explain each step is the simulation. The Monte-Carlo simulation is conducted at each MCL option (50, 20, 10, 5 and 3 μg/L). In addition, for each MCL option, the simulation is carried out for both the “Lower Bound” and “Upper Bound” scenarios discussed above. Therefore, the simulation model is carried out ten times. Each of these ten “runs” of the model is independent of the other, and can be discussed in isolation. Therefore, this section will include a generalized discussion of the model. The inputs that are used will depend on the MCL option and scenario being evaluated. It is important not to confuse a “run” of the model” as just described, with a model iteration. Each run of the model consists of 10,000 iterations. Within a single iteration, the model pulls a value for each variable from its input distribution (e.g. body weight) and calculates a value for each output variable (e.g. lifetime risk). This is done 10,000 times for each model run. The results of the model run is the distribution of the 10,000 values for each output variable.

The first step of each iteration is to calculate the relative exposure factor for each sex and age category. As shown in the following equation, the relative exposure factor is a function of daily water consumption and body weight.

$$REF_{mai} = \left(\frac{70}{2}\right) * \left(\frac{C_{mai}}{W_{mai}}\right)$$

$$REF_{fai} = \left(\frac{70}{2}\right) * \left(\frac{C_{fai}}{W_{fai}}\right)$$

where;

REF	= relative exposure factor
C	= daily water consumption (L)
W	= body weight (kg)
i	= model iteration number
a	= age category
m	= male
f	= female

Next, lifetime relative exposure factors are calculated for each sex using the relative exposure factors and information regarding the number of years in each age catagory (e.g. a person spends nine years in the 1-10 year old age category).

$$LREF_{mi} = \left(\sum_{a} REF_{mai} * N_a\right) / 70$$

$$LREF_{fi} = \left(\sum_{a} REF_{fai} * N_a\right) / 70$$

where;

LREF	= lifetime relative exposure factor
N	= number of years in age category

The model then determines, for this iteration, if the modeled individual is a male or a female. This is done using a random number generator and information concerning the sex distribution of the population.

$$LREF_i = \begin{cases} LREF_{mi} & \text{if } RN_1 \le MP \\ LREF_{fi} & \text{otherwise} \end{cases}$$

where;

RN_1 = random number from 0 to 1
MP = percentage of the population that is male (48.1%)

For each iteration, the model assumes that the individual is consuming water from either a surface water system or a ground water system. If the individual is assumed to be associated with a surface water system, then the arsenic concentration is chosen from the surface water concentration distribution; likewise, if the person is assumed to be associated with a ground water CWS, the arsenic concentration is chosen from the ground water concentration distribution.

$$AS_i = \begin{cases} AS_{gi} & \text{if } RN_2 \le GP \\ AS_{si} & \text{otherwise} \end{cases}$$

where;

AS= concentration of arsenic (μg/L)
RN_2= random number from 0 to 1
GP= percentage of the population served by ground water (62%)

Finally, the lifetime risk of bladder cancer associated with this iteration is calculated.

$$LR_i = \left(RF_i * LREF_i * AS_i / 50\right) * 10$$

where;

LR= lifetime risk of bladder cancer per 10,000 people
RF= lifetime risk of bladder cancer per 1,000 people, assuming consumption of 2 liters per day, a body weight of 70 kg, and an arsenic concentration of 50μg/L.

In order to calculate the expected number of cancer cases associated with the model run, the mean lifetime risk is multiplied by the exposed population, as follows:

$$CA = \left(\frac{\sum_i LR_i}{N} \right) * \left(\frac{P}{10{,}000} \right)$$

where;

CA	= expected number of bladder cancer cases
P	= population
N	= number of iterations

B.1.3 CWS Bladder Cancer Risk Estimates

Exhibits B-45 through B-54 provide the results of the CWS risk analysis. These exhibits provide the mean and standard deviation of expected cases of bladder cancer per 10,000 people, as well as the full distribution of expected risk values. The results for each MCL option are provided for both the Lower and the Upper Bound Scenarios.

As mentioned above, these results can be used to calculate the expected number of bladder cancers nationwide by multiplying the mean expected risk associated with an MCL option by the exposed population (in 10,000s). Likewise, the population exposed to a certain risk threshold (e.g. 10^{-4}), at a given an MCL, can be obtained by using the distribution of expected risk values. These results are provided in Chapter 5 of this RIA.

Exhibit B-45
CWS Number of Cancer Cases per 10,000 people
Baseline Under Lower Bound Scenario

Statistics:	Value
Mean	0.85
Standard Deviation	1.06

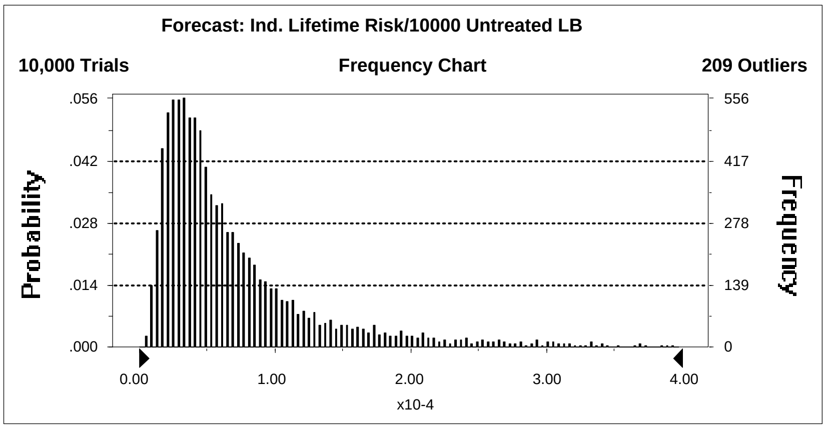


Exhibit B-46
CWS Number of Cancer Cases per 10,000 people
Baseline Under Upper Bound Scenario

Statistics:	Value
Mean	1.74
Standard Deviation	1.97

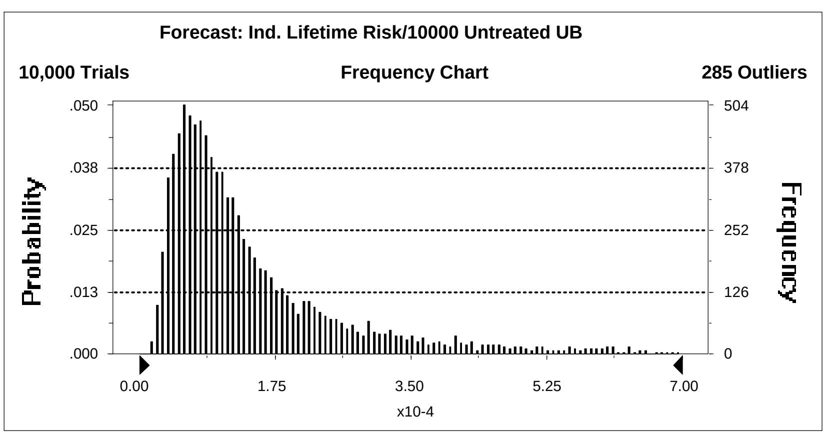


Exhibit B-47
CWS Number of Cancer Cases per 10,000 people
MCL = 20 μg/L Under Lower Bound Scenario

Statistics:	Value
Mean	0.70
Standard Deviation	0.59

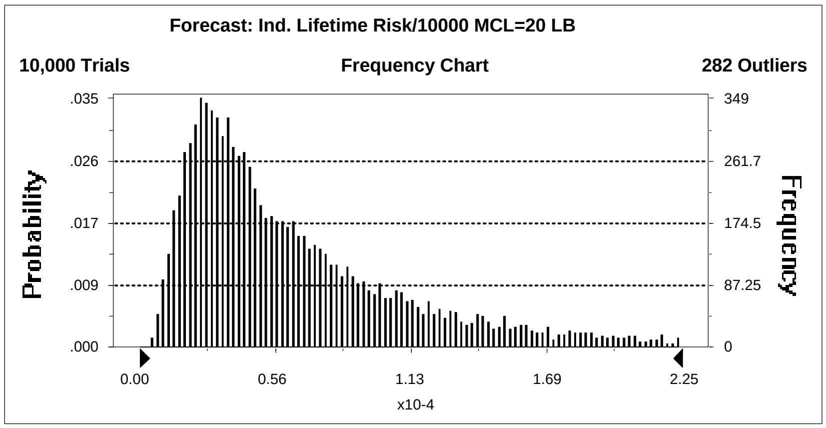


Exhibit B-48
CWS Number of Cancer Cases per 10,000 people
MCL = 20 μg/L Under Upper Bound Scenario

Statistics:	Value
Mean	1.47
Standard Deviation	1.16

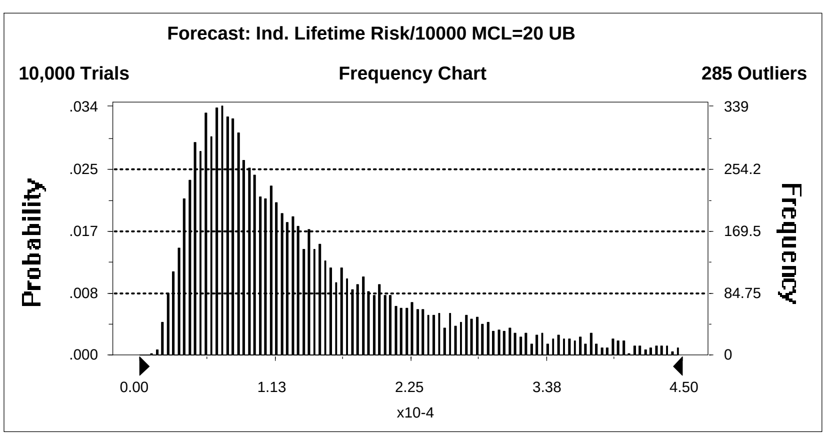


Exhibit B-49
CWS Number of Cancer Cases per 10,000 people
MCL = 10 μg/L Under Lower Bound Scenario

Statistics:	Value
Mean	0.57
Standard Deviation	0.37

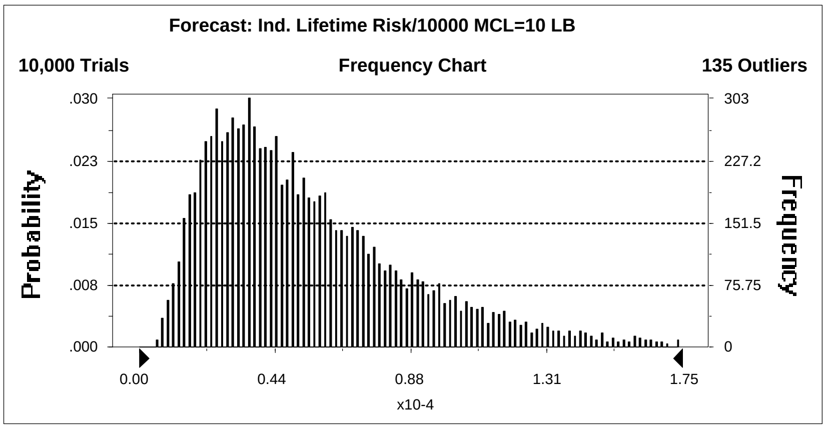


Exhibit B-50
CWS Number of Cancer Cases per 10,000 people
MCL = 10 μg/L Under Upper Bound Scenario

Statistics:	Value
Mean	1.19
Standard Deviation	0.72

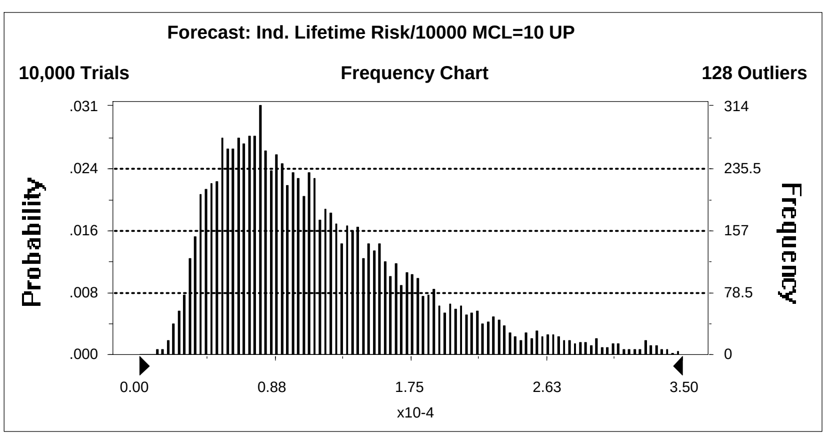


Exhibit B-51
CWS Number of Cancer Cases per 10,000 people
MCL = 5 μg/L Under Lower Bound Scenario

Statistics:	Value
Mean	0.37
Standard Deviation	0.20

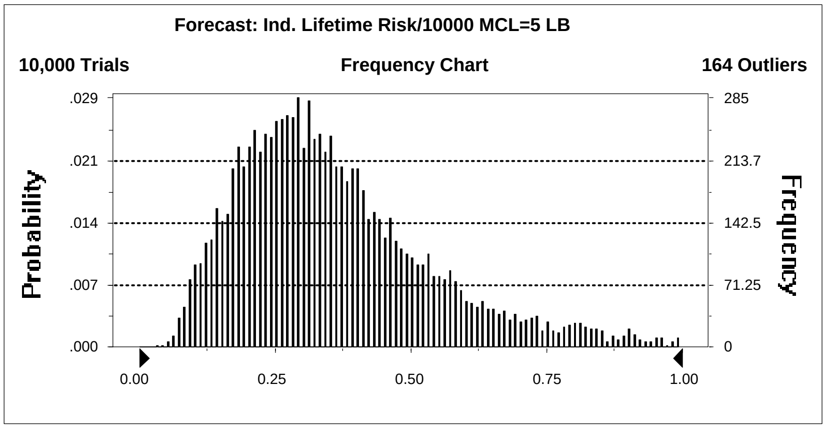


Exhibit B-52
CWS Number of Cancer Cases per 10,000 people
MCL = 5 μg/L Under Upper Bound Scenario

Statistics:	Value
Mean	0.78
Standard Deviation	0.38

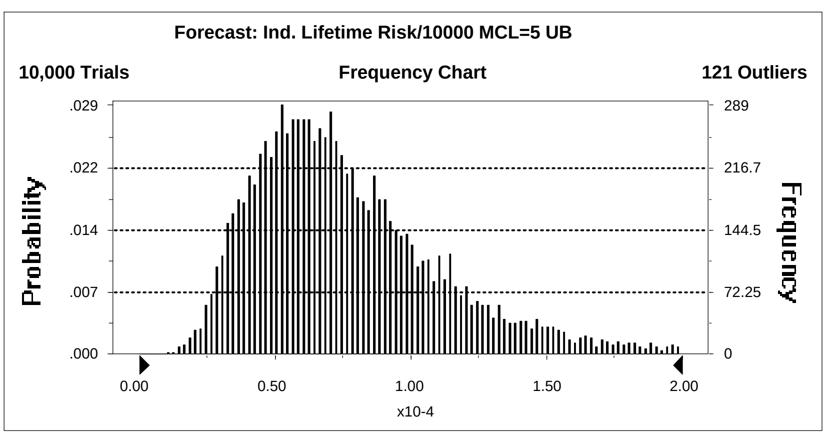


Exhibit B-53
CWS Number of Cancer Cases per 10,000 people
MCL = 3 μg/L Under Lower Bound Scenario

Statistics:	Value
Mean	0.22
Standard Deviation	0.12

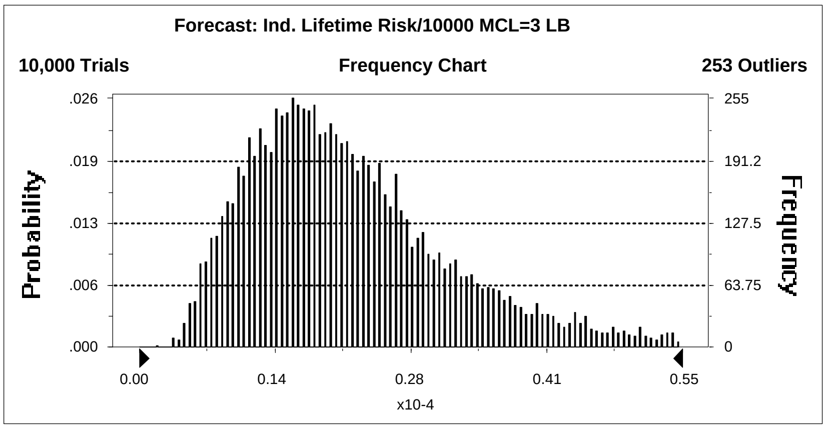
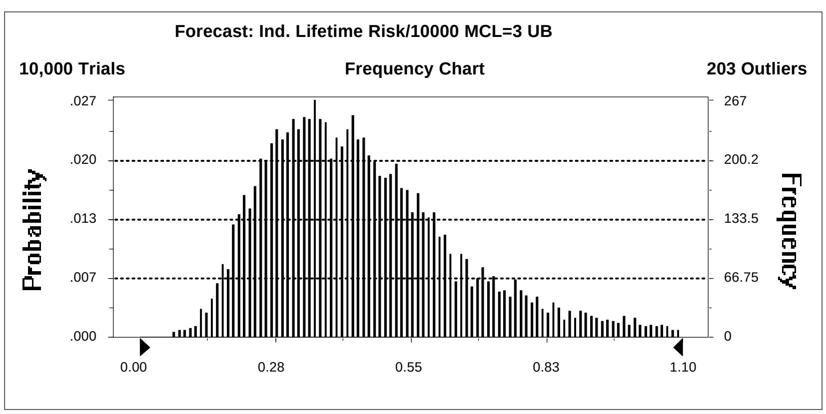


Exhibit B-54
CWS Number of Cancer Cases per 10,000 people
MCL = 3 μg/L Under Upper Bound Scenario

Statistics:	Value
Mean	0.47
Standard Deviation	0.22



B.2 Non-Transient Non-Community Water Systems

B.2.1 Data Inputs

Most of the data described above under the CWS risk model is also used in the NTNC risk model. This includes water consumption, body weight, and lifetime risk estimates (at 50 μg/L, 2 L consumption, and 70 kg body weight). Also, the ground water arsenic concentrations at each MCL used in the CWS risk model are used in the NTNC risk model.

B.2.1.1 NTNC Service Categories, Population and Exposure Time

The main differences between the CWS and NTNC risk models are how population is distributed among the different types of establishments that make up the NTNC category of systems, and the extent to which the worker and customer populations within a service category are exposed to arsenic (both in terms of length of exposure and drinking water consumed).

In addition to the CWS data already discussed, Exhibits B-55 and B-56 provide all of the data inputs necessary to model the bladder cancer risk associated with NTNC systems. First, note that in Exhibit B-55, the NTNC universe has been divided into 35 service categories. This was accomplished using the system descriptions in SDWIS (EPA, 1999b). For each service category, the total number of NTNCs and the population served by these NTNCs is taken from SDWIS. The population served by each NTNC often varies daily; the SDWIS population numbers are interpreted to mean the peak population served (both workers and customers).

The next data field in Exhibit B-55 is the number of customer cycles per year, or the number of times each year the customer base turns over. For example, if this parameter equals one, then the same customer's are served each day. If the value is seven, then seven sets of customers use the facility. The next field is the number of workers per person per day. For example, if the value is 0.1, as in the case of summer camps, then 10 percent of the peak population served (from SDWIS) is assumed to be workers. Both the number of customer cycles per year assumptions and workers per person per day data assumptions were made after investigating numerous data sources, including trade-journals and trade association information.

The next set of data fields in Exhibit B-55 are assumptions about the characteristics of the workers in each service type. The percent of workers' daily consumption is the percentage of drinking water consumed on a work day that is consumed at work. This value is assumed to be either 50 percent or 100 percent, depending on the service category. The number of days a person works is assumed to be 250 for all service categories. The number of years a person works at the NTNC establishment is assumed to be either 40 or 10, depending on the service category.

Information regarding customer behavior is provided in the next set of data fields in Exhibit B-55. The percent of customers' daily consumption is the percentage of total drinking water consumed on a day that the customer visits the NTNC, that is consumed at the NTNC. This value is assumed to be either 25 percent, 50 percent or 100 percent, depending on the service category.

The number of days a customer visits the NTNC is provided for each service category. For example, the value for nursing homes of 365 indicates that nursing home customers are served by the nursing home year round, while the value for churches of 52 indicates that churches are assumed to serve their customers once per week. The number of years a person is assumed to visits each service category is also provided.

Finally, the total exposed worker and customer populations for each service category are provided in Exhibit B-55. These numbers are calculated as follows:

$$TC_c = (P_c * CC_c) * (1 - WP_c)$$

$$TW_c = P_c * WP_c$$

where:

TC=	total number of customers
TW=	total number of workers
P=	SDWIS population
WP=	workers per person per day
CC=	number of customer cycles per year
c=	NTNC service category

Exhibit B-56 provides the final set of data required to estimate bladder cancer risk from NTNCs. The percent of worker lifetime exposure is the percent of lifetime water consumption which is consumed at the NTNC by a worker. The percent of customer lifetime exposure is the percent of lifetime water consumption consumed at the NTNC by a customer. These numbers are calculated as follows:

$$PWLE_c = \frac{PWDC_c * DW_c * YW_c}{365 * 70}$$

$$PCLE_c = \frac{PCDC_c * DC_c * YC_c}{365 * 70}$$

where;

PWLE	=percent of worker lifetime exposure
PCLE	=percent of customer lifetime exposure
PWDC	=percentage of workers daily consumption
PCDC	=percentage of customers daily consumption
DW	=worker days per year
DC	=customer days per year
YW	=worker years
YC	=customer years

Returning to Exhibit B-56, the worker age bracket is the age range (corresponding to the age ranges used in the CWS risk analysis) that a NTNC worker is assumed to fall in. For all service categories, the worker age bracket is assumed to be 20-64 years of age. The customer age bracket is the age range (corresponding to the age ranges used in the CWS risk analysis) that a NTNC customer is assumed to be in. For most service categories, the customer age bracket is assumed to be 0-70 years of age (all ages). However, certain service categories only serve certain age groups (e.g. nursing homes and schools), therefore more specific age ranges are assumed.

Exhibit B-55
NTNC Population and Exposure Time Data

	Number of Systems	Total SDWIS Population	Number of Customer Cycles/Year	Worker Per Person Per Day	Percent of Worker's Daily Consumption	Worker Days Per Year	Worker Years	Percent of Customer's Daily Consumption	Customer Days Per Year	Customer Years	Total Worker Population	Total Customer Population
Water Wholesalers	266	66,018	1.00	0	n/a	n/a	n/a	25.0%	270.00	70.00	0	66,018
Mobile Home Parks	104	19,240	1.33	0.046	50.0%	250	40	100.0%	270.00	35.00	885	24,412
Nursing Homes	130	13,910	1.00	0.23	50.0%	250	40	100.0%	365.00	10.00	3,199	10,711
Churches	230	11,500	1.00	0.01	50.0%	250	40	50.0%	52.00	70.00	115	11,385
Golf and Country Clubs	116	11,716	4.50	0.11	50.0%	250	40	50.0%	52.00	70.00	1,289	46,923
Retailers (Food related)	142	45,724	2.00	0.07	50.0%	250	40	25.0%	185.00	70.00	3,201	85,047
Retailers (Non-food related)	695	120,930	4.50	0.09	50.0%	250	40	25.0%	52.00	70.00	10,884	495,208
Restaurants	418	154,660	2.00	0.07	50.0%	250	40	25.0%	185.00	70.00	10,826	287,668
Hotels/Motels	351	46,683	86.00	0.27	50.0%	250	40	100.0%	3.40	40.00	12,604	2,930,759
Prisons/Jails	67	121,940	1.33	0.1	50.0%	250	40	100.0%	270.00	3.00	12,194	145,962
Service Stations	53	12,190	7.00	0.06	50.0%	250	40	25.0%	52.00	54.00	731	80,210
Agricultural Products/Services	368	27,968	7.00	0.125	50.0%	250	40	25.0%	52.00	50.00	3,496	171,304
Daycare Centers	809	61,484	1.00	0.145	50.0%	250	10	50.0%	250.00	5.00	8,915	52,569
Schools	8,414	3,086,012	1.00	0.073	50.0%	200	40	50.0%	200.00	12.00	225,279	2,860,733
State Parks	83	106,895	26.00	0.016	50.0%	250	40	50.0%	14.00	70.00	1,710	2,734,802
Medical Facilities	367	163,631	16.40	0.022	50.0%	250	40	100.0%	6.70	10.30	3,600	2,624,510
Campgrounds/RV Parks	123	19,680	22.50	0.041	50.0%	180	40	100.0%	5.00	50.00	807	424,645
Federal Parks	20	780	26.00	0.016	50.0%	250	40	50.0%	14.00	70.00	12	19,956
Highway Rest Areas	15	6,105	50.70	0.01	50.0%	250	40	50.0%	7.20	70.00	61	306,428
Misc. Recreation Services	259	22,533	26.00	0.016	50.0%	250	40	100.0%	14.00	70.00	361	576,484
Forest Service	107	4,494	26.00	0.016	100.0%	250	40	100.0%	14.00	50.00	72	114,974
Interstate Carriers	287	35,301	93.00	0.304	50.0%	250	40	50.0%	2.00	70.00	10,732	2,284,963
Amusement Parks	159	76,462	90.00	0.18	50.0%	250	10	50.0%	1.00	70.00	13,763	5,642,896
Summer Camps	46	6,716	8.50	0.1	100.0%	180	10	100.0%	7.00	10.00	672	51,377
Airports	101	326,860	36.50	0.308	50.0%	250	40	25.0%	10.00	70.00	100,673	8,255,830
Military Bases	95	67,525	n/a	1	50.0%	250	40	n/a	n/a	n/a	67,525	0
Non-Water Utilities	497	84,490	n/a	1	50.0%	250	40	n/a	n/a	n/a	84,490	0
Office Parks	950	181,600	n/a	1	50.0%	250	40	n/a	n/a	n/a	181,600	0
Manufacturing: Food	768	285,696	n/a	1	50.0%	250	40	n/a	n/a	n/a	285,696	0
Manufacturing: Non-Food	3,356	588,792	n/a	1	50.0%	250	40	n/a	n/a	n/a	588,792	0
Landfills	78	3,432	n/a	1	100.0%	250	40	n/a	n/a	n/a	3,432	0
Fire Departments	41	4,018	n/a	1	100.0%	250	40	n/a	n/a	n/a	4,018	0
Construction	99	5,247	n/a	1	100.0%	250	40	n/a	n/a	n/a	5,247	0
Mining	119	13,447	n/a	1	100.0%	250	40	n/a	n/a	n/a	13,447	0
Migrant Labor Camps	33	2,079	n/a	1	100.0%	250	40	n/a	n/a	n/a	2,079	0
										Subtotal =	**1,662,407**	**30,305,774**
										TOTAL =		**31,968,181**

Exhibit B-56
NTNC Percent of Lifetime Exposure and Age at Exposure

	Percent of Worker Lifetime Exposure	Percent of Customer Lifetime Exposure	Worker Age Bracket	Customer Age Bracket
Water Wholesalers	0.00%	18.49%	n/a	all
Mobile Home Parks	19.57%	36.99%	20 to 64	all
Nursing Homes	19.57%	14.29%	20 to 64	65+
Churches	19.57%	7.12%	20 to 64	all
Golf and Country Clubs	19.57%	7.12%	20 to 64	all
Retailers (Food related)	19.57%	12.67%	20 to 64	all
Retailers (Non-food related)	19.57%	3.56%	20 to 64	all
Restaurants	19.57%	12.67%	20 to 64	all
Hotels/Motels	19.57%	0.53%	20 to 64	all
Prisons/Jails	19.57%	3.17%	20 to 64	20 to 64
Service Stations	19.57%	2.75%	20 to 64	16 to 70
Agricultural Products/Services	19.57%	2.54%	20 to 64	all
Daycare Centers	4.89%	2.45%	20 to 64	<5
Schools	15.66%	4.70%	20 to 64	6 to 18
State Parks	19.57%	1.92%	20 to 64	all
Medical Facilities	19.57%	0.27%	20 to 64	all
Campgrounds/RV Parks	14.09%	0.98%	20 to 64	all
Federal Parks	19.57%	1.92%	20 to 64	all
Highway Rest Areas	19.57%	0.99%	20 to 64	all
Misc. Recreation Services	19.57%	3.84%	20 to 64	all
Forest Service	39.14%	2.74%	20 to 64	all
Interstate Carriers	19.57%	0.27%	20 to 64	all
Amusement Parks	4.89%	0.14%	20 to 64	all
Summer Camps	7.05%	0.27%	20 to 64	11 to 19
Airports	19.57%	0.68%	20 to 64	all
Military Bases	19.57%	0.00%	20 to 64	n/a
Non-Water Utilities	19.57%	0.00%	20 to 64	n/a
Office Parks	19.57%	0.00%	20 to 64	n/a
Manufacturing: Food	19.57%	0.00%	20 to 64	n/a
Manufacturing: Non-Food	19.57%	0.00%	20 to 64	n/a
Landfills	39.14%	0.00%	20 to 64	n/a
Fire Departments	39.14%	0.00%	20 to 64	n/a
Construction	39.14%	0.00%	20 to 64	n/a
Mining	39.14%	0.00%	20 to 64	n/a
Migrant Labor Camps	39.14%	0.00%	all	n/a

B.2.2 The NTNC Risk Model

Just like the CWS risk analysis, the NTNC risk analysis is a Monte-Carlo based simulation model. This section will explain each step is the simulation. The Monte-Carlo simulation is conducted at each MCL option (50, 20, 10, 5 and 3 μg/L). In addition, for each MCL option, the simulation is carried out for both the "Lower Bound" and "Upper Bound" scenarios just like in the CWS case. Therefore, the simulation model is carried out ten times. Each of these ten "runs" of the model is independent of the other, and can be discussed in isolation. Therefore, this section will include a generalized discussion of the model. The inputs that are used will depend on the MCL option and scenario being evaluated at the time. It is important not to confuse a "run" of the model" as just described, and a model iteration. Each run of the model consists of 10,000 iterations. Within a single iteration, the model pulls a value for each variable from its input distribution (e.g. body weight) and calculates a value for each output variable (e.g. lifetime risk). This is done for 10,000 times for each model run. The results of the model run is the distribution of the 10,000 values for each output variable.

The first step of each iteration is to calculate the relative exposure factor for each sex and age category. This is done exactly as it was done in the CWS risk analysis. As shown in the following equations, the relative exposure factor is a function of daily water consumption and body weight.

$$REF_{mai} = \left(\frac{70}{2}\right) * \left(\frac{C_{mai}}{W_{mai}}\right)$$

$$REF_{fai} = \left(\frac{70}{2}\right) * \left(\frac{C_{fai}}{W_{fai}}\right)$$

where;

REF	= relative exposure factor
C	= daily water consumption (L)
W	= body weight (kg)
i	= model iteration number
a	= age category
m	= male
f	= female

Next, the lifetime risk of bladder cancer (1/100,000 people) is calculated for workers and customers of each sex for each service category. The next four equations, therefore are:

$$WLR_{fci} = PWLE_{ci} * AS_{gi} * (RF_i / 50) * \left(\frac{\sum_a (REF_{fai} * Z_{ac})}{\sum_a Z_{ac}} \right) * 100$$

$$WLR_{mci} = PWLE_{ci} * AS_{gi} * (RF_i / 50) * \left(\frac{\sum_a (REF_{mai} * Z_{ac})}{\sum_a Z_{ac}} \right) * 100$$

$$CLR_{mci} = PCLE_{ci} * AS_{gi} * (RF_i / 50) * \left(\frac{\sum_a (REF_{mai} * Z_{ac})}{\sum_a Z_{ac}} \right) * 100$$

$$CLR_{fci} = PCLE_{ci} * AS_{gi} * (RF_i / 50) * \left(\frac{\sum_a (REF_{fai} * Z_{ac})}{\sum_a Z_{ac}} \right) * 100$$

where;

WLR	= worker lifetime risk (per 100,000 people)
CLR	= customer lifetime risk (per 100,000 people)
AS	= arsenic concentration (μg/L)
RF	= risk of bladder cancer at 50 μg/L, 2 liters consumption per day, and 70 kg body weight
Z	= years spent in age category
g	= ground water

The sex of the worker and customer is then chosen for the iteration to determine the worker and customer risk for each service category:

$$WLR_{ci} = \begin{cases} WLR_{mci} & \text{if } RN_1 \leq MP \\ WLR_{fci} & \text{otherwise} \end{cases}$$

$$CLR_{ci} = \begin{cases} CLR_{mci} & \text{if } RN_1 \leq MP \\ CLR_{fci} & \text{otherwise} \end{cases}$$

where;

RN_1 = random number between 0 and 1

MP = percentage of the population that is male

Finally, the lifetime risk for the model iteration is determined by choosing among the 70 combinations of worker and customer risk over of the 35 service categories. This is accomplished using a population weighted probability distribution. First, the total worker and customer populations served are computed.

$$TC = \sum_{c} TC_c$$

$$TW = \sum_{c} TW_c$$

Next, the probability that the lifetime risk for the model iteration will be equal to the worker lifetime risk associated with a service category is calculated:

$$WPR_c = \frac{TW_c}{(TW + TC)}$$

where;

WPR =probability of choosing lifetime risk estimate for any iteration to be equal to the lifetime risk estimate of a worker in a given service category

Likewise, the probability that the lifetime risk for the model iteration will be equal to the customer lifetime risk associated with a service category is calculated:

$$CPR_c = \frac{TC_c}{(TW + TC)}$$

where;

CPR =probability of choosing lifetime risk estimate for any iteration to be equal to the lifetime risk estimate of a customer in a given service category

Given these probabilities, the lifetime risk estimate for each model iteration is chosen as follows:

$$LR_i = \begin{cases} WLR_{ci} \quad \text{with} \quad \text{Probability } WPR_c \\ \\ CLR_{ci} \quad \text{with} \quad \text{Probability } CPR_c \end{cases}$$

where;

LR =Lifetime risk (1/100,000)

In order to calculate the expected number of cancer cases associated with the model run, the mean lifetime risk is multiplied by the exposed population as follows:

$$CA = \left(\frac{\sum_{i=1}^{N} LR_i}{N} \right) * \frac{(TC + TW)}{100{,}000}$$

where;

CA = expected number of bladder cancer cases

N = number of iterations

B.2.3 NTNC Risk Results

Exhibits B-57 through B-66 provide the results of the NTNC risk analysis. These exhibits provide the mean and standard deviation of expected cases of bladder cancer per 100,000 people, as well as the full distribution of expected risk values. The results for each MCL option are provided for both the Lower Bound Scenario and the Upper Bound Scenario.

As mentioned above, these results can be used to calculate the expected number of bladder cancer cases nationwide by multiplying the mean expected risk associated with an MCL option by the exposed population (in 100,000s). Likewise, the population exposed to a certain risk threshold (e.g. 10^{-4}), at a given an MCL, can be obtained by using the distribution of expected risk values. These results are provided in Chapter 5 of this RIA.

Exhibit B-57
NTNC Expected Number of Cancer Cases per 100,000 people
Baseline Under Lower Bound Scenario

Statistics:	Value
Mean	1.9E-01
Standard Deviation	6.6E-01

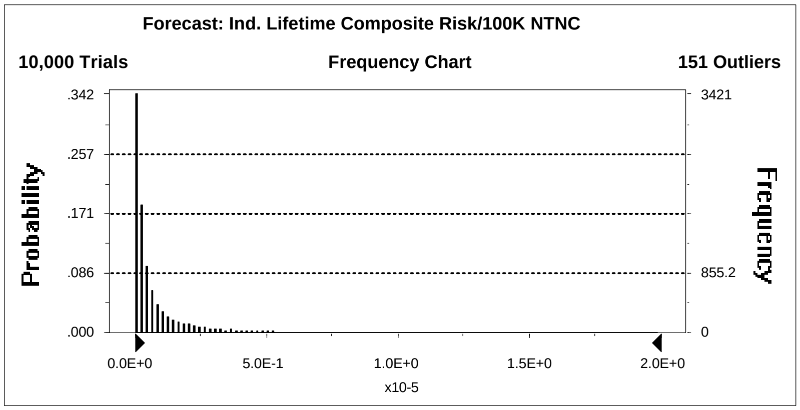


Exhibit B-58
NTNC Expected Number of Cancer Cases per 100,000 people
Baseline Under Upper Bound Scenario

Statistics:	Value
Mean	4.1E-01
Standard Deviation	1.3E+00

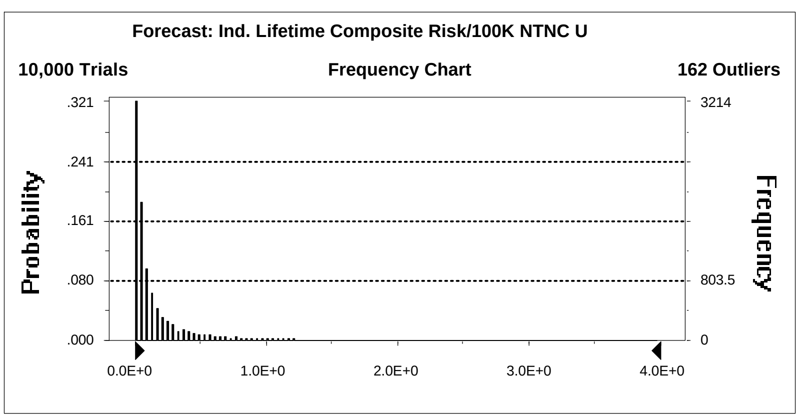


Exhibit B-59
NTNC Expected Number of Cancer Cases per 100,000 people
MCL = 20 μg/L Under Lower Bound Scenario

Statistics:	Value
Mean	1.6E-01
Standard Deviation	4.4E-01

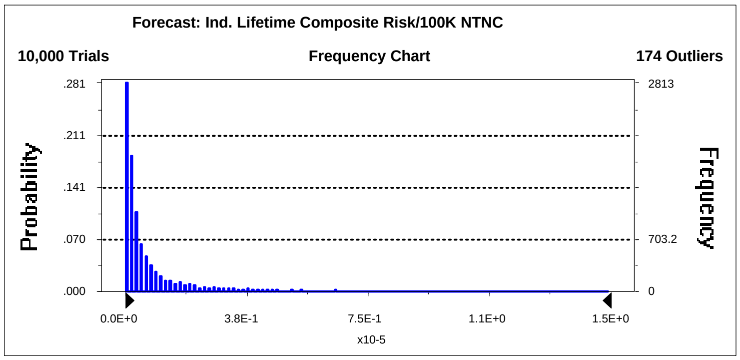


Exhibit B-60
NTNC Expected Number of Cancer Cases per 100,000 people
MCL = 20 μg/L Under Upper Bound Scenario

Statistics:	Value
Mean	3.2E-01
Standard Deviation	8.4E-01

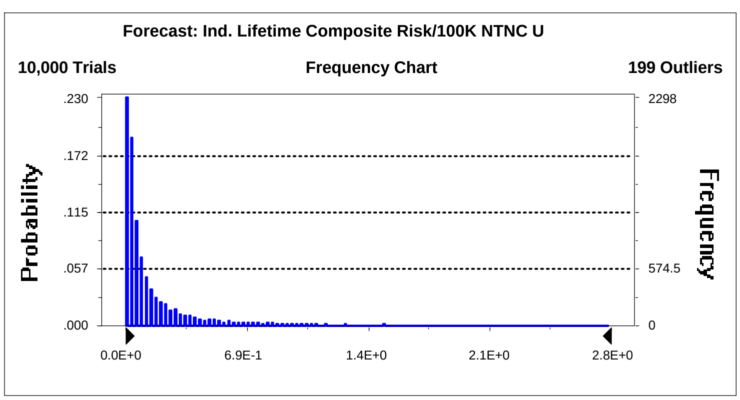


Exhibit B-61
NTNC Expected Number of Cancer Cases per 100,000 people
MCL = 10 μg/L Under Lower Bound Scenario

Statistics:	Value
Mean	1.2E-01
Standard Deviation	3.3E-01

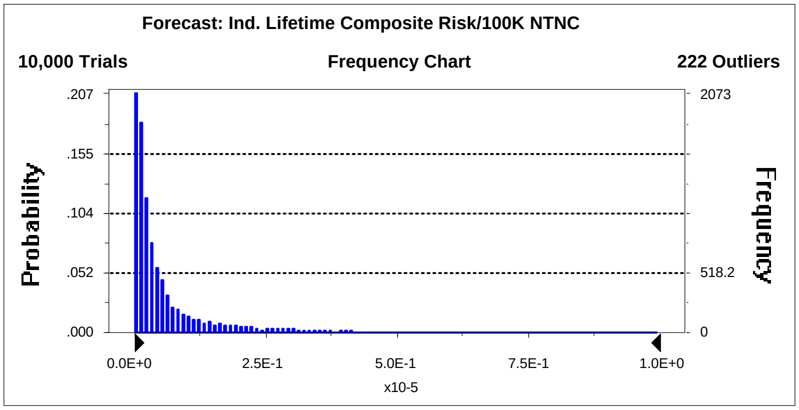


Exhibit B-62
NTNC Expected Number of Cancer Cases per 100,000 people
MCL = 10 μg/L Under Upper Bound Scenario

Statistics:	Value
Mean	2.6E-01
Standard Deviation	6.4E-01

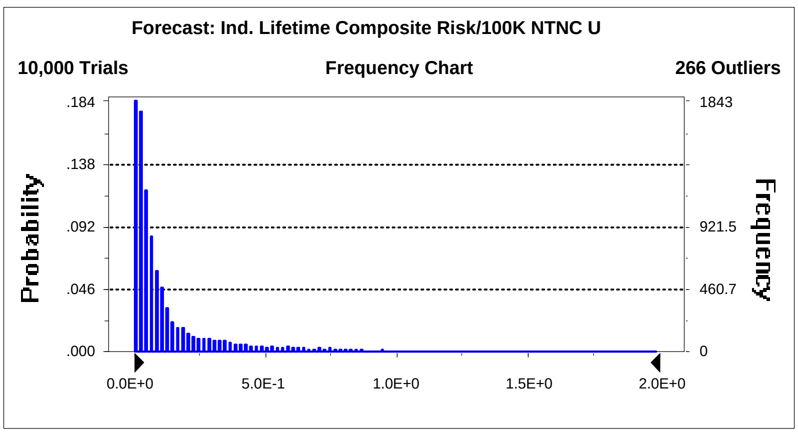


Exhibit B-63
NTNC Expected Number of Cancer Cases per 100,000 people
MCL = 5 μg/L Under Lower Bound Scenario

Statistics:	Value
Mean	7.6E-02
Standard Deviation	2.0E-01

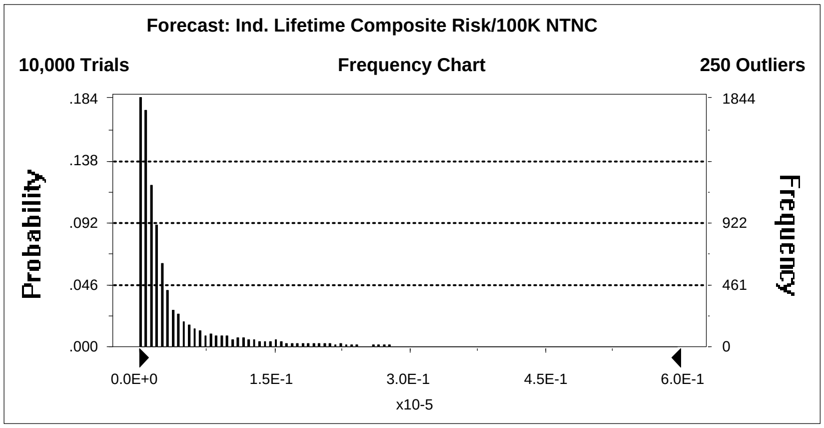


Exhibit B-64
NTNC Expected Number of Cancer Cases per 100,000 people
MCL = 5 μg/L Under Upper Bound Scenario

Statistics:	Value
Mean	1.6E-01
Standard Deviation	3.9E-01

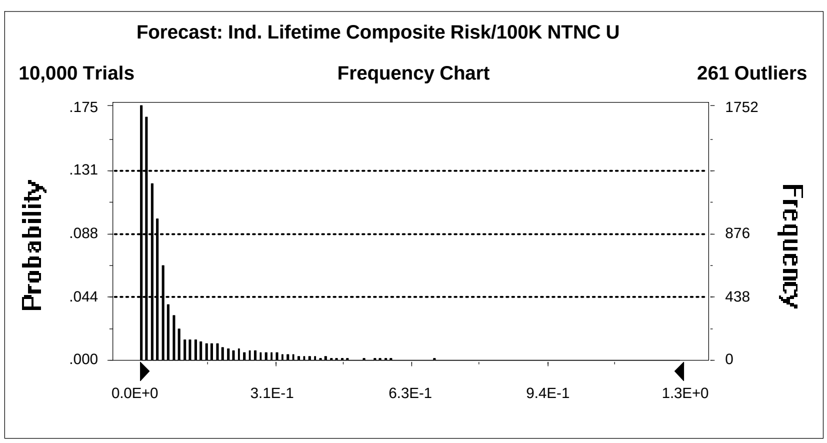


Exhibit B-65
NTNC Expected Number of Cancer Cases per 100,000 people
MCL = 3 μg/L Under Lower Bound Scenario

Statistics:	Value
Mean	4.7E-02
Standard Deviation	1.2E-01

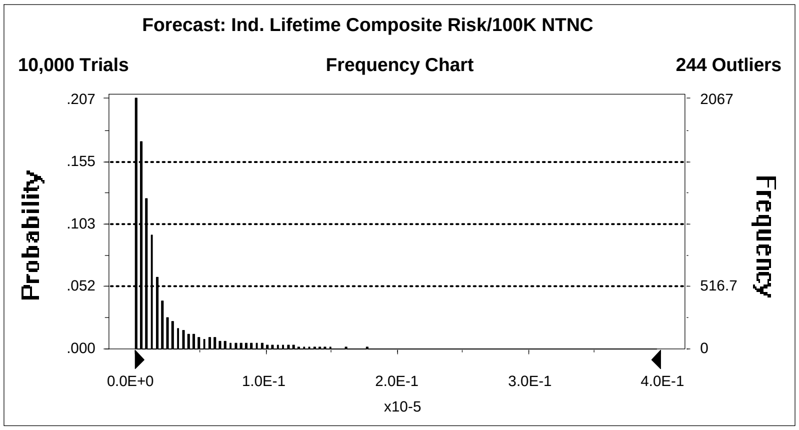


Exhibit B-66
NTNC Expected Number of Cancer Cases per 100,000 people
MCL = 3 μg/L Under Upper Bound Scenario

Statistics:	Value
Mean	1.0E-01
Standard Deviation	2.4E-01