Economic Analysis for the Stage 2 Disinfectants and Disinfection Byproducts Rule

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Acronyms and Notations

AAM	Annual Average of the Maximum
ACS	American Cancer Society
AIPC	All Indian Pueblo Council
AMWA	Association of Metropolitan Water Agencies
ARBRP	Arsenic Rule Benefits Review Panel
ASDWA	Association of State Drinking Water Administrators
AD	Advanced Disinfectants
AO	Advanced Oxidants
ATSDR	Agency for Toxic Substances and Disease Registry
AUX1	Auxiliary Database 1
AUX8	Auxiliary Database 8
AVG 1	Average sample point number 1
AVG 2	Average sample point number 2
AWWA	American Water Works Association
AWWARF	American Water Works Association Research Foundation
BAT	Best Available Technology
BCAA	Bromochloroacetic Acid
BCAN	Bromochloroacetonitrile
BDCAA	Bromodichloroacetic Acid
BDCM	Bromodichloromethane
BLS	Bureau of Labor Statistics
CATT	Cases Attributable to DBPs
CCR	Consumer Confidence Report Rule (1998)
CDBG	Community Development Block Grant
CDC	Centers for Disease Control and Prevention
CDHS	California Department of Health Services
CI	Confidence Interval
CKA	Chernoff-Kavlock Assay
CL2	Chlorine
CLM	Chloramines
CLO2	Chlorine Dioxide
COI	Cost of Illness
CPI	Consumer Price Index
CWS	Community Water System
CWSS	Community Water Systems Survey
DBAA	Dibromoacetic Acid
DBAN	Dibromoacetonitrile
DBCM	Dibromochloromethane
DBPR	Disinfectants and Disinfection Byproducts Rule
DBP	Disinfection Byproduct
DCAA	Dichloroacetic Acid
DCAN	Dichloroacetonitrile
DNA	Deoxyribonucleic Acid
DOC	Dissolved Organic Carbon
DS Average	Distribution System Average Sample Point

DSE	Distribution System Equivalent Sample Point
DS Maximum	Distribution System Maximum Sample Point
DWSRF	Drinking Water State Revolving Fund
EA	Economic Analysis
EBCT	Empty Bed Contact Time
EC	Enhanced Coagulation
ECI	Employment Cost Index Information
ED_{10}	Effective Dose for 10% response
EPA	Environmental Protection Agency
ES	Enhanced Softening
FACA	Federal Advisory Committees Act
FBRR	Filter Backwash Recycling Rule (2001)
FLR	Full Liter Resorption
FR	Federal Register
FRFA	Final Regulatory Flexibility Analysis
FTE	Full-Time Equivalent
GAC	Granular Activated Carbon
GAC10	Granular Activated Carbon—10-Minute Contact Time
GAC20	Granular Activated Carbon—20-Minute Contact Time
GDP	Gross Domestic Product
GIS	Geographical Information System
GW	Ground Water
GWR	Ground Water Rule
GWSS	Ground Water Supply Survey
GWUDI	Ground Water Under the Direct Influence of Surface Water
HAA5	Haloacetic Acids [total of five]
HAA6	Haloacetic Acids [total of six]
HAA9	Haloacetic Acids [total of nine]
HAN	Haloacetonitrile
ICMA	International City/County Management Association
ICR	Information Collection Rule (1996)
ICRSS	Information Collection Rule Supplemental Survey
ILSI	International Life Sciences Institute
IDSE	Initial Distribution System Evaluation
IDSE SMP	Initial Distribution System Evaluation Standard Monitoring Program
IESWTR	Interim Enhanced Surface Water Treatment Rule (1998)
IPCS	International Programme on Chemical Safety
IRFA	Initial Regulatory Flexibility Analysis
IRIS	Integrated Risk Information System
kg	Kilogram
KWh/y	Kilowatt Hours per Year
LED_{10}	Lower Bound on the Effective Dose for 10% response
LF	Lag Function
LH	Luteinizing Hormone
LOAEL	Lowest-Observed-Adverse-Effect-Level
LRAA	Locational Running Annual Average
LT1ESWTR	Long Term 1 Enhanced Surface Water Treatment Rule (2002)
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule (under development)

MBAA	Monobromoacetic Acid
MCAA	Monochloroacetic Acid
MCAN	Monochloroacetonitrile
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
M-DBP	Microbial-Disinfectants/Disinfection Byproducts [Advisory Committee]
MF	Microfiltration
MG	Million Gallon
MGD	Million Gallons per Day
μg/L	Micrograms per Liter
mg/kg-day	Milligrams per Kilogram per Day
mg/L	Milligrams per Liter
MHI	Median Household Income
mJ/cm^2	Millijoules per centimeter square
MLE	Maximum Likelihood Estimation
MRDL	Maximum Residual Disinfectant Level
MRDLG	Maximum Residual Disinfectant Level Goal
MRRR	Maximum Relative Risk Reduction
MW	Megawatt
mWh	Megawatt Hours
MX	3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone
NAICS	North American Industry Classification System
NCI	National Cancer Institute
NCSL	National Conference of State Legislatures
NCWS	Noncommunity Water System
NDMA	N-nitrosodimethylamine
NDWAC	National Drinking Water Advisory Council
NF	Nanofiltration
ng	Nanograms
NGA	National Governors' Association
NHEERL	National Health and Environmental Effects Research Laboratory (EPA)
NLC	National League of Cities
NOAEL	No-Observed-Adverse-Effect-Level
NODA	Notice of Data Availability
NOM	Natural Organic Matter
NPDWR	National Primary Drinking Water Regulations
NRWA	National Rural Water Association
NTNCWS	Nontransient Noncommunity Water System
NTU	Nephelometric Turbidity Unit
O_3	Ozone
OGWDW	Office of Ground Water and Drinking Water
OR	Odds Ratio
OMB	Office of Management and Budget
O&M	Operations and Maintenance
PAR	Population Attributable Risk
POE	Point-of-Entry
POU	Point-of-Use
ppb	Parts per Billion

ppm	Parts per Million
PUC	Public Utilities Commission
PSC	Public Services Commission
PV	Present Value
PWS	Public Water System
PWSID	Public Water System Identification
RAA	Running Annual Average
RFA	Regulatory Flexibility Act
RfD	Reference Dose
RIA	Regulatory Impact Analysis
RR	Relative Risk
RUS	Rural Utility Service
RSI	Risk Sciences Institute
SAB	Science Advisory Board
SBA	Small Business Administration
SBAR	Small Business Advocacy Review
SBREFA	Small Business Regulatory Enforcement Fairness Act
SCADA	Supervisory Control and Data Acquisition
SD	Sprague-Dawley
SDS	Simulated Distribution System
SDWA	Safe Drinking Water Act (1974)
SDWIS	Safe Drinking Water Information System
SEER	Surveillance, Epidemiology, and End Results
SER	Small Entity Representatives
SH	Single Highest
SIC	Standard Industrial Codes
SMP	Standard Monitoring Program
SSS	System-Specific Study
SW	Surface Water
SWAT	Surface Water Analytical Tool
Stage 1 DBPR	Stage 1 Disinfectants and Disinfection Byproducts Rule (1998)
Stage 2 DBPR	Stage 2 Disinfectants and Disinfection Byproducts Rule (under development)
SWTR	Surface Water Treatment Rule (1989)
TBAA	Tribromoacetic Acid
TCAA	Trichloroacetic Acid
TCAN	Trichloroacetonitrile
TCR	Total Coliform Rule (1989)
THM	Trihalomethane
TMF	Technical, Managerial, and Financial
TNCWS	Transient Noncommunity Water System
TOC	Total Organic Carbon
TOX	Total Organic Halides
TTHM	Total Trihalomethanes
TWG	Technical Workgroup
T&C	Technology and Cost
UF	Ultrafiltration
UMRA	Unfunded Mandates Reform Act
USC	United States Code

USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
UV	Ultraviolet [Light Disinfection]
UVA	Ultraviolet-254 Absorbance
µg/L	Micrograms per Liter
VSL	Value of a Statistical Life
WEC	Whole embryo culture
WHO	World Health Organization
WITAF	Water Industry Technical Action Fund
w(t)	cessation lag weighting factor
WTP	Willingness to Pay

Health Risk Reduction and Cost Analysis (HRRCA)

Under the Safe Drinking Water Act (SDWA) Amendments of 1996, when proposing a national primary drinking water regulation that includes an maximum contaminant level (MCL), the Environmental Protection Agency (EPA) must conduct a health risk reduction and cost analysis (HRRCA). A HRRCA contains seven requirements, all of which are addressed in this Economic Analysis (EA) for the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR). The table below shows where the HRRCA requirements are discussed in this document.

HRRCA Crosswalk to the Economic Analysis for the Stage 2 DBPR

HRRCA Requirement	Addressed in Economic Analysis
Quantifiable and nonquantifiable health risk reduction benefits	Chapter 6 (All sections and exhibits) Chapter 9 (Sections 9.2.2; Exhibits 9.1-9.4, 9.6, 9.7-9.10, and 9.12)
Quantifiable and nonquantifiable health risk reduction benefits from co-occurring contaminants	Chapter 6 (Section 6.4.3 and 6.4.4)
Quantifiable and nonquantifiable costs	Chapter 7 (All sections and exhibits) Chapter 8 (Sections 8.2, 8.3, and 8.6-8.8; Exhibits 8.1, 8.7-8.9 and 8.11-8.13) Chapter 9 (Sections 9.1.2 and 9.1.3, 9.4.2; Exhibits 9.2-9.3, 9.5, 9.7, and 9.11)
Incremental costs and benefits associated with MCL alternatives	Chapter 6 (Section 6.5.4; Exhibit 6.28) Chapter 7 (Section 7.9; Exhibit 7.19) Chapter 8 (Section 8.7.2; Exhibit 8.9) Chapter 9 (Section 9.3; Exhibits 9.9-9.15)
Effects of the contaminants on the general population and sensitive subpopulations	Chapter 6 (Sections 6.2 and 6.3.2.1; Exhibits 6.2-6.17) Chapter 8 (Sections 8.9 and 8.10)
Increased health risk that may occur as a result of compliance	Chapter 6 (Section 6.4.5)
Other relevant factors (quality and uncertainty of information)	Chapter 3 (Section 3.8; Exhibit 3.22) Chapter 5 (Section 5.7; Exhibit 5.28) Chapter 6 (Section 6.6; Exhibit 6.29) Chapter 7 (Section 7.8; Exhibit 7.18) Chapter 9 (Section 9.4; Exhibits 9.16)

Executive Summary

This document presents the Economic Analysis (EA), prepared by the U.S. Environmental Protection Agency (EPA), of the benefits and costs of the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR). Executive Order 12866 requires federal agencies to conduct an analysis of the benefits and costs of proposed and final rules that cost over $100 million annually. Although EPA's analysis of the Stage 2 DBPR has determined that its annual costs are most likely below this threshold, EPA has chosen to publish a complete EA for this rule.

ES.1 Need for the Rule

Over 48,000 public water systems (PWSs), serving more than 260 million people in the United States, chemically disinfect their water to kill or inactivate microbial contaminants (USEPA 2001c). This is an essential public health measure. Chemical disinfection, however, may pose health risks of its own. Disinfection byproducts (DBPs) result from reactions between chemical disinfectants and naturally occurring compounds in source waters. Research has shown that chlorinated waters and DBPs may be associated with increased risk of bladder and other cancers. While there are uncertainties in the quantitative relationship between the incidence of these cancers and the occurrence of DBPs in drinking water, EPA believes that additional reductions in these DBP levels in drinking water will reduce the incidence of bladder cancer and, possibly, other cancers.

In addition, results from toxicology and, particularly, epidemiology studies published in the last several years suggest a potential increased risk for pregnant women and their fetuses who are exposed to DBPs in drinking water. The studies have shown that early-term miscarriage, stillbirth, low birth weight, and some birth defects may be associated with drinking water containing DBPs. (These studies are discussed in detail in Chapter 6.) There are still uncertainties regarding which DBPs may be of greatest concern, what levels of DBPs may pose a risk, and at what period of development fetuses may be at the greatest risk. While the levels of DBPs potentially associated with specific adverse reproductive and developmental effects are not known, EPA believes the evidence supports concern for these potential hazards and warrants regulatory action.

In a separate but concurrent action, EPA is finalizing the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) to improve control of microbial contaminants, particularly *Cryptosporidium*, in surface water and to ensure that microbial protection is not compromised by efforts to reduce exposure to DBPs. Together, the Stage 2 DBPR and LT2ESWTR represent the final stage of a two-stage strategy that was developed in a regulatory negotiation effort in 1992 and 1993.[1] They reflect recommendations presented by the Stage 2 Microbial and Disinfection Byproducts (M-DBP) Federal Advisory Committee Agreement in Principle, signed in September 2000 (USEPA 2000n).

[1]The key outcomes of that regulatory negotiation effort were recommendations to proceed with rules addressing DBPs and microbial pathogens in two stages and to collect relevant information from public water supplies for use in the development of these rules and the analysis of their impacts. This two-stage approach was subsequently incorporated into the 1996 Safe Drinking Water Act (SDWA) Amendments. The first stage of the M-DBP rulemaking process culminated with the joint promulgation of the Stage 1 DBPR and the Interim Enhanced Surface Water Treatment Rule (IESWTR) by EPA in December 1998.

ES.2 Consideration of Regulatory Alternatives

The M-DBP Advisory Committee met from March 1999 to December 2000 to evaluate whether and to what degree EPA should promulgate revised or additional DBP standards to protect public health. The Advisory Committee carefully considered extensive new data on the occurrence and health effects of DBPs, as well as costs and potential impacts on PWSs, and concluded that a targeted protective public health approach should be taken to address exposure to DBPs beyond the requirements of the Stage 1 DBPR. While there had been substantial research to date, the Advisory Committee also concluded that significant uncertainty remained regarding the risk associated with DBPs in drinking water.

After extensive deliberations, the Advisory Committee recommended maintaining the MCLs for total trihalomethanes (TTHM) and haloacetic acids [total of five] (HAA5) at 0.080 mg/L (80 µg/L) and 0.060 mg/L (60 µg/L) respectively, but changing the compliance calculation from the system-wide running annual average (RAA) calculation to a locational running annual average (LRAA) calculation. Systems would also carry out an Initial Distribution System Evaluation (IDSE) to select new compliance monitoring sites that more accurately reflect higher TTHM and HAA5 levels occurring in the distribution system. The revised compliance determination would require MCLs of 0.080 mg/L for TTHM and 0.060 mg/L for HAA5 calculated as LRAAs at individual monitoring sites identified through the IDSE. The committee also provided recommendations for simultaneous compliance with the LT2ESWTR so that the reduction of DBPs does not compromise microbial protection. The M-DBP Agreement in Principle (available on the web at http://www.epa.gov/safewater/mdbp/st2fr29.html) summarizes the recommendations from the Advisory Committee (USEPA 2000m).

This EA considers four regulatory alternatives derived from a larger number discussed by the M-DBP Advisory Committee, including the Preferred Alternative that EPA is promulgating in the Stage 2 DBPR:

- Preferred Alternative: MCLs of 80 micrograms per liter (µg/L) for TTHM and 60 µg/L for HAA5, measured as an LRAA. MCL of 10 µg/L for bromate. Compliance monitoring is preceded by the IDSE.

- Alternative 1: MCLs of 80 µg/L for TTHM and 60 µg/L for HAA5, measured as an LRAA. MCL of 5 µg/L for bromate.

- Alternative 2: MCLs of 80 µg/L for TTHM and 60 µg/L for HAA5, measured as a single highest (SH) value. MCL of 10 µg/L for bromate.

- Alternative 3: MCLs of 40 µg/L for TTHM and 30 µg/L for HAA5, measured as an RAA. MCL of 10 µg/L for bromate.

For comparison with the Preferred Alternative, EPA also developed estimates of the benefits and costs for Alternatives 1, 2, and 3 in this document.

ES.3 Summary of the Stage 2 DBPR

The requirements of the Stage 2 DBPR apply to all community water systems (CWSs) and nontransient noncommunity water systems (NTNCWSs)—both ground and surface water systems[2]—that add a disinfectant other than ultraviolet light (UV), or that deliver water that has been treated with a disinfectant other than UV. New since the Stage 1 DBPR, the Stage 2 DBPR formally defines consecutive systems and includes provisions specific to consecutive systems to ensure equitable health protection for all people being served in those systems, as compared to those served by non-consecutive systems.

Each Stage 2 DBPR rule activity for the Preferred Regulatory Alternative is described below and illustrated in the flow chart in Exhibit ES.1. Exhibit ES.2 displays the compliance schedule for each rule activity. Note that consecutive systems of any size must comply with the requirements of the Stage 2 DBPR on the same schedule as required for the largest system in the combined distribution system.

Initial Distribution System Evaluations

Compliance monitoring will be preceded by an Initial Distribution System Evaluation (IDSE) to identify sample locations that represent distribution system sites with high TTHM and HAA5 levels. The IDSE consists of either standard monitoring or a system specific study (SSS), unless a system meets the criteria for a 40/30 certification or a very small system waiver. Systems will develop an IDSE plan and submit it to the primacy agency for review, collect data on TTHM and HAA5 levels throughout their distribution system, evaluate these data to determine which sampling locations are most representative of high TTHM and HAA5 levels for Stage 2 DBPR compliance monitoring, and compile this information into a report for submission to the State/Primacy Agency.

NTNCWSs serving fewer than 10,000 people are not required to perform an IDSE. Systems with low Stage 1 monitoring results (i.e., all samples less than or equal to 40 μg/L and 30 μg/L for TTHM and HAA5, respectively) can qualify for a 40/30 certification. Very small systems serving fewer than 500 people may receive waivers from the IDSE requirement.

Compliance with Stage 2 DBPR MCLs

The Stage 2 DBPR changes the way sampling results are averaged to determine compliance. The determination for the Stage 2 DBPR is based on an LRAA (i.e., compliance must be met at *each* monitoring location) instead of the system-wide RAA used under the Stage 1 DBPR.

Monitoring Plans

Systems must develop a Stage 2 DBPR monitoring plan that includes monitoring locations, monitoring dates, and compliance calculation procedures. The monitoring plan must also incorporate any agreements (e.g., permits, contracts) with third parties to sample, analyze, or report compliance information. The compliance monitoring locations identified in the monitoring plan are selected from the results of the IDSE and Stage 1 compliance monitoring.

[2] For the purposes of this EA, "surface water" is equivalent to the definition of subpart H systems used in the Stage 2 DBPR rule language and includes systems that provide ground water under the direct influence of surface water (GWUDI).

Exhibit ES.1 Summary of Stage 2 DBPR Requirements

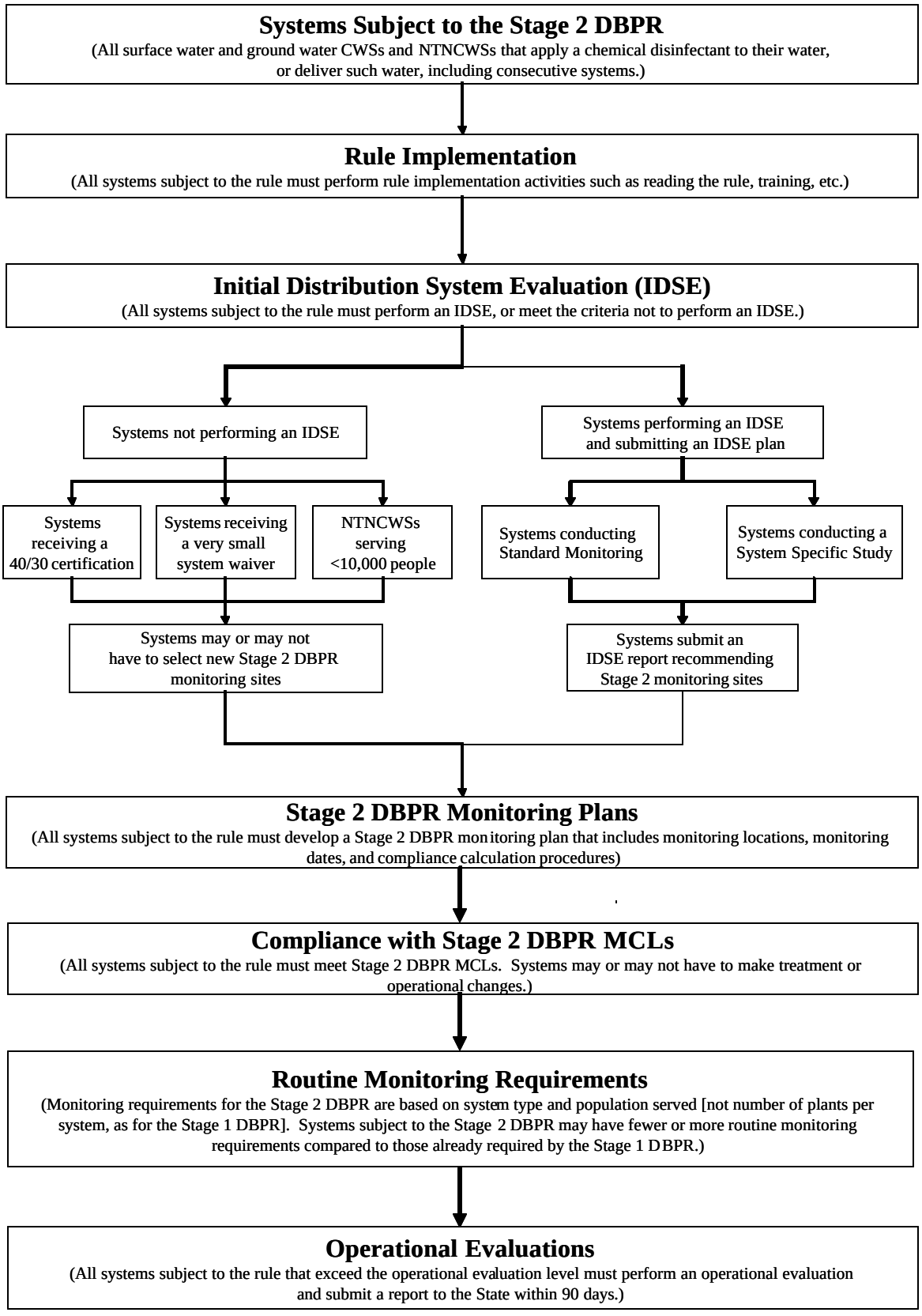
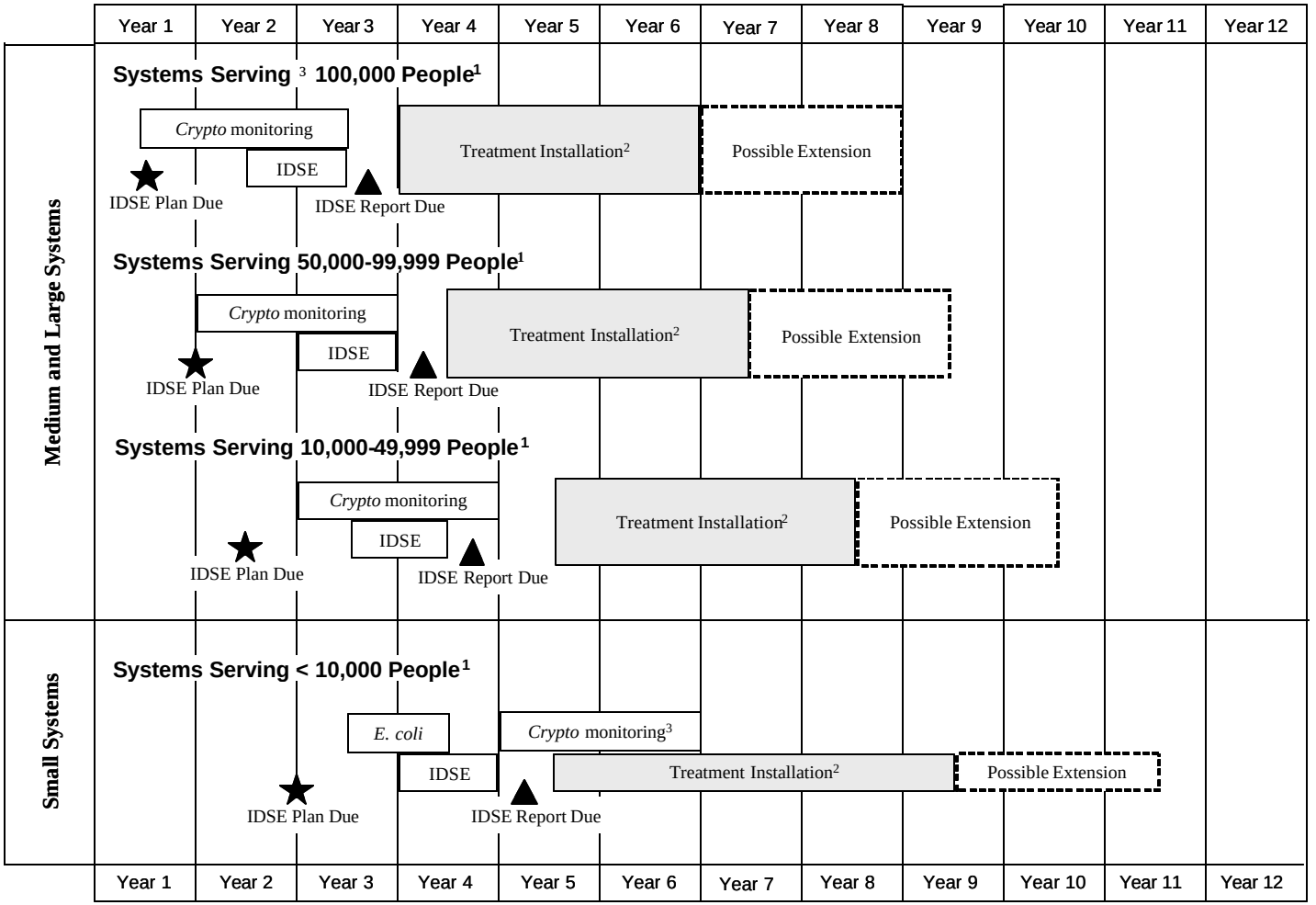


Exhibit ES.2 Implementation Timeline for the Stage 2 DBPR



[1] Includes all systems that are part of a combined distribution system that have a largest system with this population.

[2] A State may grant up to an additional 2 years for systems to comply if the State determines that additional time is necessary for capital improvements.

[3] Subpart H systems that must conduct *Cryptosporidium* monitoring have an additional 12 months to comply with the Stage 2 DBPR MCLs.

Notes: Systems adding disinfection for the GWR are predicted to add disinfection after Stage 2 systems begin compliance monitoring.
The IDSE plan is comprised of either the Standard Monitoring plan or a SSS plan. IDSE includes either completing the Standard Monitoring or a SSS.

Routine Monitoring Requirements

EPA has adopted a population-based monitoring approach for the Stage 2 DBPR, where compliance and IDSE monitoring requirements are based only on system type, source water type, and retail population served. This is a change from the plant-based approach used in the 1979 TTHM rule and the Stage 1 DBPR. EPA's decision to use a population-based approach for all systems is based on improved public health protection, flexibility, and simplified implementation. Exhibit ES.3 presents the new, population-based Stage 2 DBPR compliance monitoring requirements.

Operational Evaluations

Because Stage 2 DBPR MCL compliance is based on individual DBP measurements at a location averaged over a four-quarter period, a system could from time to time have levels at one or more of these locations significantly higher than the MCL (referred to as exceeding the operational evaluation level) while still being in compliance. This is because the high concentration could be averaged with lower concentrations at a given location. If an operational evaluation level is exceeded, the system must conduct an operational evaluation and submit a written report to the State/Primacy Agency.

New Requirements for Consecutive Systems

The Stage 2 DBPR includes provisions for consecutive systems, which are PWSs that purchase or otherwise receive finished water from another water system (a wholesale system). Previous regulation of DBP levels in consecutive systems varies widely among States. The Stage 2 DBPR provides monitoring, compliance schedule, and other requirements specifically for consecutive systems. These requirements are intended to facilitate compliance by consecutive systems with MCLs for TTHM and HAA5 under the Stage 2 DBPR and help to ensure that consumers in consecutive systems receive public health protection equivalent to consumers in non-consecutive systems.

Exhibit ES.3 Stage 2 DBPR Population-Based Compliance Monitoring Requirements

System Size (Population Served)	Distribution System Sample Locations[1]			Total Sample Locations per SYSTEM	Monitoring Frequency[3]
	Highest TTHM Locations	Highest HAA5 Locations	Existing Stage 1 Compliance Locations[2]		
Systems Using Surface Water in Whole or in Part[4]					
< 500	1	1	NA	**2**[5]	per year
500-3,300	1	1	NA	**2**[5]	per quarter
3,301-9,999	1	1	NA	**2**	per quarter
10,000-49,999	2	1	1	**4**	per quarter
50,000-249,999	3	3	2	**8**	per quarter
250,000-999,999	5	4	3	**12**	per quarter
1 Mil-4,999,999	6	6	4	**16**	per quarter
≥ 5,000,000	8	7	5	**20**	per quarter
Systems Using Only Ground Water					
< 500	1	1	NA	**2**[5]	per year
500 - 9,999	1	1	NA	**2**	per year
10,000 - 99,999	2	1	1	**4**	per quarter
100,000 - 499,999	3	2	1	**6**	per quarter
≥ 500,000	3	3	2	**8**	per quarter

[1] Locations must be based on the system's recommendations for Stage 2 DBPR compliance monitoring locations in its report to the State/Primacy Agency, unless the State/Primacy Agency requires different or additional locations. Locations should be distributed throughout the distribution system to the extent possible.

[2] Alternate between highest HAA5 LRAA and highest TTHM LRAA locations among the existing Stage 1 average resident time compliance locations. If the number of existing Stage 1 compliance locations is fewer than the specified number for Stage 2, alternate between highest HAA5 LRAA locations and highest TTHM LRAA locations from the IDSE.

[3] All systems must take at least one dual sample set during the month of highest DBP concentrations. Systems on quarterly monitoring must take dual sample sets approximately every 90 days.

[4] For the purposes of this EA, "surface water" systems are equivalent to "subpart H" systems and include systems that use GWUDI.

[5] The system is required to take individual TTHM and HAA5 samples at the locations with the highest TTHM and HAA5 concentrations, respectively. Only one location with a dual sample set per monitoring period is needed if the highest TTHM and HAA5 concentrations occur at a same location.

NA = Not Applicable

ES.4 Systems Subject to the Stage 2 DBPR

Exhibit ES.4a shows the baseline number of systems subject to the rule and the estimated number that will perform various rule activities (implementation, IDSE monitoring, monitoring plans, and operational evaluations).[3] This baseline is derived from EPA's Safe Drinking Water Information System (SDWIS) inventory, 4th quarter 2003 data.[4] The systems are subdivided by type (CWS or NTNCWS), source water type (either disinfecting ground water only, or surface water and mixed-source) and size (small or large, based on population served). The number of ground water systems in column A represents the subset of all ground water systems that currently disinfect.

As shown in column B, EPA estimates that all disinfecting CWSs and NTNCWSs will have to perform at least minimal implementation activities (reading and understanding the rule, training, etc.). All systems will also have to develop Stage 2 monitoring plans as shown in column F. The number of systems performing IDSE monitoring (shown in column D), however, is only a fraction of all systems because some will choose to perform studies or will receive waivers from IDSE requirements.

EPA has established a population-based monitoring approach for the Stage 2 DBPR, where monitoring requirements are no longer based on the number of plants per system as under the Stage 1 DBPR but rather on the population served. As a result, the number of Stage 2 compliance samples required per year for any particular system may stay the same, decrease, or increase from Stage 1 requirements.

EPA expects that some number of Stage 2-compliant systems will find TTHM and HAA5 levels high enough to trigger the requirement for an operational evaluation. Column H shows the estimated number of systems that may require operational evaluations.

In addition to those ground water systems that currently disinfect, EPA predicts that some systems will install disinfection to comply with the anticipated Ground Water Rule (GWR). Exhibit ES.4b shows the number of systems predicted to install disinfection, as reported in the GWR Economic Analysis (USEPA 2004). Because the GWR is expected to be promulgated at the same time or just after the Stage 2 DBPR is promulgated, EPA expects new systems adding disinfection to meet GWR requirements to simultaneously achieve compliance with Stage 2 MCLs. Therefore, these systems are not included in the treatment baseline. The IDSE will likely not apply to these systems because they are expected to install disinfection after the IDSE requirement period is complete. Systems installing disinfection for the GWR will, however, be required to prepare monitoring plans and in some cases, monitor DBPs for the first time under Stage 2. Exhibit ES.4b shows that all newly disinfecting ground water systems will prepare monitoring plans and conduct compliance monitoring for the first time.

[3] The baseline number of plants–as opposed to systems–that may have to make treatment technology changes to meet rule requirements is different and discussed in section ES.5.1.

[4] SDWIS-Federal Version (SDWIS/FED) is a database created by EPA containing data submitted by States and Regions regarding compliance with SDWA. The system and population baselines in this EA reflect the SDWIS 4th quarter frozen data (2003t).

Exhibit ES.4a Number of Disinfecting Systems Subject to Non-Treatment-Related Rule Activities

System Size (Population Served)	Stage 2 DBPR System Baseline	Number and Percent of Systems Performing Various Rule Activities							
		Implementation		IDSE Monitoring		Stage 2 Monitoring Plans		Operational Evaluations	
	A	B	C=B/A*100	D	E=D/A*100	F	G=F/A*100	H	I=H/A*100
Surface Water and Mixed CWSs									
<10,000	9,397	9,397	100%	7,771	83%	9,397	100%	97	1%
10,000+	2,406	2,406	100%	2,038	85%	2,406	100%	327	14%
National Totals	**11,803**	**11,803**	100%	**9,809**	83%	**11,803**	100%	**424**	4%
Disinfecting Ground Water Only CWSs									
<10,000	28,806	28,806	100%	2,707	9%	28,806	100%	0	0%
10,000+	1,423	1,423	100%	258	18%	1,423	100%	0	0%
National Totals	**30,229**	**30,229**	100%	**2,966**	10%	**30,229**	100%	**0**	0%
Surface Water and Mixed NTNCWSs									
<10,000	771	771	100%	0	0%	771	100%	0	0%
10,000+	6	6	100%	5	83%	6	100%	0	0%
National Totals	**777**	**777**	100%	**5**	1%	**777**	100%	**0**	0%
Disinfecting Ground Water Only NTNCWSs									
<10,000	5,480	5,480	100%	0	0%	5,480	100%	0	0%
10,000+	4	4	100%	1	24%	4	100%	0	0%
National Totals	**5,483**	**5,483**	100%	**1**	0%	**5,483**	100%	**0**	0%
GRAND TOTAL	**48,293**	**48,293**	**100%**	**12,780**	**26%**	**48,293**	**100%**	**424**	**1%**

Exhibit ES.4b Non-Treatment Rule Activities for Systems Installing Disinfection to Comply with the Ground Water Rule

System Size (Population Served)	Baseline No. of Systems Adding Disinfection for the GWR	Stage 2 Monitoring Plans	
	A	B	C=B/A*100
Surface Water and Mixed CWSs			
<10,000	0	0	-
10,000+	0	0	-
National Totals	**0**	**-**	-
Ground Water Only CWSs			
<10,000	1,030	1,030	100%
10,000+	13	13	100%
National Totals	**1,042**	**1,042**	100%
Surface Water and Mixed NTNCWSs			
<10,000	0	0	-
10,000+	0	0	-
National Totals	**0**	**-**	-
Ground Water Only NTNCWSs			
<10,000	1,509	1,509	100%
10,000+	1	1	100%
National Totals	**1,510**	**1,510**	100%
GRAND TOTAL	**2,552**	**2,552**	**100%**

ES.5 National Benefits and Costs of the Stage 2 DBPR Preferred Regulatory Alternative

EPA has determined from its analysis of the available animal toxicological studies and human epidemiological studies that the Stage 2 DBPR could provide benefits resulting from reduced incidence of cancer, particularly bladder cancer, and reduced incidence of adverse reproductive and developmental effects. The main category of benefits that EPA has quantified is the expected range of avoided new cases of bladder cancer each year, including both fatal and non-fatal cases. In addition, EPA has estimated the monetized value of avoiding these fatal and non-fatal bladder cancer cases.

The major steps in deriving and characterizing cancer cases avoided are the following: (1) Estimate the current and future annual bladder cancer cases; (2) Estimate how many cases can be attributed to DBP occurrence and exposure; and (3) Estimate the reduction in future cases corresponding to anticipated reductions in DBP occurrence and exposure due to the Stage 2 DBPR. For step 2, EPA has developed three equally valid approaches to estimating the number of bladder cancer cases attributable to DBPs. For simplicity's sake, one estimate, based on a 2003 meta-analysis by Villanueva et al., is carried through the full benefits analysis.

To assign a monetary value to avoided bladder cancer cases, EPA used the value of a statistical life (VSL) for fatal cases and used two alternate estimates of willingness-to-pay to avoid non-fatal cases (one based on curable lymphoma and the other based on chronic bronchitis). Exhibit ES.5 summarizes the estimated total number of bladder cases avoided and the resulting monetized benefits for the Stage 2 DBPR Preferred Regulatory Alternative. The cases avoided and monetized benefits are based on reductions in average TTHM and HAA5 concentrations that result from making treatment technology changes.

There are several categories of unquantified health and non-health benefits derived from rule implementation that could contribute to the overall value of the benefits of the Stage 2 DBPR. Two important categories are colon and rectal cancers, and reproductive and developmental effects. Human epidemiology studies on chlorinated surface water have also reported associations with colon and rectal cancers. In the Stage 1 DBPR, EPA concluded that early studies suggested a small possible increase in rectal and colon cancers from exposure to chlorinated surface waters. Since the Stage 1 DBPR, the database of studies on colon and rectal cancers continues to support a possible association, but evidence remains mixed. For these reasons, EPA performed a sensitivity analysis to determine potential reductions in rectal and colon cancer cases as a result of the Stage 2 DBPR.

Scientific knowledge about the association of reproductive and developmental health effects with DBP exposure is not known well enough to fully quantify these risks or the benefits of reduced DBP exposure. Nevertheless, although the results from different studies are mixed, a weight of evidence evaluation of the health effects data suggests a potential association between DBP exposure and various adverse reproductive and developmental outcomes. EPA believes that the benefits for reducing the reproductive and developmental effects risks by the Stage 2 DBPR could be substantial and that it is Therefore important to provide some quantitative indication of the possible magnitude of these benefits. To do this, EPA completed an illustrative calculation of potential benefits for one specific reproductive effects end-point (fetal loss). Unquantified benefits are discussed in detail in Chapter 6 and are summarized in Exhibit 9.2.

EPA's national cost estimate includes costs incurred by CWSs and NTNCWSs for rule implementation, the IDSE, preparing Stage 2 monitoring plans, conducting additional routine monitoring,

operational evaluations, and treatment technology changes (which account for the majority of the national costs) as well as estimated costs to States/Primacy Agencies. Exhibit ES.5 summarizes the total national annualized cost estimate for the Stage 2 DBPR Preferred Regulatory Alternative. Note that the exhibit presents two estimates for national costs and monetized benefits, depending upon the discount rate used for present value calculations and annualizing one-time costs.[5]

Sections ES.5.1 through ES.5.3 summarize the methods used to estimate the number of plants making treatment technology changes to comply with the rule, and the benefits and costs resulting from these treatment technology changes. Chapters 3, 5, 6, and 7 and the appendices provide a more complete discussion of all data and calculations used to derive the results in Exhibits ES.5.

ES.5.1 Derivation of the Stage 2 DBPR Compliance Forecast and Consequent Reductions in DBPs

Changes in concentrations of DBPs are the direct result of changes in treatment technologies. Therefore, it is important that EPA use consistent methodologies for forecasting treatment technology changes and predicting reductions in DBPs (specifically, the reductions in TTHM and HAA5 concentrations that are used in the benefits analysis). This section summarizes the tools used and key assumptions for the Stage 2 DBPR compliance forecasts and the consequent reductions in TTHM and HAA5 concentrations.

Since the rule was proposed, EPA has modified the compliance forecast methodology in an attempt to quantify uncertainties in the analysis. Specifically, EPA has developed a second method to predict the number of surface water plants making treatment technology changes and consequent reductions in TTHM and HAA5 concentration, which supplements the Surface Water Analytical Tool (SWAT) predictions. EPA has also quantified uncertainty in the potential impacts of the Initial Distribution System Evaluation (IDSE). Uncertainties are characterized using Monte Carlo simulation in the cost and benefits models.

Predictive Tools Used to Develop the Compliance Forecast

For this EA, EPA uses different methods for different system sizes and source water types to develop the compliance forecasts, as shown in Exhibit ES.6. Because extensive data were available from the Information Collection Rule (ICR), detailed analysis tools were used to develop compliance forecasts for large surface and ground water systems. For large surface water systems, EPA used two different methodologies, both drawing from ICR data: the Surface Water Analytical Tool (SWAT) and the ICR Matrix Method. The ICR Matrix Method uses TTHM and HAA5 distribution system data from the ICR to predict how many plants will need to make treatment technology changes for a specific regulatory alternative. SWAT uses a series of decision rules and algorithms to predict the number of plants making treatment technology changes and the type of treatment they will install for a specific regulatory alternative, based on source water quality and existing treatment as reported in the ICR database. The ICR Matrix Method and SWAT produce different results; thus, results from both are incorporated into the cost model using a Monte Carlo simulation model to account for uncertainties in both methods.

[5] For the Stage 2 DBPR cost and benefit analyses, calculations are made using two discount rates to represent current policy evaluation methodologies, 3 and 7 percent. Chapters 6 and 7 provide additional information on the derivation of these rates.

The forecast for large ground water systems was generated using the ICR Ground Water Delphi process, which convened a group of experts to evaluate plant configurations and predict technology selection for ground water plants that did not meet rule requirements. Compliance forecasts for large surface and ground water systems were used to generate forecasts for medium and small systems, making adjustments to account for different operational and water quality characteristics that exist in the latter.

Exhibit ES.5 Summary of Estimated National Benefits and Costs of the Stage 2 DBPR Preferred Regulatory Alternative ($ Million / Year)

Type of Cost or Benefit		Surface Water		Disinfecting Ground Water		State/ Primacy Agencies	Total
		< 10,000	≥ 10,000	< 10,000	≥ 10,000		
Unquantified Benefits Evidence is mixed and causality has not been established between adverse developmental and reproductive health effects and exposure to chlorinated water. Thus, numbers and types of cases avoided, as well as the value of such cases, were not quantified in the primary benefits. Qualitative assessment indicates that the value of other health benefits and non-health benefits could be positive and significant.							
Estimated Number of Bladder Cancer Cases Avoided per Year Includes both fatal and non-fatal cases. Expected value (90% confidence bounds) Based on Villanvueva et al. 2003 for baseline risk estimates, smoking/lung cancer cessation lag model, and TTHM as an indicator of all DBPs.		8.6	254.5	6.4	8.0		277.5 (101.2 - 540.1)
Benefits and Costs Based on Annualization Discount Rate of 3 %	**Annualized Monetized Benefits of Bladder Cancer Cases Avoided**						
	WTP for Lymphoma as the basis for non-fatal cases, smoking/lung cancer cessation lag model (90% confidence bounds)	$46.7 ($7.1 - $107.8)	$1,397.5 ($212.6 - $3228.1)	$34.7 ($5.3 - $80.2)	$44.1 ($6.7 - $101.9)		$1,523.0 ($231.7 - $3518.2)
	WTP for Chronic Bronchitis as the basis for non-fatal cases, smoking/lung cancer cessation lag model (90% confidence bounds)	$23.3 ($5.0 - $51.6)	$696.3 ($150.8 - $1544.9)	$17.3 ($3.7 - $38.4)	$22.0 ($4.8 - $48.8)		$758.9 ($164.3 - $1683.7)
	Annualized Total Costs (90% confidence bounds)	$13.5 ($7.5 - $19.7)	$39.6 ($21.7 - $58.7)	$18.0 ($16.0 - $20.0)	$13.4 ($12.6 - $14.3)	$1.7	$86.2 ($59.5 - $114.5)
Benefits and Costs Based on Annualization Discount Rate of 7 %	**Annualized Monetized Benefits of Bladder Cancer Cases Avoided**						
	WTP for Lymphoma as the basis for non-fatal cases, smoking/lung cancer cessation lag model (90% confidence bounds)	$37.4 ($5.7 - $86.3)	$1,138.7 ($173.4 - $2628.7)	$27.8 ($4.2 - $64.2)	$35.8 ($5.5 - $82.8)		$1,239.7 ($188.7 - $2862.0)
	WTP for Chronic Bronchitis as the basis for non-fatal cases, smoking/lung cancer cessation lag model (90% confidence bounds)	$18.6 ($4.0 - $41.3)	$567.0 ($83.7 - $854.9)	$13.8 ($3.0 - $30.7)	$17.8 ($3.9 - $39.6)		$617.3 ($133.9 - $1368.3)
	Annualized Total Costs (90% confidence bounds)	$12.7 ($7.2 - $18.4)	$40.4 ($22.3 - $59.3)	$17.0 ($15.0 - $19.1)	$12.4 ($11.6 - $13.3)	$1.7	$84.2 ($57.8 - $111.7)

Notes: Detail may not add due to independent rounding.
Monetized benefits and costs represent present values in millions of 2003 dollars. Estimates are discounted to 2005. Costs are for CWSs and NTNCWSs and include treatment and non-treatment

Benefits for the Stage 2 DBPR are estimated using three approaches for estimating baseline risk, three different cessation lag models, and either TTHMs or HAA5s as an indicator. Nominal benefits presented here are estimated using Villanueva et al. (2003) for baseline risk, TTHMs as an indicator, and the Smoking/Lung Cancer cessation lag model. Using TTHM or HAA5 as an indicator for all DBPs produces similar results. Because Villaneuva et al. (2003) and the Smoking/Lung Cancer cessation lag model result in benefits estimates that are in between the other alternatives, results are presented as a representative comparison to costs. Chapter 6 presents results for the full range of alternative approaches to estimating baselin risk and cessation lag.

90 percent confidence bounds around cost account for uncertainty in the compliance forecast methodology, potential impacts of the IDSE, and unit costs. 90 percent confidence bounds around cases avoided accounts for uncertainty in the compliance forecast, PAR, cessation lag model form, and predicted DBP reduction from the compliance forecast. 90 percent confidence bounds around monetized benefits also reflect uncertainty in VSL and WTP inputs.

Sources: Totals for bladder cancer cases avoided and monetized benefits from Exhibit 6.27. Detail for source and size provided in Appendices E and F.
Annualized total costs and state/primacy agency costs derived from Exhibits 7.5a and 7.5b.

Exhibit ES.6 Tools Used to Develop the Stage 2 DBPR Compliance Forecasts

System Size (Population Served)	Source Water Category		
	Surface Water		Disinfecting Ground Water
Large (≥ 100,000 people)	The Surface Water Analytical Tool (SWAT)	ICR Matrix Method	ICR Ground Water Delphi Group
Medium (10,000 to 99,999 people)	Extrapolation from SWAT	Extrapolation from ICR Matrix Method	Extrapolation from large ground water system results
Small (<10,000 people)	Extrapolation from SWAT, adjusted to deal with small system-specific issues	Extrapolation from ICR Matrix Method	Extrapolation from large ground water system results, adjusted to deal with small system-specific issues

Tools Used to Predict Changes in DBP Levels

For the benefits analysis, EPA needs information on the changes in both average and peak TTHM and HAA5 levels that result from implementation of the Stage 2 DBPR. Estimates of bladder cancer cases avoided and the colon and rectal cancer sensitivity analysis are based on reductions in average levels, while the illustrative analysis of potential developmental and reproductive health benefits is based on reductions in occurrences of peak concentrations.

To predict changes in average TTHM and HAA5 levels for surface water systems, EPA uses two methods: the ICR Matrix Method and SWAT. As noted in the previous section, the ICR Matrix Method evaluates distribution system data to identify plants that would need to make treatment technology changes to meet a specific regulatory alternative. To predict average DBP concentrations occurring after treatment technology changes, EPA used TTHM and HAA5 occurrence data for those surface water plants already using chloramines and/or advanced technologies at the time of the ICR. The predicted average TTHM and HAA5 levels for all surface water plants is a weighted average for plants that do and do not change treatment technology.

SWAT is a model that uses a series of decision rules and algorithms to predict (1) which surface water plants need to change treatment technology to meet a specific regulatory alternative, (2) which treatment technology those plants will select based on a least cost decision tree, and (3) resulting changes in the national average TTHM and HAA5 levels in distribution systems. As with the compliance forecast, SWAT and the ICR Matrix Method produce different results; thus, both are incorporated into a Monte Carlo simulation model to account for uncertainties in both methods.

ICR ground water plant data were not robust enough to develop a ground water model similar to SWAT; therefore, the ICR Matrix Method is the only approach used to predict reductions in average TTHM and HAA5 levels for these systems.

To predict changes in the occurrence of peak TTHM and HAA5 concentrations, EPA used only the ICR Matrix Method[6]. Similar to the way in which it is used to evaluate changes in average TTHM and HAA5 concentrations, the ICR Matrix Method evaluates distribution system data to identify plants that would need to make treatment technology changes to meet a specific regulatory alternative. To predict occurrence of peaks after treatment technology changes, EPA analyzed TTHM and HAA5 occurrence data for those surface water plants already using chloramines and/or advanced technologies at the time of the ICR. The predicted occurrence of peaks for all plants is a weighted average for plants that do and do not make treatment technology changes.

Accounting for the Stage 1 DBPR

For cost and benefit analyses, the compliance forecast and consequent reduction in DBPs needs to represent treatment technology changes from the pre-Stage 2 baseline (i.e., after implementation of the Stage 1 DBPR). The best data available to characterize large plants are from the ICR, which were collected before the Stage 1 DBPR compliance deadlines and likely represent pre-Stage 1 conditions[7]. The compliance forecast, therefore, needs to account for treatment technology changes as a result of the Stage 1 DBPR before predicting changes that are needed for the Stage 2 DBPR. Similarly, the post-Stage 2 TTHM and HAA5 predictions need to take into account changes as a result of the Stage 1 DBPR before predicting reductions that will occur as a result of the Stage 2 DBPR.

EPA uses a "delta" compliance forecast method that was developed by the Microbial / Disinfection Byproducts (M-DBP) Technical Working Group (TWG). The method has four steps. First, EPA characterizes treatment technologies and TTHM and HAA5 occurrence for the Pre-Stage 1 baseline. Secondly, EPA predicts treatment technology changes and subsequent reduction in TTHM and HAA5 levels from Pre-Stage 1 baseline to post-Stage 1 DBPR conditions. Thirdly, treatment technology changes and subsequent reductions in TTHM and HAA5 levels are predicted from pre-Stage 1 baseline to post-Stage 2 DBPR conditions. Lastly, results from step 2 are subtracted from step 3 to calculate the incremental treatment technology change and TTHM/HAA5 reduction from post-Stage 1 DBPR to post-Stage 2 DBPR conditions.

This delta method was selected by the M-DBP TWG over a more direct, two step approach (i.e., predict pre-Stage 2 conditions and then use the pre-Stage 2 conditions to predict impacts for Stage 2) because modeling tools are not able to predict the treatment technology selection or TTHM, HAA5, bromate, and chlorite levels at the plant level. The delta approach compensates, at the national level, for potential errors in treatment technology selection and resulting TTHM and HAA5 concentrations predicted for Stage 2. The TWG believed that using the delta approach reduces the impact of uncertainty in SWAT predictive equations for TTHM and HAA5. The delta approach is used with both the ICR Matrix Method and SWAT analyses.

[6] Although the SWAT model was calibrated to national average TTHM and HAA5 concentrations in distribution systems and validated against industry treatment technology predictions, it was not calibrated to plant-level DBP predictions and, thus, could not be used to assess changes in occurrence of peak levels. See Appendix A for more information on SWAT.

[7] There is uncertainty in using the ICR data to represent pre-Stage 1 conditions because some plants may have begun making changes prior to the ICR in anticipation of the Stage 1 DBPR (McGuire et al., 2002). See Section 3.8 for a full discussion of uncertainties in ICR data.

Accounting for *the IDSE*

Because the purpose of the IDSE is to identify Stage 2 compliance monitoring locations with high DBP levels, it is possible that systems may measure higher DBP levels at Stage 2 compliance monitoring sites than were measured under the ICR. This suggests that the number of plants predicted to make treatment technology changes, the level of treatment they select, and the resulting reductions in TTHM and HAA5 levels, all based on ICR data, could be underestimated.

The M-DBP TWG recommended that the Stage 1 and Stage 2 compliance forecast methodology incorporate an operational safety margin of 20 percent to represent the operational level (i.e., 80 percent of the MCL) at which systems typically take some action to ensure consistent compliance with a new drinking water standard and the level at which systems target new treatment technologies to meet the standard. EPA believes that this safety margin already accounts for the impacts of the IDSE for some systems, including small systems, ground water systems, and those using chloramines[8]. EPA believes, however, that the 20 percent safety margin is not sufficient to account for the potential impacts of the IDSE on large and medium surface water systems because spatial variability of DBP levels and distribution system complexity are greatest in these systems. Since the proposal, EPA developed a methodology that analyzed ICR data from surface water plants to assess the extent of spatial variability of TTHM and HAA5 levels and used this as a basis for quantifying the impacts of the IDSE for large and medium surface water systems.

Results

Exhibit ES.7a shows the mean number and percent of plants expected to make advanced treatment technologies changes to meet the requirements of the Stage 2 DBPR. Advanced technologies include alternative disinfectants such as ozone, UV, and chlorine dioxide, and DBP precursor removal technologies such as microfiltration or ultrafiltration. The 90 percent confidence intervals around the mean estimate for surface water systems accounts for alternative compliance forecast methodologies (SWAT and the ICR Matrix Method) and uncertainty in the potential impacts of the IDSE. Because one method (instead of two) was used to predict ground water plants making treatment technology changes, Exhibit ES.7a only presents a mean value for these plants.

Exhibit ES.7b shows the reduction in the national average TTHM and HAA5 concentrations occurring in drinking water distribution systems as a result of treatment technology changes to meet Stage 2 DBPR requirements. The 90 percent confidence intervals around the mean estimate for surface water systems accounts for alternative methodologies (SWAT and the ICR Matrix Method) and the potential impacts of the IDSE.

[8]EPA believes that the 20 percent safety margin accounts for potential impacts of the IDSE for small systems because their distributions are not as complex when compared to large systems. EPA also believes that the safety margin accounts for the IDSE for ground water systems because the year-to-year variability in source water quality (and thus, TTHM and HAA5 formation) is low. Chloramine systems generally observe lower spatial and temporal variability in TTHM and HAA5 distribution system levels (USEPA 2005k); thus, EPA believes the 20 percent safety margin accounts for potential impacts of the IDSE for these systems.

Exhibit ES.7a Plants Making Treatment Technology Changes, Preferred Regulatory Alternative

System Size (Population Served)	Stage 2 DBPR Plant Baseline	Number of Plants Making Treatment Technology Changes			Percentage of Plants Making Treatment Technology Changes		
		Mean	5th %ile	95th %ile	Mean	5th %ile	95th %ile
	A	B	C	D	E=B/A	F=C/A	G = D/A
Primarily Surface Water CWSs							
<10,000	3,996	386	200	572	9.7%	5.0%	14.3%
10,000+	2,555	408	180	668	16.0%	7.0%	26.1%
National Totals	**6,552**	**795**	**380**	**1,240**	**12.1%**	**5.8%**	**18.9%**
Primarily Ground Water CWSs							
<10,000	40,376	1,169			2.9%		
10,000+	7,044	145			2.1%		
National Totals	**47,419**	**1,314**			**2.8%**		
Primarily Suface Water NTNCWSs							
<10,000	760	75	39	111	9.9%	5.1%	14.6%
10,000+	6	1	0	2	16.0%	7.0%	26.1%
National Totals	**766**	**76**	**39**	**113**	**9.9%**	**5.1%**	**14.7%**
Primarily Ground Water NTNCWSs							
<10,000	5,480	153			2.8%		
10,000+	4	0			2.1%		
National Totals	**5,483**	**154**			**2.8%**		
Grand Total All Plants	**60,220**	**2,338**	**1,887**	**2,820**	**3.9%**	**3.1%**	**4.7%**

Note: Detail may not add to totals due to independent rounding. Treatment changes include adding adanced technologies and/or chloramines.

Sources:
(A) Exhibit 3.2, column AB. Represents 4th quarter 2003 SDWIS data. System baseline converted to plant baseline through four steps: 1) link purchase systems to their respective sellers, 2) estimate percent of ground water systems that disinfect, 3) categorize systems by primary source, and 4) multiple the system inventory by estimate of mean plants per system to produce plant inventory.
(B) - (D) Exhibit 7.3. The 90 percent confidence intervals for surface water systems represent alternative compliance forecast methodologies (SWAT and the ICR Matrix Method) and uncertainty in the potential impacts of the IDSE.

Exhibit ES.7b Estimated Reduction in TTHM and HAA5 from Pre-Stage 2 to Post-Stage 2, Preferred Regulatory Alternative

Source Water Type	System Size (Population Served)	Population	TTHM						
			Pre-Stage 2 Level (µg/L)	Post-Stage 2 Level (µg/L)			Percent Reduction		
				mean	5th	95th	Mean	5th	95th
		A	B	C = B * (1-D)			D		
SW	Large (> 10,000)	160,935,736	35.5	32.2	33.6	30.7	9.3%	5.2%	13.5%
	Small (= 10,000)	8,422,403	35.5	32.9	33.8	32.0	7.2%	4.7%	9.7%
GW	Large (> 10,000)	65,152,168	13.2	13.0			1.4%		
	Small (= 10,000)	28,514,211	15.6	15.5			0.7%		
All Systems*		**263,024,518**	**27.79**	**25.63**	**26.55**	**24.72**	**7.8%**	**4.5%**	**11.1%**

Source Water Type	System Size (Population Served)	Population	HAA5						
			Pre-Stage 2 Level (µg/L)	Post-Stage 2 Level (µg/L)			Percent Reduction		
				mean	5th	95th	Mean	5th	95th
		A	E	F = E * (1-G)			G		
SW	Large (> 10,000)	160,935,736	25.0	22.5	23.7	21.1	10.0%	5.3%	15.5%
	Small (= 10,000)	8,422,403	25.0	23.1	23.8	22.4	7.6%	4.7%	10.5%
GW	Large (> 10,000)	65,152,168	7.0	6.6			4.5%		
	Small (= 10,000)	28,514,211	8.5	8.3			2.2%		
All Systems*		**263,024,518**	**18.75**	**17.06**	**17.81**	**16.22**	**9.0%**	**5.0%**	**13.5%**

Notes:

All TTHM and HAA5 concentrations represent the mean of all plant-mean concentrations

The benefits analysis performs the monte carlo simulation model using percent reductions in DBPs (not post-stage 2 DBP values). Thus, columns C and F are calculated, and D and G are outputs from the model.

* TTHM and HAA5 concentrations for all systems are the population-weighted values

(A) SDWIS 2003 3rd quarter freeze, community water system population (exhibit 3.3, CWSs only)

(B) and (E) Exhibit 5.22

(D) and (G) Outputs from the benefits monte carlo simulation model. Confidence bounds for large and medium SW systems account for uncertainties in compliance forecast methodologies and potential impacts of the IDSE. Confidence bounds for small SW systems account for uncertainties in compliance forecast methodologies.

ES.5.2 Derivation of Benefits

Three categories of benefits are addressed in this EA: those associated with reductions in the incidence of bladder cancer, those associated with decreasing cases of colon and rectal cancers, and those associated with reductions in the incidence of adverse reproductive and developmental health effects. The primary benefits analysis in this EA is based on reductions in bladder cancer cases. Potential benefits associated with reduced incidence of colon and rectal cancers are quantified in a sensitivity analysis, while potential benefits associated with decreasing adverse developmental and reproductive health effects (specifically, fetal losses) are presented as an illustrative calculation.

EPA used similar approaches to estimate the number of bladder cancer cases avoided (the primary benefits analysis), the number of colon and rectal cancer avoided (the sensitivity analysis), and the number of avoided incidence of fetal loss (the illustrative calculation). The major steps in deriving and characterizing cases avoided are:

- Estimate the current and future annual cases of illness from all causes
- Estimate how many cases can be attributed to DBP occurrence and exposure
- Estimate the reduction in future cases corresponding to anticipated reductions in DBP occurrence and exposure due to the Stage 2 DBPR

All benefit calculations were performed using the Stage 2 DBPR Benefits Model (USEPA 2005h).

For bladder cancer, EPA computed the monetized benefits of the Stage 2 DBPR by multiplying the estimated number of bladder cases avoided by the estimated monetary value associated with avoiding both fatal and non-fatal cases of bladder cancer. The value of a statistical life (VSL) was used for fatal bladder cancers, while two alternate estimates of willingness-to-pay to avoid non-fatal bladder cancer are used (one based on avoiding a case of curable lymphoma and the other based on avoiding a case of chronic bronchitis). EPA also computed the benefits for the reduction in colon and rectal cancer by using the same VSL and willingness to pay (WTP) estimates. EPA recognizes that there could be a significant value associated with the number of avoided fetal losses estimated in the illustrative calculation. However, the Agency is unable at this time either to develop a specific estimate of this value or to use a benefit transfer method to estimate the value from studies that address other endpoints (see Section 6.8 for a full discussion of this issue).

Bladder Cancer

To calculate potential benefits from reduced incidence of bladder cancer cases, EPA began by estimating the number of new bladder cancer cases occurring per year from all causes. The National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER, 2004) program provides data on cancer rates (new cases per 100,000 population per year) as a function of age. EPA used this information in conjunction with population-by-age data from the 2000 U.S. Census to estimate the number of new cases of bladder cancer. Results show that the number of new bladder cancer cases per year starts to increase at about age 35 and peaks at 1,500 to 2,000 cases from about age 60 to 80. Although the annual rate of bladder cancer does not decline much after age 80, the incidence of new bladder cancers does, which represents the overall decline in the number of individuals alive after that age. The resulting total number of new bladder cancer cases per year, 56,505, is slightly lower than that currently

estimated by the American Cancer Society (ACS).[9] This likely represents EPA's use of the census population data from 2000.

To estimate the baseline number of cases attributable to DBP exposure, EPA used three different approaches:

- Using the range of Population Attributable Risk (PAR) values derived from consideration of 5 individual epidemiology studies used for the Stage 1 EA and the Stage 2 proposal EA (yields a pre-Stage 1 range of best estimates for PAR of 2% to 17%).

- Using the Odds Ratio (OR) of 1.2 from the Villanueva et al. (2003) meta-analysis that reflects both sexes, ever exposed population from the studies considered (yields a pre-Stage 1 best estimate for PAR of ~16%)

- Using the Villanueva et al. (2004) pooled data analysis to develop a dose-response relationship for OR as a function of Average TTHM. The dose-response relationship was modeled as linear with an intercept of OR = 1.0 at TTHM exposure level = 0 (yields a pre-Stage 1 best estimate for PAR of ~17%)

All three approaches are considered equally valid and provide feasible estimates of risk. For the sake of simplicity, EPA carried only one these approaches, that based on Villanueva et al. (2003), through the entire benefits model.

To quantify the reduction in cases, EPA assumes that there is a linear relationship between average DBP concentration and relative risk of bladder cancer. Thus, percent reductions in national average DBPs are used to determine the percent reductions in bladder cancer cases attributable to DBPs. Predicted reductions in national average TTHM and HAA5 levels resulting from predicted treatment technology changes to comply with Stage 2 were used as indicators of overall chlorination DBP reductions. The baseline cases attributable to DBPs multiplied by the percent reductions in TTHM or HAA5 concentrations result in the estimated annual bladder cancer cases "ultimately avoidable" for the Stage 1 and Stage 2 rules.

Over the long run, the annual cases ultimately avoidable (derived as described above) will be attained. They will not be achieved instantaneously, however. Research shows that a lag period (referred to as "cessation lag") exists between the point in time when reduction in exposure to a carcinogen occurs and the point in time when the full risk reduction benefit of that exposure reduction is realized by affected individuals. Because there is no epidemiological or other empirical data available that specifically address the rate of achieving bladder cancer benefits resulting from DBP reductions, EPA uses data from three epidemiological studies that address the rate of risk reduction following exposure reduction to other carcinogens (namely cigarette smoke and arsenic) to generate three possible cessation lag functions for bladder cancer and DBPs.

The cessation lag functions are used to project the number of bladder cancer cases avoided each year after implementation as a result of the Stage 2 DBPR over a 100-year period. A 100-year period was selected as the timeframe after which effectively all of the exposed population is composed of

[9]The American Cancer Society estimated in 2004 that 60,240 new cases of bladder cancer would occur in the U.S. population that year (ACS website, 2004).

individuals exposed only to post-Stage 2 levels for their entire lifetime. At that time (and from that point forward) the annual bladder cancer cases ultimately avoidable are achieved for the exposed population. The projected number of cases avoided each year is then further adjusted forward in time to reflect when systems are expected to install new treatment to reduce DBPs based on the rule implementation schedule. Although a 100-year cessation lag period is modeled, annual avoided cases of bladder cancer are calculated primarily for the first 25 years after rule promulgation. A 25-year time period was used to coincide with the estimated life span of capital equipment and a time lag of five to ten years for technology installation after rule promulgation.

The final step in the benefit calculation is to monetize the average annual cases avoided. This is done by applying economic values for avoided illnesses and deaths. EPA has estimated that 74 percent of bladder cancer cases are non-fatal (USEPA, 1999a). The value of avoiding non-fatal bladder cancer cases is based on people's WTP for incremental reductions in the risk they face of contracting cancer. The metric of WTP to avoid an increased risk includes the desire to avoid treatment costs, pain and discomfort, productivity losses, and any other adverse consequences related to a non-fatal case of bladder cancer. Because specific estimates of WTP for avoiding non-fatal bladder cancer are not available, EPA estimated values from two other non-fatal illnesses: curable lymphoma and chronic bronchitis. Both are considered valid estimates of WTP for non-fatal cancer.

For fatal bladder cancer cases, VSL is used to capture the value of benefits. The VSL represents an estimate of the monetary value of reducing risks of premature death from cancer. Therefore, it is not an estimate of the value of saving a particular individual's life. Rather, it represents the sum of the values placed on small individual risk reductions across an exposed population. Other economic factors are taken into consideration when calculating benefits over time, such as income growth and social discount rates.

There are several areas of uncertainty with respect to quantified benefits for bladder cancer. Many are described qualitatively in the analysis, while other are incorporated explicitly as follows:

- There is uncertainty in the percent reduction in TTHM and HAA5 concentrations resulting from predicted treatment technology changes (i.e., the compliance forecasts). Uncertainty in SWAT and potential impacts of the IDSE are quantified in the primary analysis.

- Three approaches were used to estimate the baseline number of bladder cancer cases attributable to DBP exposure. For the sake of simplicity, one approach using data from Villanueva et al. (2003) was carried through the full benefits model.

- The estimated PAR values from the Villanueva et al. (2003) meta-analysis include confidence bounds resulting from statistical uncertainty in the odds ratio underlying the PAR calculation. The confidence bounds from Villanueva et al. (2003) capture a significant portion of the confidence intervals of the other two approaches.

- Three independent cessation lag models derived from three different epidemiological studies are used in the model. Also, two functional forms are used for each of these data sets and uncertainty in the parameters of those functions is included in the analysis.

- EPA uses two alternatives for valuing non-fatal bladder cancer.

Colon and Rectal Cancers

Human epidemiology studies on chlorinated surface water have reported associations with colon and rectal cancers. Colon and rectal cancers combined are the third most common type of new cancer cases and deaths in both men and women in the U.S., excluding skin cancers. Therefore, any benefit from reducing the incidence of colon and rectal cancers could be significant. EPA is including a quantitative sensitivity analysis for benefits accrued from the Stage 2 DBPR from avoiding colon and rectal cancers.

EPA estimated the reduction in colon and rectal cancer in a similar manner to bladder cancer cases. Background incidence data were available from the SEER cancer registry and two quality studies were chosen to estimate a PAR value. Using the percent reductions in DBPs and the smoking and lung cancer cessation lag model, the number of colon and rectal cancer cases avoided annually was estimated and monetized with the same VSL and WTP estimates as for bladder cancer.

Developmental And Reproductive Health Effects

As noted previously, EPA predicts that a significant portion of the total benefit of this rule could come from reductions in developmental and reproductive health effects, although the relationship of these effects to DBP exposure is not known well enough to fully quantify risks or benefits. EPA was able to do a preliminary calculation of the benefits of reducing the risk of fetal loss, the non-cancer effect for which the most epidemiological data exist in relation to DBP exposure. Because approximately one million of the six million pregnancies each year in the United States end in a miscarriage or stillbirth (Ventura et al. 2000), avoiding even a small risk attributable to DBP exposure by reducing DBP levels may result in a significant number of avoided fetal losses.

EPA estimated the reduction in fetal losses in a similar manner to bladder cancer cases. A range of possible PAR values for relating annual fetal losses to DBP exposure was obtained from available epidemiological studies. Reductions in the number of peak DBP events due to the Stage 1 DBPR and the Stage 2 DBPR were estimated. Reductions in exposure to peak DBPs were assumed to be proportional to reductions in peak DBP events. Like the analysis of bladder cancer, there is uncertainty in fetal loss PAR values, reflected in the range of values used in the analysis. There are other important uncertainties in this illustrative calculation, including the assumed proportional relationship between reduction in fetal losses and reduction in exposure to peak levels due to the Stage 2 DBPR.

ES.5.3 Derivation of Costs

To estimate the total national costs of the Stage 2 DBPR, EPA calculated the incremental costs to be incurred by PWSs and States/Primacy Agencies from the Stage 1 DBPR to the Stage 2 DBPR. Cost analyses for PWSs include identifying treatment process improvements that systems may make, as well as estimating the costs to implement the rule, conduct IDSEs, prepare monitoring plans, perform additional routine monitoring, and conduct operational evaluations (referred to as "non-treatment" activities in this document). The cost analysis for States/Primacy Agencies includes estimates of the labor burdens that they would face, such as training employees in the requirements of the Stage 2 DBPR, responding to PWS reports, and record keeping. Cost calculations are performed using the Stage 2 DBPR Cost Model (USEPA 2005i). The methodology for estimating treatment and non-treatment related

costs for systems is discussed in the next several paragraphs, followed by a discussion of uncertainties. (A complete discussion of the cost analysis is provided in Chapter 7.)

All treatment costs are based on mean unit cost estimates for advanced technologies and chloramines. Technology unit cost estimates are in the form of "dollars per plant" for initial capital and ongoing operation and maintenance (O&M) activities. Derivation of unit costs for a wide range of plant sizes, represented by different design and average daily flow rates, are described in detail in the document, *Technologies and Costs for Control of Microbial Contaminants and Disinfection Byproducts* (USEPA 2003o). EPA uses mean population per system for each of the nine system size categories (derived from SDWIS) combined with regression equations to estimate mean design and average daily flows as a function of population served, for ground and surface water plants.[10] Unit costs (capital and O&M) for each of the nine system size categories can be calculated using these mean flow values. The unit costs are then combined with the predicted number of plants selecting each technology to produce national treatment cost estimates.

Non-treatment costs for implementation, the IDSE, monitoring plans, additional routine monitoring, and operational evaluations are based on estimates of labor hours for performing these activities and on additional laboratory costs. For all non-treatment cost calculations, EPA used the Stage 2 DBPR system baseline shown in Exhibit ES.4a plus the estimate of additional ground water systems expected to install disinfection for the GWR as shown in ES.4b (for routine monitoring and monitoring plan costs only).

EPA recognizes that systems vary with respect to many of the attributes that are used as input parameters to the Stage 2 DBPR cost model (e.g., plants per system, population served, flow per population, labor rates). In most cases, there is insufficient information to characterize fully the variability on a national scale. EPA believes that mean values for the various input parameters are adequate to generate EPA's best estimate of national costs for the rule.

EPA has quantified several large areas of uncertainty in costs by quantifying uncertainty in compliance forecasts, as noted in section ES.5.1. There is uncertainty in the national average unit capital and O&M costs for the various technologies expected to be implemented in response to the Stage 2 DBPR. This uncertainty has been incorporated into the cost model (using Monte Carlo simulation procedures). The national costs of the Stage 2 DBPR summarized in Exhibit ES.5 show both the expected values and the 90 percent confidence bounds on the national cost estimates obtained from the cost model.

[10] System size categories are based on population served and are as follows: <100; 100-499; 500-999; 1,000-3,300; 3,301-9,999; 10,000-49,999; 50,000-99,999; 100,000-999,999; 1 million +. These categories are consistent with data in the Drinking Water Baseline Handbook (USEPA 2001c).

ES.6 Estimated Impacts on Household Costs

EPA assumes that systems will, to the extent possible, pass cost increases onto their customers through increases in water rates. Exhibit ES.8 presents estimated annual household cost increases for the Stage 2 DBPR Preferred Regulatory Alternative. The top half of the exhibit shows summary statistics for all households served by systems subject to the rule, including those that will not make treatment technology changes but will incur other minimal costs, such as for rule implementation or additional routine monitoring. The bottom half shows statistics just for those households served by systems actually making treatment technology changes to comply with the rule (see Exhibit ES.7a for estimates of the percent of plants making treatment technology changes). Because treatment technology changes represent the majority of rule costs, this provides insight into how the rule will affect that segment of the population most impacted by the rule.

Exhibit ES.8 Summary of Annual Household Cost Increases

	Total Number of Households Served	Mean Annual Household Cost Increase	Median Annual Household Cost Increase	90th Percentile Annual Household Cost Increase	95th Percentile Annual Household Cost Increase	Percentage of Annual Household Cost Increase < $12	Percentage of Annual Household Cost Increase < $120
All Systems	101,553,868	$ 0.66	$ 0.03	$ 0.39	$ 1.26	99%	100%
All Small Systems	14,261,241	$ 2.26	$ 0.10	$ 0.79	$ 2.69	97%	99%
SW < 10,000	3,251,893	$ 4.95	$ 0.79	$ 2.69	$ 13.80	95%	99%
SW ≥ 10,000	62,137,350	$ 0.50	$ 0.02	$ 0.35	$ 1.84	99%	100%
GW < 10,000	11,009,348	$ 1.47	$ 0.02	$ 0.39	$ 0.99	98%	100%
GW > 10,000	25,155,277	$ 0.14	$ 0.01	$ 0.03	$ 0.11	100%	100%
Households Served by Plants Adding Treatment							
	Total Number of Households Served	Mean Annual Household Cost Increase	Median Annual Household Cost Increase	90th Percentile Annual Household Cost Increase	95th Percentile Annual Household Cost Increase	Percentage of Household Cost Increase < $12	Percentage of Household Cost Increase < $120
All Systems	11,062,385	$ 5.38	$ 0.80	$ 10.04	$ 21.43	92%	99%
All Small Systems	619,628	$ 45.76	$ 17.09	$ 168.85	$ 190.19	39%	88%
SW < 10,000	314,083	$ 43.06	$ 13.79	$ 173.53	$ 177.93	47%	85%
SW ≥ 10,000	9,933,196	$ 2.83	$ 0.80	$ 6.98	$ 11.31	96%	100%
GW < 10,000	305,545	$ 48.55	$ 16.65	$ 106.39	$ 196.50	31%	92%
GW > 10,000	509,562	$ 5.98	$ 1.37	$ 26.83	$ 33.87	79%	100%

Notes: Detail may not add to total due to independent rounding. Number of households served by systems adding treatment will be higher than households served by plants adding treatment because an entire system will incur costs even if only some of the plants for that system add treatment (this would result in lower household costs, however).

Source: Exhibit 7.15

As shown in Exhibit ES.8, the mean, median, and 90th percentile annual household cost increases for all systems are $0.68, $0.03, and $0.39 per year, respectively. The mean, median, and 90th percentile household cost increases for those served by plants making treatment technology changes are $5.43, $0.80, and $10.03, respectively. Households in small systems served by plants making treatment technology changes will experience the highest household cost increases because they must spread technology costs over a smaller customer base.

[Information on the small system affordability analysis to be provided once the revised affordability criteria become available.]

ES.7 Comparison of Costs and Benefits for Four Regulatory Alternatives

Section ES.2 described the four regulatory alternatives considered in this economic analysis. Benefits and costs for these four alternatives are summarized in Exhibit ES.9 and ES.10, respectively. EPA recognizes that the quantified benefits based on reduced cases of bladder cancer, shown in Exhibit ES.9, could be zero for all alternatives since causality has not yet been established between exposure to chlorinated water and bladder cancer.

As shown in Exhibit ES.10, EPA chose the least-cost alternative that targets the highest risks. Estimated costs for Alternative 1 are approximately three times those for the Preferred Alternative because of the more stringent bromate standard. Quantified benefits based on bladder cancer cases avoided are nearly the same for Alternative 1 and the Preferred Alternative (Exhibit ES.9), although the benefits of avoiding potential cancer cases by lowering the bromate standard in Alternative 1 are unquantified. EPA did not favor this alternative because of a concern that lowering the bromate level to 5 µg/L could have adverse effects on microbial protection (see Chapter 4 for a full discussion). The range of quantified benefits increases significantly with Alternatives 2 and 3. However, these alternatives do not include the risk targeting strategy of the Preferred Alternative. EPA has estimated that a large portion of the surface water systems covered by the rule would have to switch from their current treatment practice to more expensive advanced technologies to comply with these alternatives. The associated costs presented in ES.9 show mean estimated values between $444 and $658 million per year at a 3 percent discount rate. The M-DBP Advisory Committee did not favor Alternatives 2 and 3 because it believed that the health effects data are not certain enough to warrant such a drastic shift in the nation's drinking water treatment practices.

A comparison of alternatives can also be made using net benefits: the difference between the annualized costs and the annualized monetized benefits. Exhibit ES.10 shows that the Preferred Alternative has higher net benefits than Alternative 1, but lower net benefits than Alternatives 2 and 3 using either estimate of WTP for non-fatal bladder cancer. Net benefits, however, do not include the unquantified benefits.

A further consideration is the relative cost effectiveness of each regulatory alternative of the Stage 2 DBPR. The rule is cost effective if it achieves an acceptable level of benefit for a given expenditure; or if it yields the required level of benefits below an acceptable cost. The most cost effective regulatory alternative would achieve the greatest benefits for a given expenditure, or would impose the least cost for achieving a given level of benefit. Cost effectiveness analysis (CEA) usually produces a ratio consisting of a cost measure and an effectiveness measure, i.e., dollars per bladder cancer case avoided. The problem with CEA is that, as with analysis of benefit cost ratios, it does not take into account the scale of benefits or costs; therefore, when considering alternatives such as those in the Stage 2 DBPR, CEA does not provide enough information for choosing a regulatory alternative, and is only part of a complete analysis as presented in this EA.

Exhibit ES.9 Comparison of Benefits for All Regulatory Alternatives, Villanueva et al. (2003) for Baseline Risk, TTHMs as an Indicator, Smoking/Lung Cancer Cessation Lag Model (Millions, 2003$)

	Discount Rate, WTP for Non-Fatal Cases	Regulatory Alternative			
		Preferred	A1	A2	A3
Average Annual Number of Cases Avoided		277 (101 - 540)	249 (126 - 395)	928 (477 - 1,449)	1273 (663 - 1,954)
Annualized Mean Benefits of Cases Avoided (90% Confidence Bounds)	3%, Lymphoma	$1,523 ($232 - 3,518)	$1,368 ($208 - 3,160)	$5,103 ($776 - 11,787)	$7,005 ($1,066 - 16,181)
	7%, Lymphoma	$1,240 ($189 - 2,862)	$1,119 ($170 - 2,583)	$4,174 ($636 - 9,636)	$5,731 ($873 - 13,230)
	3%, Bronchitis	$759 ($164 - 1,684)	$682 ($148 - 1,512)	$2,542 ($551 - 5,640)	$3,490 ($756 - 7,743)
	7%, Bronchitis	$617 ($134 - 1,368)	$557 ($121 - 1,235)	$2,078 ($451 - 4,606)	$2,853 ($619 - 6,324)

Notes:

Average annual avoided cases is based upon the 25-year period of analysis and so is much lower than the maximum cases to be avoided following the cessation lag period. The cessation lag is explained in detail in Appendix E.

Sources: Exhibit 6.27

Exhibit ES.10 Comparison of Costs for Regulatory Alternatives (Millions, 2003$)

	Annualized Total Regulation Costs					
	Discounted at 3%, 25 Years			Discounted at 7%, 25 Years		
		90 Percent Confidence Bound			90 Percent Confidence Bound	
Regulatory Alternative	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Mean Value	Lower (5th %tile)	Upper (95th %tile)
Preferred	$86.2	$59.5	$114.5	$84.2	$57.8	$111.7
A1	$276.9	$170.7	$387.6	$265.5	$163.3	$372.6
A2	$444.1	$375.1	$516.1	$431.2	$363.5	$501.9
A3	$661.2	$548.7	$778.5	$644.3	$533.8	$759.7

Source: Appendix J.

For the Preferred Alternative, see Exhibit J.2as for 3% and J.2aw for 7%.

For Alternative 1, see Exhibit J.3i for 3% and J.3m for 7%.

For Alternative 2, see Exhibit J.4i for 3% and J.4m for 7%.

For Alternative 3, see Exhibit J.5i for 3% and J.5m for 7%.

Exhibit ES.11 Comparison of Annualized Mean Net Benefits for All Regulatory Alternatives, Villanueva et al. (2003) for Baseline Risk, TTHMs as an Indicator, Smoking/Lung Cancer Cessation Lag Model (Millions, 2003$)

WTP for Non-Fatal Bladder Cancer Cases	Rule Alternative	Annualized Value	
		3%, 25 Years	7%, 25 Years
Lymphoma	Preferred	$ 1,437	$ 1,155
	A1	$ 1,091	$ 853
	A2	$ 4,659	$ 3,743
	A3	$ 6,344	$ 5,087
Bronchitis	Preferred	$ 673	$ 533
	A1	$ 405	$ 292
	A2	$ 2,098	$ 1,647
	A3	$ 2,829	$ 2,209

Source: Exhibit 9.12

The CEA provided in Exhibit ES.12, however, does provide some useful information. This exhibit shows the cost per bladder cancer case avoided, based upon costs and cases avoided discounted at 3 and 7 percent, in order of increasing cost ratio for all alternatives. As a threshold for cost effectiveness, consider the WTP measures for avoidance of non-fatal lymphoma (mean of $4.49 million per case avoided in 2003$) or chronic bronchitis (mean of $0.80 million per case avoided in 2003$), which serve in this EA as surrogates for a measure of what society is willing to pay to avoid a non-fatal case of bladder cancer.[11] If an alternative is cost effective, it will have an average cost ratio that is equal to or less than the value of the WTP estimate. The Preferred Alternative meets this criterion and has the lowest cost per case avoided: at discount rates of 3 and 7 percent, its unit costs of $0.38 and $0.46 million, respectively, are less than the lymphoma and bronchitis WTP values of $4.49 and $0.80 million, respectively. Alternatives 2 and 3 are generally also below the minimum threshold of $0.80 million per case avoided, except for Alternative 3 at a 7 percent discount rate, which is close to but slightly greater at a cost of $0.87 million.

Additionally, Exhibit ES.12 presents the incremental costs, which follow the same pattern as the average cost ratio analysis in the prior paragraph: incremental cost per case avoided is better than

[11]The WTP values, shown here in 2003$, could be used to develop an annualized WTP value for the most accurate comparison to the annualized cost per case avoided values presented in Exhibit ES.12. First, they would be increased over the period of analysis to reflect the elasticity of WTP in response to increases in real income. Second, the WTP value would be weighted differentially over the period of analysis to reflect in the annualized value the difference in the number of cases avoided, which varies on an annual basis. Third, because the cases avoided in the CEA ratio include both fatal and non-fatal cases, the VSL would be incorporated into a weighted average (to reflect that 26% of cases are fatal) with the WTP value after it, too, was increased over time to reflect the above 2 considerations. However, each of these factors would increase the threshold used in this analysis; therefore annualized WTP values are not calculated because the Preferred Alternative, and most of the other alternatives, have costs per case avoided that are already below the lowest of the thresholds ($0.80 million in 2003$).

(below) the lowest threshold. The notable exception to this is Alternative 1, for which the costs of bromate reduction are included without quantification of benefits from reduced bromate exposure.

Exhibit ES.12 Cost and Incremental Cost Per Discounted Case Avoided, Villanueva et al. (2003) for Baseline Risk, TTHMs as DBP Indicator, Smoking/Lung Cancer Cessation Model, by Discount Rate and Regulatory Alternative (Millions, 2003$)

Rule Alternative	Cost Per Case Avoided		Incremental Cost Per Case Avoided	
	3%	7%	3%	7%
Preferred	$ 0.36	$ 0.45	$ 0.36	$ 0.45
Alternative 1	$ 1.30	$ 1.57	Note 2	
Alternative 2	$ 0.56	$ 0.68	$ 0.64	$ 0.78
Alternative 3	$ 0.61	$ 0.74	$ 0.73	$ 0.90

Notes: Cost per case avoided is in year 2003 dollars ($Millions), discounted for the 25 year analysis period to year 2005.

1) The cost effectiveness ratios are a conservative estimate in that the regulatory costs in the numerator are not adjusted by subtracting the medical costs associated with cases avoided to produce a net cost numerator. Adjustment of the numerator in this CEA would not alter the relative cost effectiveness of the alternatives or change their rankings, because it involves the subtraction of a constant. In the case where thresholds of maximum public expenditure or minimum cases to be avoided are prescribed, defining the numerator more precisely by making such adjustments would be appropriate.

2) In reference to conducting incremental CEA, OMB states that the analyst should make sure that "When constructing and comparing incremental cost-effectiveness ratios, [analysts] ... should make sure that inferior alternatives identified by the principles of strong and weak dominance are eliminated from consideration. " (OMB Circular A-4, p. 10) Alternative 1 is dominated by the Preferred Alternative and is therefore not included in the incremental analysis. The reason for this domination is mainly that the Preferred Alternative includes IDSE and Alternative 1 does not; and to a lesser degree because the bromate control included in Alternative 1 increases the costs but the benefits of this control are not quantified at this time. Alternative 2 is compared directly to the Preferred Alternative (skipping Alternative 1) in this analysis.

Source: Exhibit 9.14

ES.8 Conclusions

EPA is finalizing the Stage 2 DBPR to reduce the risks that byproducts of chlorination pose to consumers of drinking water. Disinfection itself is important for protecting the public against waterborne microbes, and is practiced by over 48,000 PWSs in the United States. The chemicals commonly used, however, can react with substances in the source water to create harmful DBPs. These DBPs include TTHMs and HAA5s, which are potentially associated with increased incidence of bladder and possibly other cancers. They may also cause adverse reproductive and developmental effects such as early-term miscarriage, stillbirth, low birth weight, and some birth defects. There is uncertainty in the scientific literature regarding the extent to which DBPs contribute to the incidence of these adverse effects in the exposed population. Nevertheless, EPA believes that the weight of evidence warrants concern for these potential hazards and justifies additional regulatory action beyond the Stage 1 DBPR.

1. Introduction

This document presents an analysis of the costs and benefits of the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR). The analysis is performed in compliance with Executive Order 12866, *Regulatory Planning and Review* (USEPA 1993), which requires that the Environmental Protection Agency (EPA) estimate the economic impact of rules costing over $100 million annually in an Economic Analysis (EA) and to submit the analysis in conjunction with publishing the rule.

This chapter provides a summary of the Stage 2 DBPR in Section 1.1. Section 1.2 outlines the organization of this EA and Section 1.3 provides information regarding supporting calculations and citations in this EA.

1.1 Summary of the Stage 2 DBPR

The requirements of the Stage 2 DBPR apply to all community water systems (CWSs) and nontransient noncommunity water systems (NTNCWSs) that add a disinfectant other than ultraviolet light (UV) or that deliver water that has been treated with a disinfectant other than UV. New since the Stage 1 DBPR, EPA has included requirements specifically for consecutive systems to ensure uniform regulation of consecutive systems in all States. The Stage 2 DBPR defines consecutive systems as public water systems that purchase or otherwise receive finished water from another water system (a wholesale system).

The Stage 2 DBPR builds on the 1979 Total Trihalomethane Rule and the 1998 Stage 1 DBPR by requiring reduced levels of DBPs in distribution systems. Each rule activity for the Preferred Regulatory Alternative and the associated rule schedule are described below. Note that consecutive systems of any size must comply with the requirements of the Stage 2 DBPR at the same time as the largest system in the combined distribution system.

The numerical maximum contaminant levels (MCLs) for the Stage 2 DBPR are the same as for the Stage 1 DBPR MCLs: 80 micrograms per liter (μg/L) for total trihalomethanes (TTHM), and 60 μg/L for haloacetic acids (five) (HAA5). The Stage 2 DBPR is designed to reduce high TTHM and HAA5 levels in the distribution system by changing compliance monitoring and calculation requirements. The compliance determination for the Stage 2 DBPR is based on a locational running annual average (LRAA) instead of the system-wide running annual average (RAA) used under the Stage 1 DBPR. LRAAs are essentially RAAs calculated separately for each sample location in the distribution system. With the Stage 2 LRAA requirement, the TTHM and HAA5 MCLs must be met at each monitoring location, while the Stage 1 RAA requires a system to average results over all monitoring locations. Exhibit 1.1 provides a comparison of Stage 1 and Stage 2 DBPR compliance calculations.

For many systems, compliance monitoring will be preceded by an initial distribution system evaluation (IDSE) to identify sample locations for Stage 2 compliance monitoring that represent distribution system sites with high TTHM and HAA5 levels. Systems may perform an IDSE either by completing a system specific study (SSS) or conducting standard monitoring , unless a system meets the criteria for a 40/30 certification or a very small systems waiver. To meet the criteria for a 40/30 certification, systems must have low Stage 1 monitoring results (all samples less than or equal to 40 μg/L

and 30 μg/L for TTHM and HAA5, respectively). Systems can qualify for a very small systems waiver if they serve fewer than 500 people. In addition, NTNCWSs serving fewer than 10,000 people are not required to conduct an IDSE.

The Stage 2 DBPR changes the way in which compliance monitoring requirements are determined. Stage 1 compliance monitoring for TTHM and HAA5 is based on a system's population served, source water type, system type, and number of plants treating water in that system. This "plant-based" approach is grounded in the assumption that larger systems have more treatment plants and thus greater system complexity. While this is generally true, the plant-based approach created disproportionately burdensome monitoring requirements for some systems where the number of plants did not represent system size, such as larger systems with very large plants or smaller systems with many disinfecting wells. Moreover, a plant-based approach can complicate monitoring of purchased water systems, particularly complex ones with multiple connections. For these reasons, EPA has developed a "population-based" monitoring approach for the Stage 2 DBPR, whereby the monitoring requirements are based on population served, source water type, and system type (not plants per system). Exhibit 1.2 shows the new, population-based standard monitoring requirements for the IDSE. Exhibit 1.3 presents the new, population-based Stage 2 DBPR compliance monitoring requirements. EPA believes that the new Stage 2 population-based approach makes monitoring requirements simpler and more equitable for systems of the same size and type.

Systems must develop a Stage 2 DBPR monitoring plan that includes monitoring locations, monitoring dates, and compliance calculation procedures. The monitoring plan must also incorporate any agreements (e.g., permits, contracts) with third parties to sample, analyze, or report compliance information.

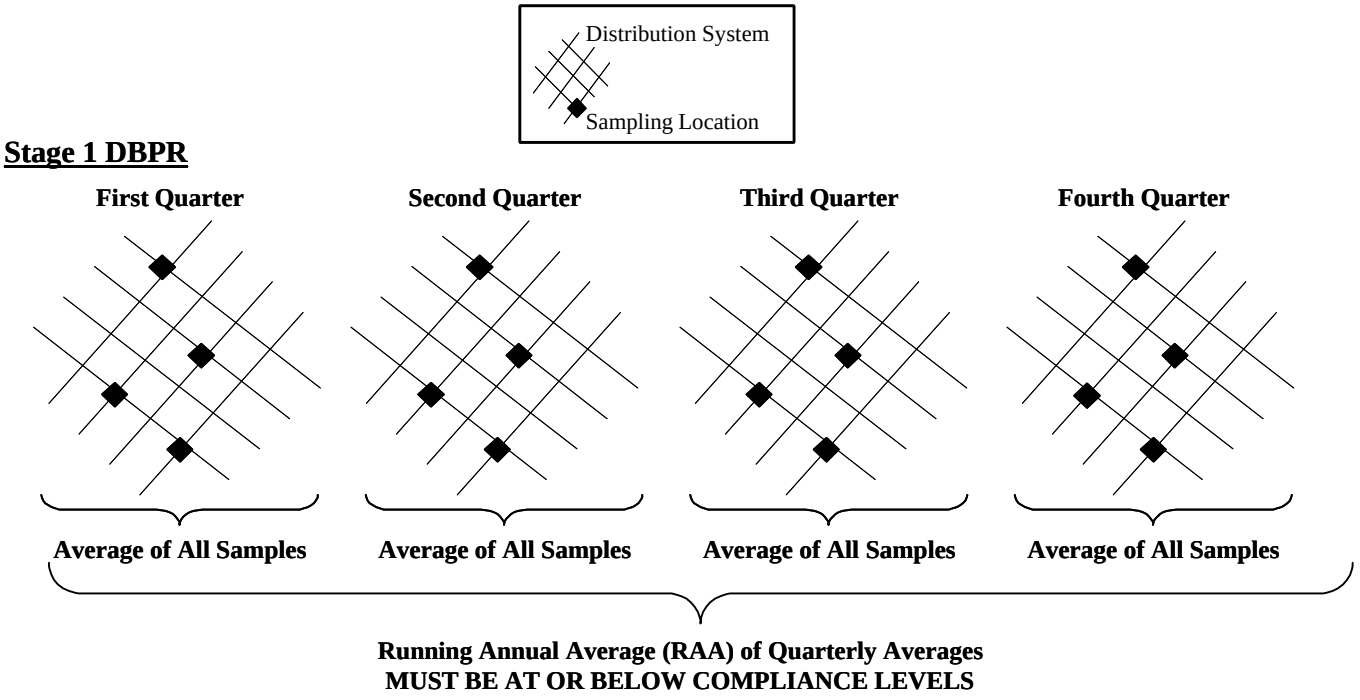
The Stage 2 DBPR is being promulgated simultaneously with the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) to address complex risk trade-offs between DBPs and microbial pathogens. The schedule for the Stage 2 DBPR is summarized in Exhibit 1.4. Note that the compliance deadlines are based on population served. For consecutive and wholesale systems, the compliance schedule is based on the population served by the largest system in a combined distribution.

Because Stage 2 DBPR MCL compliance is based on individual DBP measurements at a location averaged over a four-quarter period, a system could find higher TTHM or HAA5 levels than the MCL values, while at the same time maintaining compliance with the Stage 2 DBPR. This is because the high concentration could be averaged with lower concentrations at a given location. For this reason, the Stage 2 DBPR includes a provision for "operational evaluations" as follows:

- A system has exceeded an operational evaluation level at any monitoring location when the sum of the two previous quarters' compliance monitoring results plus twice the current quarters result, divided by 4, exceeds 80 μg/L for TTHM or 60 μg/L for HAA5.

If an operational evaluation level is exceeded, the system must conduct an "operational evaluation" and submit a written report of the evaluation to the State/Primacy Agency no later than 90 days after being notified of the analytical results that caused the excursion.

Exhibit 1.1 Comparison of Stage 1 and Stage 2 DBPR Compliance Calculations



Stage 2B DBPR (Note that some sampling locations may change as a result of the IDSE.)

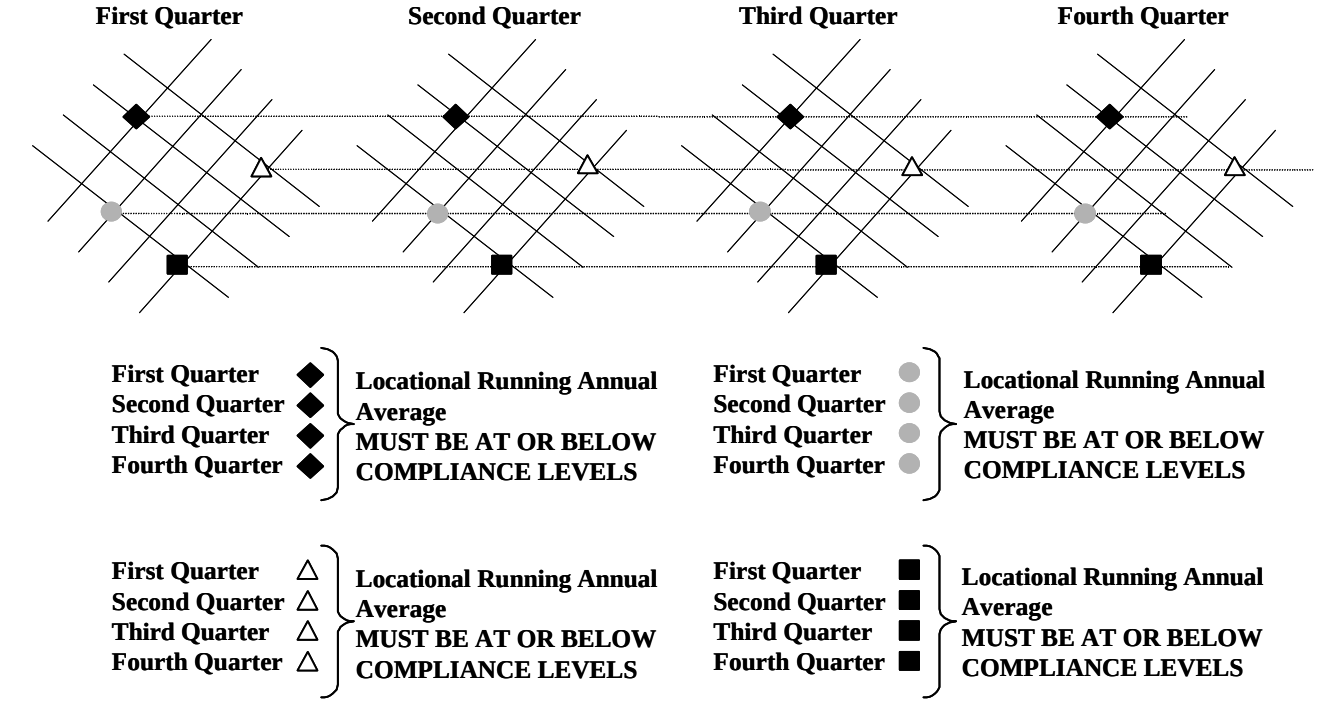


Exhibit 1.2 IDSE Standard Monitoring Requirements

System Size (Population Served)	Number of Distribution System Sites[1] (by location type) per System				Total Number of Sites per System	Number of Monitoring Periods and Frequency for the 1-year IDSE period
	Near Entry Point [2]	Average Residence Time	High TTHM	High HAA5		
Systems Using Surface Water in Whole or in Part[3]						
< 500	1[4]	-	1	-	**2**	1 (during peak historical month)[5]
500 - 3,300	-	-	1	1	**2**	4 (every 90 days)
3,301 - 9,999	-	1	2	1	**4**	4 (every 90 days)
10,000 - 49,999	1	2	3	2	**8**	6 (every 60 days)
50,000 - 249,999	3	4	5	4	**16**	6 (every 60 days)
250,000 - 999,999	4	6	8	6	**24**	6 (every 60 days)
1 million - 4,999,999	6	8	10	8	**32**	6 (every 60 days)
≥ 5,000,000	8	10	12	10	**40**	6 (every 60 days)
Systems Using Only Ground Water						
< 500	1[4]	-	1	-	**2**	1 (during peak historical month)[5]
500 - 9,999	-	-	1	1	**2**	4 (every 90 days)
10,000 - 99,999	1	1	2	2	**6**	4 (every 90 days)
100,000 - 499,999	1	1	3	3	**8**	4 (every 90 days)
≥ 500,000	2	2	4	4	**12**	4 (every 90 days)

[11] Samples must be taken at locations other than existing Stage 1 monitoring locations. Dual sample sets (i.e., a TTHM and an HAA5 sample) must be taken at each monitoring location during each monitoring period. Sampling location must be distributed throughout the distribution system.

[2] If the number of entry points to the distribution system is fewer than the specified number of sampling locations, additional samples must be taken equally at high TTHM and HAA5 locations. If there is an odd extra location number, a sample at a high TTHM location must be taken. If the number of entry points to the distribution system is more than the specified number of sample locations, samples must be taken at entry points to the distribution system having the highest water flows.

[3] For the purposes of this EA, "surface water" systems are equivalent to "subpart H" systems and include systems that use ground water under the direct influence of surface water (GWUDI).

[4] Consecutive systems must monitor at or near the entry point. Non-consecutive systems must monitor at a high HAA5 location.

[5] The peak historical month is the month with the highest TTHM or HAA5 levels or the warmest water temperature.

Exhibit 1.3 Stage 2 Population-Based Monitoring Requirements

System Size (Population Served)	Distribution System Sample Locations[1]			Total Sample Locations per System	Monitoring Frequency[3]
	Highest TTHM Locations	Highest HAA5 Locations	Existing Stage 1 Compliance Locations[2]		
Systems Using Surface Water in Whole or in Part[4]					
< 500	1	1		**2[5]**	per year
500-3,300	1	1		**2[5]**	per quarter
3,301-9,999	1	1		**2**	per quarter
10,000-49,999	2	1	1	**4**	per quarter
50,000-249,999	3	3	2	**8**	per quarter
250,000-999,999	5	4	3	**12**	per quarter
1 Mil-4,999,999	6	6	4	**16**	per quarter
≥ 5,000,000	8	7	5	**20**	per quarter
Systems Using Only Ground Water					
< 500	1	1		**2[5]**	per year
500 - 9,999	1	1		**2**	per year
10,000 - 99,999	2	1	1	**4**	per quarter
100,000 - 499,999	3	2	1	**6**	per quarter
≥ 500,000	3	3	2	**8**	per quarter

[1] Locations must be based on the system's recommendations for Stage 2 DBPR compliance monitoring locations in its report to the State/Primacy Agency, unless the State/Primacy Agency requires different or additional locations. Locations should be distributed throughout the distribution system to the extent possible.

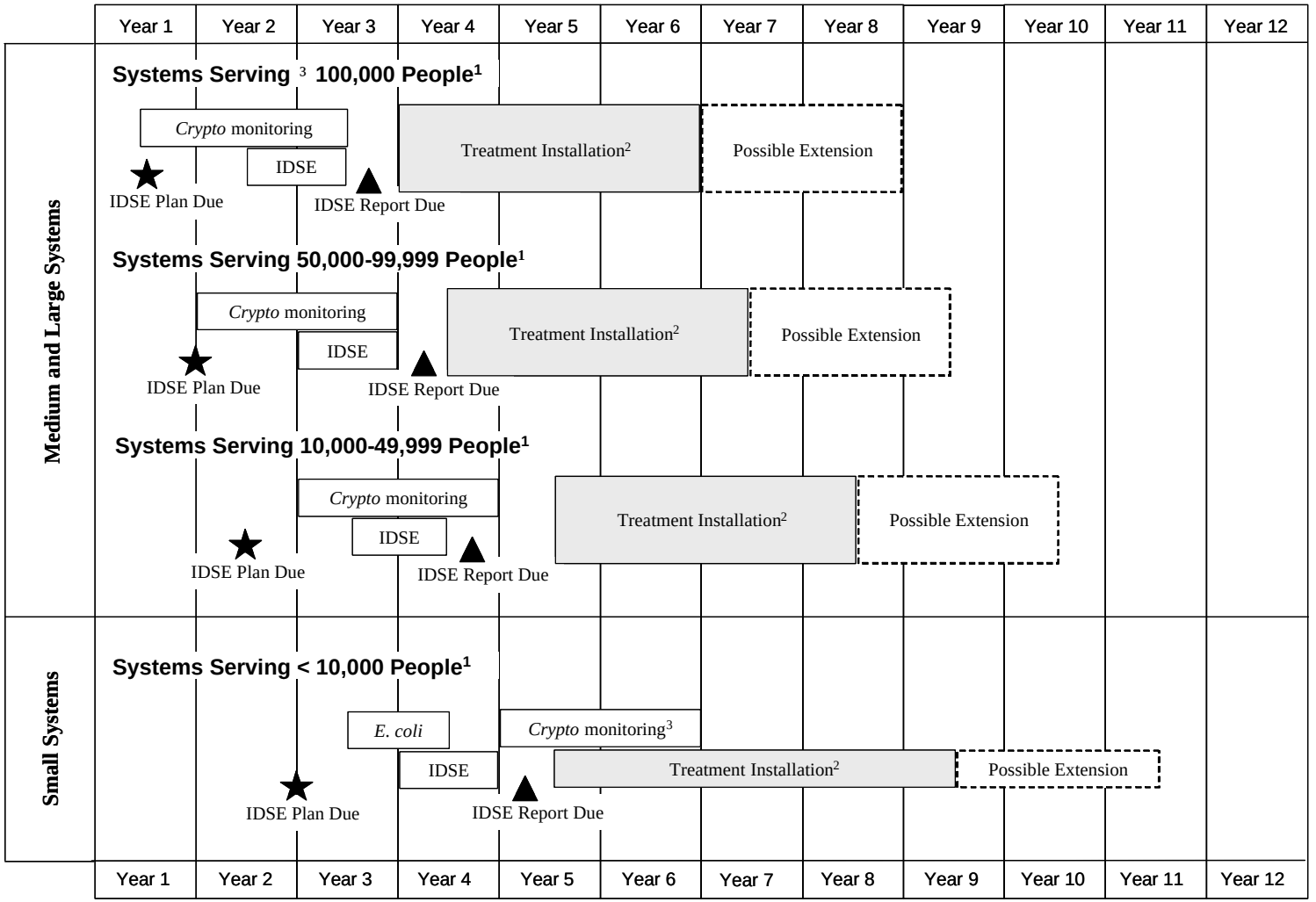
[2] Alternate between highest HAA5 LRAA and highest TTHM LRAA locations among the existing Stage 1 average resident time compliance locations. If the number of existing Stage 1 compliance locations is fewer than the specified number for Stage 2, alternate between highest HAA5 LRAA locations and highest TTHM LRAA locations from the IDSE.

[3] All systems must take at least one dual sample set during the month of highest DBP concentrations. Systems on quarterly monitoring must take dual sample sets approximately every 90 days.

[4] For the purposes of this EA, "surface water" systems are equivalent to "subpart H" systems and include systems that use GWUDI.

[5] The system is required to take individual TTHM and HAA5 samples at the locations with the highest TTHM and HAA5 concentrations, respectively. Only one location with a dual sample set per monitoring period is needed if the highest TTHM and HAA5 concentrations occur at a same location.

Exhibit 1.4 Stage 2 DBPR Implementation Schedule



[1] Includes all systems that are part of a combined distribution system that have a largest system with this population.

[2] A State may grant up to an additional 2 years for systems to comply if the State determines that additional time is necessary for capital improvements.

[3] Subpart H systems that must conduct *Cryptosporidium* monitoring have an additional 12 months to comply with the Stage 2 DBPR MCLs.

Notes: Systems adding disinfection for the GWR are predicted to add disinfection after Stage 2 systems begin compliance monitoring.
The IDSE plan is comprised of either the Standard Monitoring plan or a SSS plan. IDSE includes either completing the Standard Monitoring or a SSS.

1.2 Document Organization

The rest of this EA is organized into the following chapters:

- Chapter 2 identifies public health concerns addressed by the rule and provides a 20-year regulatory history that includes a description of relevant National Primary Drinking Water Regulations (NPDWRs). It also explains the statutory authority for promulgating the Stage 2 DBPR and the economic rationale for choosing a regulatory approach.

- Chapter 3 characterizes conditions that exist (including system inventory, treatment, and water quality data) before systems make changes to meet the Stage 2 DBPR requirements.

- Chapter 4 reviews alternative regulatory approaches that EPA considered during the development of the rule and presents the rationale for selecting the Preferred Regulatory Alternative.

- Chapter 5 summarizes the methodology used to develop the compliance forecasts and predictions of reductions in DBPs. It also contains compliance forecast results for the Stage 1 DBPR and the Stage 2 DBPR Preferred Regulatory Alternative.

- Chapter 6 reviews available epidemiological and toxicological data related to DBPs. The public health and economic benefits of this rule, as well as several sensitivity analyses, are provided in this chapter.

- Chapter 7 presents an estimate of the costs of implementing the rule to industry, households, and States/Primacy Agencies. It also compares the costs of the four regulatory alternatives.

- Chapter 8 discusses analyses performed to evaluate the effects of the rule on different segments of the population and considers various executive orders and requirements, including the Regulatory Flexibility Act (RFA) and Unfunded Mandates Reform Act (UMRA).

- Chapter 9 compares the rule's benefits and costs to evaluate whether projected benefits exceed costs. The results for the Preferred Regulatory Alternative are discussed and compared to the regulatory alternatives considered.

1.3 Calculations and Citations

This EA presents results from detailed and complex analyses. To help the reader track the various calculations and analyses, the following are provided:

- A detailed reference section (see Chapter 10).
- A row on most tabular exhibits throughout the document that gives the formulas used to compute the contents of each column.
- Sources for elements of exhibits throughout the document that are not calculated in the exhibits themselves.
- Supporting electronic files (Stage 2 DBPR cost model; Stage 2 DBPR benefits model; Stage 2 DBPR Surface Water Analytical Tool (SWAT) supporting files).

2. Need for the Rule

2.1 Introduction

This chapter first identifies the issue to be addressed by the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR) (section 2.1.1) and then summarizes in section 2.2 the public health concerns addressed by the rule. Section 2.3 provides the regulatory history leading up to the Stage 2 DBPR, and section 2.4 addresses the economic rationale for choosing this regulatory approach.

2.1.1 Description of the Issue

Over 48,000 community water systems (CWSs) and nontransient noncommunity water systems (NTNCWS) in the United States disinfect their water (source: Exhibit H.1). These systems receive water from either ground water sources (wells) or surface water[1] sources (lakes, reservoirs, and rivers). Although ground water systems greatly outnumber surface water systems, large surface water systems serve most people's water needs. Most water is not pure enough to be safely ingested directly from the source. For this reason, water systems usually apply some form of contaminant control. Disinfection is one important and widespread (but not universal) practice used to meet the public health goal of providing safe drinking water. Systems often disinfect their drinking water supplies by adding chemicals to kill or inactivate microbial contaminants.

Chemical disinfection, however, poses health risks of its own. Disinfection byproducts (DBPs) result from reactions between chemical disinfectants and organic and inorganic compounds in source waters. Some of these byproducts, including chlorination byproducts that are the subject of this rule (total trihalomethanes (TTHM) and haloacetic acids (HAA5)), are potentially associated with cancer and adverse reproductive and developmental health effects. Research on DBP formation and DBP-associated health effects is ongoing; results of recent research on the health risks associated with DBPs were used in the development of the Stage 2 DBPR and are discussed in Chapter 6.

Because disinfection reduces risks from microbial contamination, reducing DBPs by decreasing the concentration of disinfectant or its contact time could increase the risk from microbial contamination. The Environmental Protection Agency's (EPA's) Science Advisory Board (SAB), an independent panel established by Congress, has reported that microbiological contaminants (e.g., bacteria, protozoa, and viruses) are likely the greatest remaining risk-management challenge for drinking water suppliers. The Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) is being finalized and implemented concurrently with the Stage 2 DBPR to ensure that microbial protection is not compromised by efforts to reduce exposure to DBPs.

[1] For the purposes of this document, "surface water" systems include subpart H systems using surface water or ground water under the direct influence of surface water (GWUDI) as a source.

2.2 Public Health Concerns to Be Addressed

EPA's primary mission is to protect human health and the environment. In carrying out this mission, EPA must often make regulatory decisions based on incomplete or uncertain information. The Agency believes it is appropriate and prudent to take action to protect public health when evidence indicates that exposure to a contaminant could present significant risks to the public, rather than take no action until risks are unequivocally proven. Additionally, the 1996 Amendments to the Safe Drinking Water Act (SDWA) require EPA to address DBP and microbial risks by certain statutory deadlines.

An important consideration in assessing public health risks is the number of people who may be exposed to a particular contaminant. More than 260 million people in the United States potentially are exposed to DBPs via drinking water because they are served by public water systems (PWSs) that add chemical disinfectants (see Exhibit 3.3 for the Stage 2 population baseline). While effective in controlling many harmful microorganisms, chemical disinfectants also form DBPs, some of which may pose health risks. Because of the large number of people potentially exposed to DBPs, EPA is concerned about any health risks that may be associated with DBPs. Information on these risks can come from two types of studies–epidemiological and toxicological.

Epidemiological studies have investigated the relationship between exposure to chlorinated drinking water and cancer. These studies suggest an association between bladder, rectal, and colon cancers and exposure to chlorinated drinking water. Numerous toxicology studies have shown several DBPs (such as bromodichloromethane, bromoform, dichloroacetic acid, and bromate) to be carcinogenic in laboratory animals (see Chapter 6 for details).

Other epidemiological studies indicate a potential link between DBP exposure and adverse reproductive and developmental health effects, particularly early-term miscarriage (see Chapter 6 for discussion). In addition, toxicological studies have shown that several DBPs cause adverse reproductive and developmental health effects in laboratory animals. EPA believes that these studies together provide evidence that DBPs may present potential public health risks to pregnant women and their fetuses.

Research, therefore, supports EPA's conclusion that chlorinated drinking water could potentially be a source of health risk to the general public. While EPA recognizes the uncertainties in the available data on health effects from DBPs and on the exposure levels at which adverse health effects occur, the Agency believes the weight of evidence supports concern for these potential hazards and justifies additional regulatory action beyond the Stage 1 DBPR.

2.3 Regulatory History

2.3.1 Statutory Authority for Promulgating the Rule

The primary responsibility for regulating the quality of drinking water lies with EPA. The SDWA establishes this responsibility and defines the mechanisms at the Agency's disposal to protect public health. EPA sets standards by identifying which contaminants should be regulated and by establishing the maximum levels of the contaminants allowed in drinking water.

Section 1412(b)(1) of the 1996 SDWA reauthorization mandated new drinking water requirements. EPA's general authority to set Maximum Contaminant Level Goals (MCLGs) and develop the National Primary Drinking Water Regulations (NPDWRs) was modified to apply to contaminants that "may have an adverse effect on the health of persons," are "known to occur or there is a substantial likelihood that the contaminant will occur in public water systems with a frequency and at levels of public health concern," and for which, "in the sole judgment of the Administrator, regulation of such contaminant presents a meaningful opportunity for health risk reductions for persons served by public water systems" (SDWA 1412(b)(1)(A)).

To regulate a contaminant, EPA sets an MCLG at a level at which no known or anticipated adverse health effects occur. MCLGs are established solely on the basis of protecting public health and are not enforceable. EPA simultaneously sets an enforceable Maximum Contaminant Level (MCL) as close as technologically feasible to the MCLG, while taking costs into consideration. If it is not feasible to measure the contaminant at levels presumed to have impacts on health, a treatment technique can be specified in place of an MCL. For water systems, compliance with a drinking water regulation means either not exceeding the MCL or meeting treatment technology requirements.

Additionally, EPA identifies maximum concentrations of residual disinfectants that can occur in water without harming human health and sets maximum residual disinfectant level goals (MRDLGs) and maximum residual disinfectant levels (MRDLs). PWSs maintain residual levels of disinfectants in the distribution system, following treatment, to ensure consumer protection from microbial contaminants. Like MCLGs, MRDLGs are not enforceable, while MRDLs are.

In addition to the general authorities cited above, SDWA 1412(b)(2)(C) requires specifically that EPA promulgate the Stage 2 DBPR.

> The Administrator shall promulgate an Interim Enhanced Surface Water Treatment Rule, a Final Enhanced Surface Water Treatment Rule, a Stage 1 Disinfectants and Disinfection Byproducts Rule, and a Stage 2 Disinfectants and Disinfection Byproducts Rule in accordance with the schedule published in Volume 29, Federal Register, Page 6361 (February 10, 1994), in Table III.13 of the proposed Information Collection Rule. (SDWA 1412(b)(2)(C))

The following sections summarize the development of relevant NPDWRs over the past 20 years.

2.3.2 1979 Total Trihalomethane Rule

Under the Total Trihalomethane Rule (44 Federal Register (FR) 68624, November 29, 1979), EPA set an MCL for TTHM (the sum of the concentrations of chloroform, bromoform, bromodichloro-methane, and dibromochloromethane) of 0.10 milligrams per liter (mg/L) as a running annual average (RAA) of quarterly measurements. This standard applied to CWSs using surface or ground water that served at least 10,000 people and that added a disinfectant to the drinking water during any part of the treatment process. This 1979 rule was superseded by the 1998 Stage 1 DBPR (section 2.3.7) with which all CWSs and NTNCWSs must have complied by January 2004.

2.3.3 1989 Total Coliform Rule

The Total Coliform Rule (TCR) (54 FR 27544, June 29, 1989) applies to all PWSs. Because monitoring PWSs for every possible pathogenic organism is not feasible, coliform organisms are used as indicators of possible contamination. Coliforms are easily detected in water and are used to indicate a system's vulnerability to pathogens. In the TCR, EPA set an MCLG of zero for total coliforms. EPA also set a monthly MCL for total coliforms and required testing of total-coliform-positive cultures for the presence of *E. coli* or fecal coliforms. *E.coli* and fecal coliforms indicate more immediate health risks from sewage or fecal contamination and are used as the indicator of an acute MCL violation. Coliform monitoring frequency is determined by population served, the type of system (community or noncommunity) and the type of source water (surface water or ground water). In addition, the TCR required sanitary surveys every 5 years (or 10 years for noncommunity systems using disinfected ground water) for systems that collect fewer than 5 routine total coliform samples per month (typically systems serving fewer than 4,100 people).

2.3.4 1989 Surface Water Treatment Rule

Under the Surface Water Treatment Rule (SWTR) (54 FR 27486, June 29, 1989), EPA set MCLGs of zero for *Giardia lamblia*, viruses, and *Legionella* and established requirements for all PWSs using surface water or GWUDI as a source. The SWTR includes treatment technique requirements for filtered and unfiltered systems that are intended to protect against the adverse health effects associated with *Giardia lamblia*, viruses, and *Legionella*, as well as many other pathogenic organisms. These requirements include:

- Maintenance of a disinfectant residual in water entering and within the distribution system.

- Removal or inactivation of at least 99.9 percent (3 logs) of *Giardia* and 99.99 percent (4 logs) of viruses.

- For filtered systems, meeting a turbidity performance standard for the combined filter effluent of 5 nephelometric turbidity units (NTUs) as a maximum and 0.5 NTU in 95 percent of monthly measurements, based on 4-hour monitoring for treatment plants using conventional treatment or direct filtration (with separate standards for other filtration technologies). These requirements were enhanced by the 1998 Interim Enhanced Surface Water Treatment Rule (IESWTR) and the 2002 Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR).

- Watershed control programs and other requirements for unfiltered systems.

2.3.5 1996 Information Collection Rule

The Information Collection Rule (ICR) (61 FR 24354, May 14, 1996) applied to PWSs serving more than 100,000 people. A more limited set of ICR requirements covered ground water systems serving 50,000 to 100,000 people.

The ICR authorized EPA to collect occurrence and treatment information from water treatment plants to help evaluate the possible need for changes to microbial requirements and microbial treatment practices and to help evaluate the need for future regulation of disinfectants and DBPs. The ICR provided EPA with information on the national occurrence of (1) chemical byproducts that form when disinfectants used for microbial control react with naturally occurring compounds and ions present in source water; and (2) disease-causing microorganisms including *Cryptosporidium*, *Giardia*, viruses, and coliform bacteria. The ICR also mandated the collection of data on how water systems currently treat for contaminants. The ICR monthly sampling data provided 18 months of information on the quality of the influent and treated water, including pH, alkalinity, turbidity, temperature, calcium, total hardness, total organic carbon, ultraviolet$_{254}$ (UV) absorbency, bromide, ammonia, and disinfectant residual. These data provide some indication of the "treatability" of the water, the occurrence of contaminants, and the potential for DBP formation. The data collected under the ICR are being analyzed to help develop the LT2ESWTR and Stage 2 DBPR.

2.3.6 1998 Interim Enhanced Surface Water Treatment Rule

The IESWTR (63 FR 69478, December 16, 1998) enhances the 1989 SWTR. It applies to PWSs serving at least 10,000 people and using surface water or GWUDI as a source. These systems began compliance with the IESWTR in January 2002. The purpose of the IESWTR is to improve control of the protozoan *Cryptosporidium* and to address tradeoffs between the risks of microbial pathogens and those of DBPs. The requirements and guidelines include:

- An MCLG of zero for *Cryptosporidium*.
- Removal of 99 percent (2 logs) of *Cryptosporidium* for systems that use filters.
- For filtered systems, a turbidity performance standard for the combined filter effluent of 1 NTU as a maximum and 0.3 NTU as a minimum in 95 percent of monthly measurements, based on 4-hour monitoring for treatment plants using conventional treatment or direct filtration.
- Continuous monitoring of individual filter effluent in conventional and direct filtration plants and recording turbidity readings every 15 minutes when these filters are on-line.
- A disinfection benchmark to assess the level of microbial protection provided before facilities change their disinfection practices to meet the requirements of the Stage 1 DBPR.
- Inclusion of *Cryptosporidium* in the definition of GWUDI and in the watershed control requirements for unfiltered PWSs.
- Covers for all new finished water storage facilities.
- A primacy provision that requires States to conduct sanitary surveys for all surface water systems, including those serving fewer than 10,000 people.

The IESWTR was promulgated concurrently with the Stage 1 DBPR so that systems could coordinate their response to the risks posed by DBPs and microbial pathogens.

2.3.7 1998 Stage 1 Disinfectants and Disinfection Byproducts Rule

The Stage 1 DBPR (63 FR 69390, December 16, 1998) applies to all CWSs and NTNCWSs that add a chemical disinfectant to their water. Certain requirements designed to provide protection against acute health effects from chlorine dioxide also apply to transient noncommunity water systems (TNCWSs). Compliance for surface water and GWUDI systems serving at least 10,000 people began in January 2002. Surface water and GWUDI systems serving fewer than 10,000 people and all ground water systems were required to comply by January 2004.

The Stage 1 DBPR sets MRDLGs for chlorine (4 mg/L as chlorine (Cl_2)), chloramines (4.0 mg/L as Cl_2), and chlorine dioxide (0.8 mg/L as ClO_2); and MCLGs for bromodichloromethane (0 mg/L), bromoform (0 mg/L), dibromochloromethane (0.06 mg/L), dichloroacetic acid (0 mg/L), trichloroacetic acid (0.3 mg/L), bromate (0 mg/L), and chlorite (0.8 mg/L). The rule sets MRDLs for chlorine (4.0 mg/L as Cl_2), chloramines (4.0 mg/L as Cl_2), and chlorine dioxide (0.8 mg/L as ClO_2); and MCLs for TTHM (0.080 mg/L), HAA5 (0.060 mg/L), bromate (0.010 mg/L), and chlorite (1.0 mg/L). The MRDLs and MCLs, except those for chlorite and chlorine dioxide, are calculated as RAAs. For conventional surface water and GWUDI systems, a treatment technique—enhanced coagulation/softening—is specified for the removal of DBP precursors.

As noted in section 2.3.6, the Stage 1 DBPR was promulgated concurrently with the IESWTR to coordinate the control of DBPs and microbial contaminants.

2.3.8 2005 Ground Water Rule

The proposed Ground Water Rule (65 FR 30194, May 10, 2000) addresses fecal contamination in ground water systems. It also builds on the TCR through provisions based on further evaluation of *E. coli* monitoring results measured under the TCR. Key components of the approach for protection of ground water included in the proposed rule are:

- Sanitary surveys for all ground water systems.
- Hydrogeologic sensitivity assessments to identify ground water wells that are susceptible to fecal contamination.
- Triggered source water monitoring for an indicator of fecal contamination for all systems that do not achieve 4-log treatment, and in addition, routine source water monitoring for an indicator of fecal contamination that have been determined to draw from sensitive ground water sources.

- Correction of significant deficiencies and fecal contamination by eliminating the source of contamination, correcting the deficiency, providing an alternative source of water, or providing inactivation and/or removal of 99.99 percent (4 logs) of viruses.

- Compliance monitoring to ensure that disinfection treatment is reliably operated when it is used.

2.3.9 2001 Arsenic Rule

The Arsenic Rule (66 FR 6976, January 22, 2001) increases the level of public health protection against exposure to arsenic in drinking water. The rule revises the MCL for arsenic in drinking water from 0.05 mg/L to 0.010 mg/L and sets an MCLG of 0 mg/L for all CWSs and NTNCWSs. Clarification on how compliance is demonstrated for many inorganic and organic contaminants in drinking water is also given. All existing CWSs and NTNCWSs must comply with the Arsenic Rule by January 23, 2006.

2.3.10 2001 Filter Backwash Recycling Rule

The Filter Backwash Recycling Rule (FBRR) (66 FR 31086, June 8, 2001) regulates systems that return filter backwash to the treatment process. The rule applies to surface water and GWUDI systems that use direct or conventional filtration and recycle spent filter backwash water, sludge thickener supernatant, or liquids from dewatering processes. The rule requires that these recycled liquids be returned to a location such that all steps of a system's conventional or direct filtration are employed. The rule also requires systems to notify the State that they practice recycling. Finally, systems must collect and maintain information for review by the State.

2.3.11 2002 Long Term 1 Enhanced Surface Water Treatment Rule

The LT1ESWTR (67 FR 1812, January 14, 2002) enhances the 1989 SWTR requirements for small systems. LT1ESWTR enhances control of *Cryptosporidium* and other disease-causing microbes for surface water and GWUDI systems that serve fewer than 10,000 people. Key provisions in the LT1ESWTR are very similar to those for the IESWTR, but provide additional flexibility for small systems.

2.3.12 2005 Long Term 2 Enhanced Surface Water Treatment Rule

To be made final in concert with the Stage 2 DBPR, the LT2ESWTR strengthens control of *Cryptosporidium*, and applies to all PWSs that use surface water or GWUDI as a source. It incorporates system-specific treatment requirements based on a "Microbial Framework" approach that targets high-risk systems. This approach involves assigning systems to different categories (or "bins") based on the levels of *Cryptosporidium* found in the source water. Additional treatment requirements, if any, are linked to the level of *Cryptosporidium*. A system will choose technologies and management practices from a "toolbox" of options appropriate to its bin.

Medium and large systems (those serving at least 10,000 people) that filter will be required to conduct *Cryptosporidium* source water monitoring for 24 months to determine their bin classification. Small systems (those serving fewer than 10,000 people) that filter will monitor *E. coli* bacteria in their source water biweekly for 12 months. Based on their *E. coli* results, they may be required to monitor *Cryptosporidium* as well.

In addition to requirements for filtered systems, the LT2ESWTR will require unfiltered systems to continue to meet the filtration avoidance criteria under the 1989 SWTR and provide inactivation at 4 logs (99.99 percent) for virus, 3 logs (99.9 percent) for *Giardia*, and 2 to 3 logs (99 to 99.9 percent) for *Cryptosporidium* (depending on results of *Cryptosporidium* monitoring of source water). Building on the SWTR requirements, inactivation requirements for unfiltered systems subject to the LT2ESWTR must be met using a minimum of two disinfectants.

Also, the LT2ESWTR will require systems with uncovered finished water reservoirs to cover the reservoirs or treat reservoir discharge to the distribution system to achieve 4-log virus inactivation, 3-log *Giardia* inactivation, and 2-log *Cryptosporidium* inactivation.

2.4 Economic Rationale

This section addresses the economic rationale for choosing a regulatory approach. Such a rationale is required by Executive Order Number 12866, *Regulatory Planning and Review* (USEPA 1993), 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, Office of Management and Budget (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" (USEPA 1996b).

In a perfectly competitive market, prices and quantities are determined solely by the aggregated decisions of buyers and sellers. Such a market occurs when many producers of a product are selling to many buyers, and both producers and consumers have perfect information on the characteristics and prices of each firm's products. Barriers to entry in the industry cannot exist, and individual buyers and sellers must be "price takers"; i.e., their individual decisions cannot affect the price. Several properties of the public water supply do not satisfy the conditions for a perfectly competitive market and, thus, lead to market failures that require regulation.

First, many water systems are natural monopolies. A natural monopoly exists when it is impossible for more than one firm in each area to recover the costs of production and survive. There are high fixed costs associated with reservoirs and wells, transmission and distribution systems, treatment plants, and other facilities. For other potential suppliers to enter the market, they would have to provide the same extensive infrastructure to realize similar economies of scale and be competitive. A splitting of the market with increased fixed costs (for example, two supplier networks in a single market) usually

makes this situation unprofitable for one or both suppliers. The result is a market suitable for a single supplier and one that is hostile to alternative suppliers. In such natural monopolies, suppliers have fewer incentives for providing high-quality services or maintaining competitive prices. In these situations, governments often intervene to help protect the public interest.

Because PWSs are legal, as well as natural, monopolies, they often are subject to price controls, if not outright public ownership. While customers may demand improvements in water quality, the regulatory regime may not transmit that demand to the water supplier or allow the supplier to raise its price to recover the cost of the improvements. If consumers do not believe that their drinking water is safe enough, they cannot simply switch to another water utility. Other options for obtaining safe drinking water (e.g., buying bottled water or installing point-of-use filtration) most often cost consumers more than the purchase from public water supplies. Therefore, the water supplier may have little incentive to improve water quality.

Second, the public may not understand the health and safety issues associated with drinking water quality. Understanding the health risks potentially posed by trace quantities of drinking water contaminants involves analysis and synthesis of complex toxicological and health sciences data. Therefore, the public may not be aware of the risks it faces. EPA has implemented a Consumer Confidence Report Rule (CCR) (63 FR 44512 August 1998) that makes water quality information more easily available to consumers. This rule requires CWSs to publish an annual report on local drinking water quality. Consumers, however, still have to analyze this information for its health risk implications. Even if informed consumers are able to engage water systems in a dialogue about health issues, the transaction costs of such interaction (measured in personal time and monetary outlays) present another significant impediment to consumer expression of risk reduction preferences.

SDWA regulations are intended to provide a level of protection from exposure to drinking water contaminants. The regulations set minimum performance requirements to protect consumers from exposure to contaminants. They are not intended to restructure market mechanisms or to establish competition in supply; rather, they establish the level of service to be provided that best represents public preference for safety. The federal regulations reduce the high information and transaction costs by acting on behalf of consumers in balancing risk reduction and the social costs of achieving this risk reduction.

3. Baseline Conditions

3.1 Introduction

To quantify the effects of the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR), it is necessary to have a baseline against which to compare the set of regulatory alternatives. The baseline is a characterization of the industry and its operations under the conditions expected to exist before systems make changes to meet requirements of the Stage 2 DBPR. The baseline allows a consistent comparison of public health impacts (developed in Chapter 6) and the economic and financial impacts (developed in Chapters 7 and 8) of each regulatory alternative.

Development of the baseline consists of the following processes:

- Compiling an industry profile
- Characterizing the relevant properties of the raw water treated by the industry
- Characterizing the types and frequency of advanced treatment technologies being used at water treatment plants
- Characterizing disinfection byproduct (DBP) occurrence in finished water and in the distribution system

The appropriate baseline for assessing the impacts of Stage 2 would be conditions following implementation of Stage 1. However, the compliance deadline for the Stage 1 DBPR occurred only recently (January 2004) for small surface water systems and all ground water systems and in January 2002 for large and medium surface water systems. Thus, the observed water quality data and occurrence of treatment technologies presented in this chapter represent pre-Stage 1 conditions. Predictions of pre-Stage 2 baseline (as well as post-Stage 2) conditions are presented in Chapters 5, 6, and 7.

Some characteristics of the pre-Stage 1 baseline are modeled to allow for consistent comparison to post-Stage 1 and post-Stage 2 conditions. This chapter presents DBP occurrence and treatment technologies in place for large surface water plants as predicted using a tool developed by the Environmental Protection Agency (EPA), the Surface Water Analytical Tool (SWAT).

Sections 3.2 and 3.3 describe the data sources and tools used to characterize the pre-Stage 1 baseline. Section 3.4 characterizes the water industry, including the baseline estimates of treatment plants and population subject to the Stage 2 DBPR. Influent water quality is summarized in section 3.5, and section 3.6 describes the types of treatment technologies used by systems prior to the Stage 1 DBPR. Treated water quality, as it relates to the pre-Stage 1 baseline, is presented in section 3.7. Lastly, section 3.8 itemizes and estimates the effects of uncertainties in the baseline analysis.

This chapter presents an analysis at a level of detail and precision appropriate to support subsequent analyses and regulatory decisions for the Stage 2 DBPR. Therefore, it does not give an exhaustive review of the water supply industry, source waters, or industry practices.

3.2 Data Sources

Several data sources were used to characterize the baseline and to predict treatment technology changes and water quality for different regulatory alternatives. The Safe Drinking Water Information System-Federal Version (SDWIS/FED[1]) data (4th Quarter Freeze Year 2003 data) is used to create system and population baselines (USEPA 2003t). SDWIS is EPA's national regulatory compliance database for the drinking water program. It includes information on the nation's 170,000 public water systems (PWSs) and on violations of drinking water regulations. A second key source of data used to develop the industry profile is the Third Edition of the *Water Industry Baseline Handbook* (Baseline Handbook) (USEPA 2001c) published in May 2001, which compiles data derived from the 1995 Community Water System Survey (CWSS) and SDWIS. The 1995 CWSS was a mail survey that covered ground and surface water systems of all sizes (based on population served). The survey was based on a two-phased, stratified sample design. Phase 1 was a telephone screening survey that provided a sampling frame for the main data collection in Phase 2. The survey sample in Phase 2 was stratified according to water system size (residential population served), ownership (public, private, or ancillary), and primary water source (ground or surface). A total of 3,681 systems covering a range of source water types and system sizes were randomly selected to receive the main survey questionnaire. Of these, 1,980 systems responded. See the EPA Report, "Community Water System Survey, Volume 2" (USEPA 1997c), for more information on the 1995 CWSS sample design and data evaluation.

EPA also used the December 2000 document, "Geometries and Characteristics of Water Systems Report" (Model Systems Report) (USEPA 2000c). In this document, EPA analyzed 1995 CWSS data to develop equations relating flow and population, among other things.

The data source providing the most comprehensive information on influent water quality, treatment processes, and finished water quality came from the 1996 Information Collection Rule (ICR), which applied to all PWSs serving at least 100,000 people, with a more limited set of ICR requirements pertaining to ground water systems serving 50,000 to 100,000. The purpose of the ICR was to collect DBP and microbial occurrence and treatment information to help evaluate the need for microbial and DBP rules. The ICR gathered plant-level data from approximately 300 water systems over 18 months (July 1997–December 1998). These data characterize the source waters and the water quality at each step in the treatment process and at points in the distribution system. The water quality data include information about the DBPs formed when chemical disinfectants react with naturally occurring compounds present in source water. In addition, the ICR collected treatment and process train data that were used in the predictive analyses described in this chapter.

The American Water Works Association (AWWA) submitted several comments in response to the proposed Stage 1 DBPR that underscore the necessity of the ICR in developing the Stage 2 DBPR. AWWA stated, "Promulgation of the Stage 2 D/DBPR and LT2ESWTR [Long Term 2 Enhanced Surface Water Treatment Rule] is contingent upon completion of necessary health effects research and analysis of the ICR data" (USEPA 1998b) and "AWWA believes that the data from both the ICR and complimentary research will ensure that a scientific database will be created to make important and cost effective decisions on the direction of both the final ESWTR and Stage 2 of the D/DBPR" (USEPA 1997d). In addition, AWWA concurred with the appropriateness of the phased approach to allow for

[1] Throughout this document, the acronym "SDWIS/FED" is shortened to "SDWIS."Refer to EPA's website for more information on SDWIS (http://www.epa.gov/safewater/sdwisfed/sdwis.htm)

analysis of ICR data in its comments on the 1994 rule versions. Comments on the 1994 rule from AWWA explain that data collected through the ICR would be used to determine the occurrence of DBPs and DBP precursors as well as treatment capabilities associated with DBP control in developing the Stage 2 DBPR (USEPA 1994b).

For medium systems (serving 10,000 to 99,999 people) and small systems (serving fewer than 10,000 people), several additional data sources were used to characterize the source water and finished water quality:[2]

- ICR Supplemental Surveys
- The National Rural Water Association (NRWA) Survey
- The Ground Water Supply Survey
- Small surface and ground water plant data collected by various States (several States provided DBP data to EPA)
- The Water Utility Database (WATER:\STATS, AWWA 2000)

Data from these sources were also used to help predict treatment technologies changes to comply with regulatory alternatives. These data are presented in detail in the *Stage 2 Occurrence Assessment for Disinfectants and Disinfection Byproducts (D/DBPs)* (Occurrence Assessment) (USEPA 2005k). The Occurrence Assessment and Appendix L also discuss the data quality of each of the sources used in this Economic Analysis (EA).

3.3 Surface Water Analytical Tool

Although observed DBP data are available for pre-Stage 1 conditions, finished water quality is modeled to give a consistent basis to compare with the pre-Stage 2 and post-Stage 2 predictions. The SWAT is the main tool developed by EPA to model DBP occurrence for different regulatory alternatives. SWAT uses a series of algorithms and decision rules to predict the type of treatment a plant will use and the resulting DBP occurrence, given a specific regulatory alternative and source water quality based on ICR data. Additional description of SWAT is provided in Appendix A and the SWAT Operations Manual (USEPA 2000a).

SWAT was designed to provide answers to two broad questions:

- What treatment technologies will large surface water treatment plants implement (given a pre-determined, least-cost decision tree) to comply with a defined set of disinfection and DBP compliance criteria?

[2] Although the language in EPA rules generally does not include systems serving exactly 10,000 people in the "small" category, this document places them in the small category to be consistent with the system and population data categories from the Baseline Handbook.

- What is the predicted finished and delivered water quality (particularly DBP levels) produced by large surface water treatment plants after implementation of a range of treatment technologies for a given set of disinfection criteria?

SWAT has four major components (Exhibit 3.1a), including:

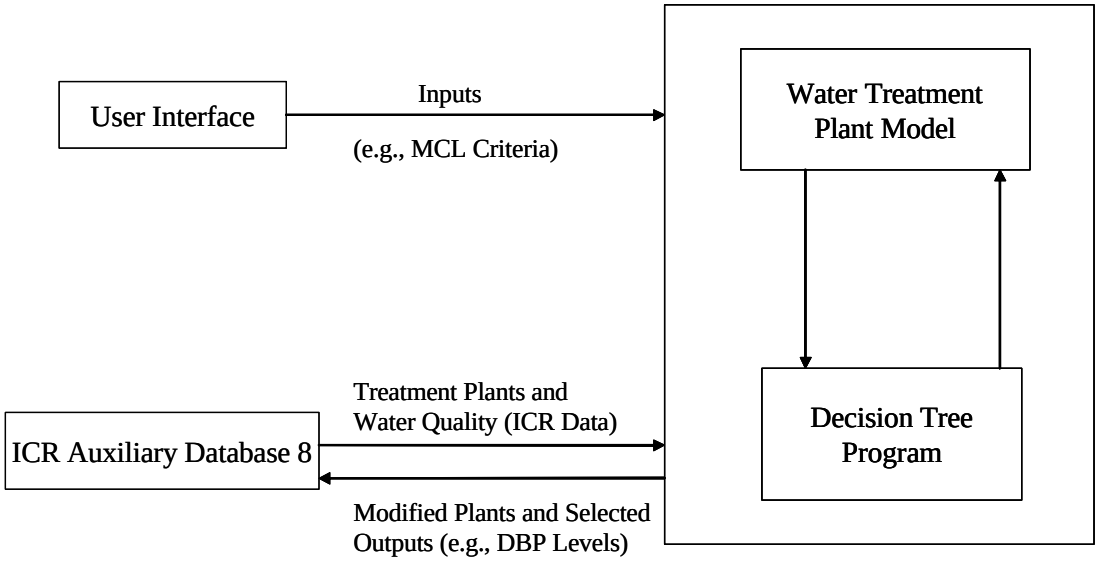
- ICR Auxiliary Database 8 (AUX8) - It is a Microsoft Access™ database that contains both inputs and outputs of the SWAT program. Inputs include ICR influent water quality and plant process train data. Outputs consist of treatment technologies predicted for compliance, treated water quality, and modified process train data.

- Decision Tree Program—This part of SWAT determines how a treatment plant is modified to comply with defined regulatory alternatives. First, the program determines if an individual plant can be modified using the least expensive (and typically least effective) treatment technology to comply with the regulatory alternative. If not, the program moves to the next lowest-cost treatment technology. This process continues until the plant achieves compliance. The program receives inputs from the database (AUX8), and uses the Water Treatment Plant Model (described in the next bullet) to estimate treated water quality before and after predicted treatment technology changes, and sends results back to the database.

- Water Treatment Plant Model—This model is the main predictive component of SWAT. It generates predictions of treated water quality (e.g., DBP levels) for the water treatment process trains defined by the Decision Tree Program. Predictive modules of the model were calibrated using the central tendency of the ICR data.

- User Interface—A Windows™ interface enables the user to specify the disinfection and DBP criteria, as well as numerous other assumptions for a SWAT run.

Exhibit 3.1a SWAT Components



The Water Treatment Plant Model and the Decision Tree Program work together to predict DBP occurrence levels and treatment plant modifications. The Water Treatment Plant Model computes DBP concentrations that represent the treatment process train for a plant, influent water quality characteristics, and specific treatment constraints. TTHM and HAA5 concentrations are predicted for two distribution system conditions–maximum water residence time and average water residence time.[3] If the DBP concentrations do not meet regulatory constraints at the average residence time (for Stage 1) or at maximum residence time (for Stage 2), the Decision Tree Program modifies the process train to meet the specified water quality objectives using a least-cost decision sequence. For the pre-Stage 2 DBPR baseline runs (conditions following implementation of the Stage 1 DBPR) and Stage 2 DBPR regulatory alternative runs, these criteria are based on specified maximum contaminant levels (MCLs) for DBPs. If a plant's predicted DBP occurrence exceeds an MCL, the Decision Tree Program chooses a more effective treatment technology (i.e., the next higher-cost option) in the decision tree, and the Water Treatment Plant Model generates a new DBP prediction. This selection process continues until a selected treatment technology results in the plant meeting the regulatory alternative. SWAT was also run for a pre-Stage 1 baseline, where the model only predicted the DBP levels based on the inputted process train and water quality data. This run was to serve as a comparison to the ICR data to evaluate and calibrate predictions (see Appendix A).

SWAT was run using actual data from the ICR on influent water quality, treatment trains, and related characteristics of 273 ICR surface water plants. All SWAT results are based on a 12-month period using input data from months 7–18 (January 1998–December 1998). The number of months with valid data input varied among plants; therefore, the output of SWAT does not contain 12 months of data for every plant, as is discussed in greater detail in Appendix A.

Exhibit 3.1b summarizes the inputs and outputs used in the SWAT modeling process. Appendix A describes the treatment technology selection process of the decision tree, the assumptions contained within SWAT, and the analysis of uncertainty. For further programming details, refer to *The Surface Water Analytical Tool (SWAT) Version 1.1–Program Design and Assumptions* (USEPA 2000a).

3.4 Industry Profile

This section provides the water industry characterization used to derive costs and benefits for the Stage 2 DBPR. It is organized as follows:

- Section 3.4.1 is a background section with terminology and definitions used to characterize the water industry baseline. It also identifies distinctions that are important for regulatory analysis.

- Section 3.4.2 presents the baseline numbers of systems, plants, and population subject to the Stage 2 DBPR.

[3] Empirical equations are used to estimate DBP formation based on residence time (see Appendix A for discussion of these equations).

- Section 3.4.3 presents mean plant design and average daily flows.

- Section 3.4.4 estimates the total number of households subject to the Stage 2 DBPR.

Exhibit 3.1b SWAT Inputs and Outputs

Input data	
Source water quality	• pH • Temperature (average and annual minimum) • Total organic carbon (TOC) • Ultraviolet$_{254}$ (UV) absorbance • Bromide • Alkalinity • Hardness (total and calcium) • Ammonia • Turbidity
Treatment plant characteristics	• Flow (average and peak hourly) • Presence of, sequence of, and parameters (e.g., volumes and retention times) for unit processes, including rapid mix, flocculation, settling basin, filtration, contact tank, reservoir, granulated activated carbon, membranes, and ozone chambers • Dosages and chemical feeds (e.g., alum, ammonium sulfate, ammonia, CO_2, NaOH, Cl_2 (gas), ClO_2, ferric chloride, lime, ozone, potassium permanganate, soda ash, SO_2, and H_2SO_4) • Average and maximum distribution system residence times
Compliance measures (DBPs)	
Finished water concentration	• For each plant, and for each month for which data are available for that plant, the DBP concentration at the entry point to the distribution system is calculated, representing a residence time of 0. These monthly values can then be used in compliance calculations.
Distribution system average concentration	• For each plant, and for each month for which data are available for that plant, the DBP concentration in the distribution system is calculated based on the *average* distribution system residence time reported by the system. These monthly values can then be used in different compliance calculations.
Distribution system maximum concentration	• For each plant, and for each month for which data are available for that plant, the DBP concentration in the distribution system is calculated based on the *maximum* distribution system residence time reported by the system. These monthly values can then be used in different compliance calculations.

Source: Appendix A.

3.4.1 Public Water System Categorization

Categorization of water systems is important because system size, ownership, and retail/wholesale relationships dictate the way in which costs and benefits are estimated. This section explains the water system categories as defined by EPA's National Primary Drinking Water Regulations (NPDWRs) and describes further subdivisions according to water source, size (population served), and ownership for regulatory analysis purposes.

PWS Type

NPDWRs apply to all PWSs. A PWS is a system that provides water for human consumption through pipes or other constructed conveyances and that has at least 15 service connections or regularly serves an average of at least 25 individuals per day for at least 60 days per year. PWSs are categorized as follows:

- A ***Community Water System (CWS)*** is a PWS that has at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents.

- A ***Noncommunity Water System (NCWS)*** is a PWS that is not a CWS. NCWSs are subdivided into two categories:

  - A ***Nontransient Noncommunity Water System (NTNCWS)*** is a NCWS that regularly serves at least 25 of the same people more than 6 months per year.

  - A ***Transient Noncommunity Water System (TNCWS)*** is a NCWS that does not regularly serve at least 25 of the same people more than 6 months per year.

Source Water Type

For the purposes of regulatory analysis, systems are typically categorized according to the source of their water. Types of sources include surface water (reservoirs, lakes, or flowing streams), ground water under the direct influence of surface water (GWUDI), ground water (aquifers not under the influence of surface water), and treated water that is purchased from other systems. For the purposes of this document, "surface water" includes GWUDI sources.[4]

In SDWIS and the Baseline Handbook (USEPA 2001c), systems are assigned a source type using the following hierarchy, in descending order: Surface Water, Purchased Surface Water, Ground Water, and Purchased Ground Water. The presence of the first source in this list determines the source assignment for that system. As a result, all "mixed systems" (systems with both a ground and surface water source) are placed in the surface water system category. Based on an analysis in the Model Systems Report (USEPA 2000c), it is estimated that 21 percent of surface water systems obtain some of their water from ground water sources. Approximately one-third of these, or 8 percent of all surface

[4] EPA also refers to the grouping of surface water and GWUDI systems as "subpart H" systems in the Stage 2 DBPR rule language. Surface water and GWUDI systems are grouped together because they fall under the same requirements in the Safe Drinking Water Act (SDWA) regulations.

water systems in SDWIS and the Baseline Handbook, receive the majority of their flow from ground water.

Other data sets classify systems differently. For example, the ICR Auxiliary Database 1 (AUX1) classifies systems that receive more than 80 percent of their source water from surface water as surface water systems. Systems that rely on ground water for more than 80 percent of their supply are considered ground water systems. Systems that receive more than 80 percent of their supply from another system are considered purchased water systems. All other systems are considered mixed. The 1995 CWSS data are classified by primary source (the source that provides more than 50 percent of average flow to the distribution system). In cases where there are three different sources (e.g., surface, ground, and purchased), systems in the 1995 CWSS are classified by the largest source.

This EA begins with numbers from the SDWIS database. These numbers are then reclassified according to primary source water type based on the CWSS data.

Ownership

Systems are categorized in SDWIS and in the Baseline Handbook according to three ownership types: "private," "public," and "other." Private systems are owned by private corporations or individuals. Public systems are owned by public entities such as municipalities, counties, or special districts and have access to capital and means of financing that are not available to private systems. The "other" category contains systems where ownership is not reported in SDWIS. These distinctions become important in calculating household costs (see Chapter 7) and in assessing Unfunded Mandates Reform Act (UMRA) requirements (see Chapter 8).

Purchased Water and Wholesale System Types

Systems are typically categorized according to whether they treat water themselves or purchase treated water from other systems. The Stage 2 DBPR defines a consecutive system as a PWS that buys or otherwise receives some or all of its finished water from one or more wholesale systems. A wholesale system is defined as a PWS that treats and then sells or otherwise delivers finished water to another PWS. Treatment modifications are generally not made by consecutive water systems, but are instead made by the associated wholesale systems. Costs of these treatment modifications are typically passed on to the consecutive systems in the form of water rate increases.

Population Served

The number of people served by systems (indicating system size) is a key parameter used to calculate benefits and costs of drinking water regulations. This EA defines two types of system populations: the *retail* customers of a system who buy water directly from the system, and the *wholesale* customers of a system who are served by a second system that purchases treated water from the first. Systems are categorized in SDWIS and the Baseline Handbook by *retail* population served. Systems in the 1995 CWSS database are classified by total population (wholesale and retail).

Systems are categorized by population in order to group them for analyses. Mean estimates are used for each of the nine population size categories in this EA. Although some variability is lost by characterizing systems by nine population size categories, EPA believes the level of analysis provides

adequate information to characterize national costs and benefits. This approach is consistent with other regulations developed by EPA.

3.4.2 Systems, Plants, and Population Subject to the Stage 2 DBPR

To estimate costs and benefits attributable to the Stage 2 DBPR, EPA has developed the following industry baselines:

- The *System Baseline* (Appendix H) is used to estimate non-treatment costs incurred by systems for rule implementation, IDSEs, Stage 2 monitoring plans, additional routine monitoring, and operational evaluations. Systems are categorized based on the population breakouts used for Stage 2 DBPR monitoring requirements which are different than the standard nine size categories used in the rest of this EA. The derivation of the system baseline is in Appendix H, section H.1.

- The *Plant Baseline* (Exhibit 3.2) is used to estimate treatment costs (based on predictions of plants changing to various advanced treatment technologies).

- The *Population Baseline* (Exhibit 3.3) is used to estimate cancer cases avoided as a result of the Stage 2 DBPR and subsequent monetized benefits.

The purpose of this section is to define these baselines and describe how they were derived.

3.4.2.1 Plant Baseline

Exhibit 3.2, presented at the end of this subsection, shows the derivation of the baseline number of treatment plants subject to the Stage 2 DBPR (i.e., the plant baseline). The derivation is described below in four steps. Step 1 involves modifying the surface water system inventory to better represent the size and number of plants that exist by "linking" purchasing surface water systems to their respective sellers. Only surface water systems were modified in this step (the number of purchasing ground water systems is such a small proportion of all ground water systems that linking them to sellers was not expected to change the characterization of the ground water plant baseline). Step 2 removes systems which do not disinfect from the baseline. In step 3, the system inventory was reclassified from the SDWIS source water categorization to the primary source water type (i.e., the source type that provides more than 50 percent of the water to a system). The final step, step 4, involves converting the system inventory to a treatment plant inventory based on estimates of average treatment plants per system.

Step 1: Modify the Surface Water System Inventory by Linking Buyers and Sellers

Because population served is used directly to estimate the volume of water treated, the type of system population reported is key to defining an accurate treatment plant baseline. As noted in section 3.4.1, system populations in SDWIS represent retail populations only. In other words, system populations reported in SDWIS do not include the populations of those consecutive systems to whom they sell water (purchased water systems are considered separate, stand-alone systems). More than half of the surface

water systems are consecutive, stand-alone systems. Purchased-water systems comprise a much lower proportion of ground water systems (approximately five percent).

The advantage of classifying systems by retail population as done in SDWIS is that it appropriately accounts for both the total number of individual PWSs in the United States and the total population served by all of those systems. However, a disadvantage (especially for surface water CWSs) when estimating national costs of regulations is that it does not directly account for the fact that the water delivered by the consecutive systems to their retail customers *is actually treated by other systems*. It is important to recognize that the total flow of surface water is actually treated by fewer than half of the surface water systems accounted for in SDWIS. Because of economies of scale, the cost of treatment (in cents per gallon) is less for systems treating larger flows than it is for systems treating smaller flows. For example, it is typically more expensive to build and operate two treatment plants serving 5,000 people than one treatment plant serving 10,000 people. Failing to account for the fact that surface water is actually treated in larger quantities at a smaller number of systems than SDWIS suggests could result in an upward bias in national cost estimates of rules that affect a substantial portion of surface water systems.

To rectify this bias, an analysis was performed to "link" consecutive surface water systems to their respective wholesale system using data from SDWIS (each purchased system lists the PWS identification number(s) for systems that sell water to it) . If a consecutive system could be linked to a wholesaler, that system was removed from the system count and its population was added to the population of the wholesale system.

The methodology used to link the SDWIS 2003 system inventory is described in detail below:

- If a system has multiple sources, (e.g., it has a primary source of surface water in addition to a purchased surface water source), it was assumed to be adequately represented as a non-purchased surface water system, and was not linked to its seller (i.e., only 100-percent-purchased-surface-water systems were linked).

- For systems that purchase water, all sellers were identified using SDWIS data (SDWIS has a table that lists the PWS identification number (PWSID) for each seller).

- If a purchased surface water system (System P) purchases all of its water from *one* non-purchased surface water system (System S), its population was added to that of System S, and it was removed from the inventory of purchased systems.

- If the purchased surface water system buys water from *multiple* non-purchased systems, it was assigned to the most directly related non-purchased seller with the largest population. For example, a purchased system (System C) purchases from a non-purchased system (System B1) and a purchased system (System B2), which in turn purchases from a non-purchased system (System A). In this case, System C was linked to System B1; in other words, the population of System C was added to that of System B1. It was not linked to either System B2 or System A, even if those systems were larger.

- Some purchased systems have what is referred to as "cascading provider relationships." For instance, a purchased system, System C, may purchase water from another system, System B. System B does not treat its own water but, instead purchases water from a non-purchased system, System A. For this analysis, the populations of both Systems B and C were added to the population of System A, and Systems B and C were removed from the inventory of unlinked systems.

- When the purchased system and its seller are not of the same type (e.g., a CWS purchasing from a NTNCWS), they were not linked and are counted as separate, unlinked purchased systems. Systems purchasing from systems of different ownership type (e.g., a public water system purchasing from a private water system), however, were linked.

- If the ID number of the seller did not correspond to an active water system, the purchased system was counted as a separate, unlinked, purchased system.

- In a few cases, the seller could not be found, i.e., a purchased system (e.g., System C) cannot be linked to a non-purchased system. These purchased systems were counted as separate, unlinked, purchased systems.

Results of the linking exercise for surface water CWSs and NTNCWSs are shown in Exhibit 3.2, columns F through J.

As shown in Exhibit 3.2, columns F and G, there are approximately 2,700 purchasing systems remaining unlinked in the inventory. These include surface water systems that could not be linked (e.g., many surface water NTNCWSs purchase water from CWSs and were not be linked), purchased surface water systems with a non-purchased ground water source, and the unlinked purchased ground water systems. For the purposes of estimating treatment costs in this EA, EPA includes the remaining unlinked purchased water systems in the system inventory and evaluates them as if they are treating water themselves. As described previously, evaluating purchasing systems as if they are stand-alone, treating systems could result in an upward bias in national cost estimates. This bias is greatly reduced, however, by the linking effort described in this step.

While EPA believes that linking consecutive systems with their wholesalers will improve the accuracy of cost estimates, it is possible that purchased systems may be out of compliance even when the wholesaler is in compliance, thereby obligates them to incur treatment costs that are not being captured by this approach. EPA believes that the number of these systems, however, is small and will not have a measurable effect on the costs or benefits of the Stage 2 DBPR.

Step 2: Remove Systems which do not Disinfect

The Stage 2 DBPR applies only to systems which disinfect their water. Therefore systems which do not disinfect were removed from the baseline. The inventory is reduced by the percent disinfecting (shown in Exhibit 3.2, column K) to produce the results shown in columns L through P.

The estimate of percent disinfecting in column P comes from several sources. The percent of ground water CWSs providing disinfection is derived from 1995 CWSS results, as summarized in Table

B1.3.3 of the Baseline Handbook. The percent of ground water NTNCWSs that disinfect was derived from *Ground Water Disinfection and Protective Practices in the United States* (USEPA 1996a). These data sources do not include systems that may add disinfection to correct a significant deficiency under the Ground Water Rule (GWR). Because the GWR is expected to be promulgated at the same time or just after the Stage 2 DBPR is promulgated, EPA expects new systems adding disinfection to meet GWR requirements to simultaneously achieve compliance with Stage 2 MCLs. Therefore, these systems are not included in the treatment baseline.

Step 3: Re-classify Systems by Primary Source Water Type

The characterization of distribution system DBP levels and predictions of treatment technology changes are very different for ground and surface water plants. This is mainly because ground water sources generally have lower DBP precursor (e.g., TOC) concentrations than surface water; thus, DBP levels and predicted changes to meet Stage 2 DBPR requirements are generally less for plants treating ground water than for plants treating surface water.

As noted in section 3.4.1, all mixed systems (even those that are primarily ground water) are grouped with the 100 percent surface water systems in SDWIS. If EPA applied the compliance forecasts for surface water plants to systems that are primarily served by ground water sources, costs could be overstated. Therefore, systems were reclassified by primary source. This is consistent with recommendations in the Arsenic NDWAC Final Report (National Drinking Water Advisory Council 2001).

SDWIS does not contain information on whether or not a system is mixed or the relative proportions of surface and ground water flow used, indicating only whether it is served by all ground water or by at least some proportion of surface water. Therefore, to reclassify by primary source, EPA used flow data from the 1995 CWSS to estimate the proportion of surface water and mixed CWSs that received more than 50 percent of their flow from a ground water source (percentages are shown in Exhibit 3.2, column Q). These systems, originally classified as surface water CWSs in SDWIS, were re-assigned to the ground water CWS category. Note that this adjustment was not made for NTNCWSs because these systems are most often a single building or in a small area, and are less likely to be served by more than one source type.

Step 4: Convert System Inventory to Plant Inventory

The 1995 CWSS data (question 18 from the CWSS questionnaire) were used to estimate the number of treatment plants per system for both surface and ground water CWSs for all system sizes. The analysis produced a distribution of plants per system within each system size category. For analyses in this EA, EPA uses the *mean* plant per system estimate (presented in column W of Exhibit 3.2). For NTNCWSs, EPA assumed a 1:1 plant per system ratio for all sizes and source water types because these systems are most often a single building or located in a small area.

1
2

Exhibit 3.2 Derivation of the Stage 2 DBPR Plant Baseline

Step 1: Use modified inventory for surface water systems										
	No. of Purchased Systems from SDWIS		No. of Non-Purchased Systems from SDWIS			Remaining Unlinked Systems		No. of Linked Systems		Total
System Size (population served)	Public	Private	Public	Private	Total No. of Systems from SDWIS	Public	Private	Public	Private	Number of Linked Systems
	A	B	C	D	E=A+B+C+D	F	G	H	I	J = F+G+H+I
Surface Water and All Mixed CWSs										
<100	413	293	183	196	1,085	23	8	149	193	373
100-499	855	630	433	294	2,212	41	24	416	290	771
500-999	655	385	333	97	1,470	21	11	309	98	439
1,000-3,299	1,189	302	940	157	2,588	53	23	862	153	1,091
3,300-9,999	862	139	955	86	2,042	48	15	947	90	1,100
10,000-49,999	704	91	878	100	1,773	32	2	967	103	1,104
50,000-99,999	111	18	174	31	334	7	0	222	36	265
100,000-999,999	59	9	188	25	281	7	0	238	28	273
1,000,000+	0	0	15	3	18	0	0	20	3	23
Total	4,848	1,867	4,099	989	11,803	232	83	4,130	994	5,439
Ground Water-Only CWSs										
<100	156	106	1,243	10,395	11,900	156	106	1,243	10,395	11,900
100-499	613	252	4,294	9,569	14,728	613	252	4,294	9,569	14,728
500-999	326	103	2,794	1,613	4,836	326	103	2,794	1,613	4,836
1,000-3,299	332	83	4,197	1,257	5,869	332	83	4,197	1,257	5,869
3,300-9,999	113	19	2,117	412	2,661	113	19	2,117	412	2,661
10,000-49,999	34	6	1,040	200	1,280	34	6	1,040	200	1,280
50,000-99,999	1	0	113	28	142	1	0	113	28	142
100,000-999,999	1	0	52	12	65	1	0	52	12	65
1,000,000+	0	0	3	0	3	0	0	3	0	3
Total	1,576	569	15,853	23,486	41,484	1,576	569	15,853	23,486	41,484
Surface Water and All Mixed NTNCWSs										
<100	15	36	90	90	231	15	31	90	90	226
100-499	31	44	124	118	317	31	42	123	116	312
500-999	10	16	38	42	106	10	14	39	43	106
1,000-3,299	17	12	26	37	92	16	12	25	38	91
3,300-9,999	8	3	5	9	25	8	3	6	8	25
10,000-49,999	2	2	0	1	5	2	2	0	1	5
50,000-99,999	0	0	0	0	0	0	0	0	0	0
100,000-999,999	1	0	0	0	1	1	0	0	0	1
1,000,000+	0	0	0	0	0	0	0	0	0	0
Total	84	113	283	297	777	83	104	283	296	766
Ground Water-Only NTNCWSs										
<100	11	10	1,703	6,872	8,596	11	10	1,703	6,872	8,596
100-499	17	17	3,166	4,141	7,341	17	17	3,166	4,141	7,341
500-999	7	3	1,224	798	2,032	7	3	1,224	798	2,032
1,000-3,299	8	1	432	411	852	8	1	432	411	852
3,300-9,999	5	1	28	40	74	5	1	28	40	74
10,000-49,999	3	0	5	3	11	3	0	5	3	11
50,000-99,999	0	0	1	0	1	0	0	1	0	1
100,000-999,999	0	0	0	1	1	0	0	0	1	1
1,000,000+	0	0	0	0	0	0	0	0	0	0
Total	51	32	6,559	12,266	18,908	51	32	6,559	12,266	18,908
Grand Total, All Systems	6,559	2,581	26,794	37,038	72,972	1,942	788	26,825	37,042	66,597

Sources:
(A) - (D) SDWIS 4th Quarter 2003 Frozen Database, systems with an other ownership designation were considered public
(F) - (I) Analysis of data in the SDWIS 4th Quarter 2003 Frozen Database

Exhibit 3.2 Derivation of the Stage 2 DBPR Plant Baseline (Continued)

Step 2: Calculate Disinfecting Systems						
		Remaining Disinfecting Unlinked Systems		No. of Linked Disinfecting Systems		
System Size (population served)	Percent Disinfecting	Public	Private	Public	Private	Total No. of Linked Disinfecting Systems
	K	L=K*F	M=K*G	N=K*H	O=K*I	P=L+M+N+O
	LINKED Disinfecting Surface Water and All Mixed CWSs					
<100	100%	23	8	149	193	373
100-499	100%	41	24	416	290	771
500-999	100%	21	11	309	98	439
1,000-3,299	100%	53	23	862	153	1,091
3,300-9,999	100%	48	15	947	90	1,100
10,000-49,999	100%	32	2	967	103	1,104
50,000-99,999	100%	7	0	222	36	265
100,000-999,999	100%	7	0	238	28	273
1,000,000+	100%	0	0	20	3	23
Total	-	232	83	4,130	994	5,439
	Disinfecting Ground Water-Only CWSs					
<100	53%	82	56	656	5,489	6,283
100-499	78%	478	196	3,345	7,454	11,473
500-999	84%	274	87	2,347	1,355	4,062
1,000-3,299	80%	265	66	3,345	1,002	4,678
3,300-9,999	87%	98	16	1,838	358	2,310
10,000-49,999	97%	33	6	1,004	193	1,235
50,000-99,999	86%	1	0	98	24	123
100,000-999,999	96%	1	0	50	12	63
1,000,000+	100%	0	0	3	0	3
Total	-	1,231	427	12,685	15,886	30,229
	LINKED Disinfecting Surface Water and All Mixed NTNCWSs					
<100	100%	15	31	90	90	226
100-499	100%	31	42	123	116	312
500-999	100%	10	14	39	43	106
1,000-3,299	100%	16	12	25	38	91
3,300-9,999	100%	8	3	6	8	25
10,000-49,999	100%	2	2	0	1	5
50,000-99,999	100%	0	0	0	0	0
100,000-999,999	100%	1	0	0	0	1
1,000,000+	100%	0	0	0	0	0
Total	-	83	104	283	296	766
	Disinfecting Ground Water-Only NTNCWSs					
<100	29%	3	3	494	1,993	2,493
100-499	29%	5	5	918	1,201	2,129
500-999	29%	2	1	355	231	589
1,000-3,299	29%	2	0	125	119	247
3,300-9,999	29%	1	0	8	12	21
10,000-49,999	29%	1	0	1	1	3
50,000-99,999	29%	0	0	0	0	0
100,000-999,999	29%	0	0	0	0	0
1,000,000+	29%	0	0	0	0	0
Total	-	15	9	1,902	3,557	5,483
Grand Total, All Systems	-	1,561	624	19,000	20,733	41,918

Sources:

Sources:
(K) Percentage of ground water CWSs that disinfect is estimated using percentage of treatment in place from the Third Edition of the Baseline Handbook (Table B1.3.3), originally derived from the 1995 CWSS.

Exhibit 3.2 Derivation of the Stage 2 DBPR Plant Baseline (Continued)

Step 3: Re-allocate such that systems are categorized by primary source water type						
System Size (population served)	% SW that are Primarily GW	No. of Disinfecting, Purchased Systems by Primary Source		No. of Disinfecting, Non-Purchased Systems by Source		Total No. of Disinfecting, Linked Systems
		Public	Private	Public	Private	
	Q	R	S	T	U	V=R+S+T+U
LINKED Primarily Surface Water CWSs						
<100	3.7%	22	8	143	186	359
100-499	9.6%	37	22	376	262	697
500-999	0.0%	21	11	309	98	439
1,000-3,299	5.9%	50	22	811	144	1,027
3,300-9,999	12.0%	42	13	833	79	968
10,000-49,999	10.0%	29	2	870	93	994
50,000-99,999	8.9%	6	0	202	33	241
100,000-999,999	14.0%	6	0	205	24	235
1,000,000+	0.0%	0	0	20	3	23
Total	8.4%	214	77	3,770	922	4,983
Primarily Ground Water CWSs						
<100	-	83	56	662	5,496	6,297
100-499	-	481	199	3,385	7,482	11,547
500-999	-	274	87	2,347	1,355	4,062
1,000-3,299	-	268	68	3,396	1,011	4,742
3,300-9,999	-	104	18	1,951	368	2,442
10,000-49,999	-	36	6	1,100	203	1,346
50,000-99,999	-	1	0	117	27	146
100,000-999,999	-	2	0	83	15	101
1,000,000+	-	0	0	3	0	3
Total	-	1,250	433	13,045	15,958	30,686
LINKED Primarily Surface Water NTNCWSs						
<100	0.0%	15	31	90	90	226
100-499	0.0%	31	42	123	116	312
500-999	0.0%	10	14	39	43	106
1,000-3,299	0.0%	16	12	25	38	91
3,300-9,999	0.0%	8	3	6	8	25
10,000-49,999	0.0%	2	2	0	1	5
50,000-99,999	0.0%	0	0	0	0	0
100,000-999,999	0.0%	1	0	0	0	1
1,000,000+	0.0%	0	0	0	0	0
Total	0.0%	83	104	283	296	766
Primarily Ground Water NTNCWSs						
<100	-	3	3	494	1,993	2,493
100-499	-	5	5	918	1,201	2,129
500-999	-	2	1	355	231	589
1,000-3,299	-	2	0	125	119	247
3,300-9,999	-	1	0	8	12	21
10,000-49,999	-	1	0	1	1	3
50,000-99,999	-	0	0	0	0	0
100,000-999,999	-	0	0	0	0	0
1,000,000+	-	0	0	0	0	0
Total	-	15	9	1,902	3,557	5,483
Grand Total, All Sys.	-	1,561	624	19,000	20,733	41,918

Sources:
(Q) Percentage of SW systems that are primarily GW from "Geometries and Characteristics of Public Water Supplies" (USEPA 2000c), Exhibit 2.9.
(R) For surface water, R=L*(1-Q); for ground water, R=L+((Q for SW)*(L for SW)).

Exhibit 3.2 Derivation of the Stage 2 DBPR Plant Baseline (Continued)

		Baseline Number of Plants Subject to the Stage 2 DBPR				
Step 4: Convert system inventory to plant inventory						
		Disinfecting, Purchased Plants		Disinfecting, Non-Purchased Plants		
System Size (population served)	Plants per System	Public	Private	Public	Private	**Total No.of Disinfecting Plants**
	W	X=W*R	Y=W*S	Z=W*T	AA=W*U	**AB = X+Y+Z+AA**
LINKED Primarily Surface Water CWSs						
<100	1.0	22	8	143	186	**359**
100-499	1.1	41	24	414	288	**767**
500-999	1.1	23	12	340	108	**483**
1,000-3,299	1.1	55	24	892	158	**1,129**
3,300-9,999	1.3	55	17	1,083	103	**1,258**
10,000-49,999	1.3	37	2	1,131	121	**1,292**
50,000-99,999	2.4	15	0	485	79	**579**
100,000-999,999	2.6	16	0	532	63	**610**
1,000,000+	3.2	0	0	64	10	**74**
Total	-	264	87	5,086	1,115	**6,552**
Disinfecting Primarily Ground Water CWSs						
<100	1.0	85	57	675	5,606	**6,423**
100-499	1.3	636	262	4,468	9,876	**15,242**
500-999	1.5	411	130	3,520	2,032	**6,093**
1,000-3,299	1.6	428	108	5,433	1,617	**7,587**
3,300-9,999	2.1	214	38	4,019	759	**5,030**
10,000-49,999	4.0	144	24	4,401	813	**5,382**
50,000-99,999	4.9	7	0	575	134	**716**
100,000-999,999	9.1	18	0	759	141	**918**
1,000,000+	9.1	0	0	27	0	**27**
Total	-	1,942	619	23,879	20,979	**47,419**
LINKED Primarily Surface Water NTNCWSs						
<100	1.0	15	31	90	90	**226**
100-499	1.0	31	42	123	116	**312**
500-999	1.0	10	14	39	43	**106**
1,000-3,299	1.0	16	12	25	38	**91**
3,300-9,999	1.0	8	3	6	8	**25**
10,000-49,999	1.0	2	2	0	1	**5**
50,000-99,999	1.0	0	0	0	0	**0**
100,000-999,999	1.0	1	0	0	0	**1**
1,000,000+	1.0	0	0	0	0	**0**
Total	-	83	104	283	296	**766**
LINKED Disinfecting Primarily Ground Water NTNCWSs						
<100	1.0	3	3	494	1,993	**2,493**
100-499	1.0	5	5	918	1,201	**2,129**
500-999	1.0	2	1	355	231	**589**
1,000-3,299	1.0	2	0	125	119	**247**
3,300-9,999	1.0	1	0	8	12	**21**
10,000-49,999	1.0	1	0	1	1	**3**
50,000-99,999	1.0	0	0	0	0	**0**
100,000-999,999	1.0	0	0	0	0	**0**
1,000,000+	1.0	0	0	0	0	**0**
Total	-	15	9	1,902	3,557	**5,483**
Grand Total, All Sys.	-	2,304	819	31,150	25,947	**60,220**

Sources:
(W) Derived from Question 18 of the 1995 CWSS, calculations based on classification of systems by primary source. Methodology to be included in subsequent drafts of the Geometries Document (USEPA 2000c).

3.4.2.2 Population Baseline

The population baseline is used in the Stage 2 DBPR benefits analysis to help derive the cases of bladder cancer avoided as a result of treatment technology changes resulting from the Stage 2 DBPR (see chapter 6). Because the benefits of the rule are a function of treatment technology changes and subsequent DBP reductions, the population baseline must be consistent with the plant baseline. Thus, the derivation of the Stage 2 DBPR population baseline is similar to that of the Stage 2 DBPR plant baseline (with the exception of Step 4– convert system inventory to plant inventory; this is not needed given that the population served by all plants in a size category and all systems in a size category are the same).

Note that because NTNCWs are most often businesses such as restaurants, schools, campgrounds, etc., their population generally duplicates the population served by CWSs. Total population served by disinfecting systems as derived in this section is just the total of the CWS population served, or 264,513,763 (169,358,139 + 95,155,624) from Exhibit 3.3, column Q.

Step 1: Modify the Surface Water System Inventory by Linking Buyers and Sellers

As with the plant baseline, EPA has modified the system-level population data in SDWIS to add, for surface water systems, populations served by purchasing systems to the population served by their wholesale seller. The overall effect of this step shifts population into higher system size categories; however, it does not alter the total population served by all surface water systems as reported in SDWIS. Section 3.4.2.1 provides the rationale and detailed methodology used to modify the surface water inventory.

Step 2: Remove Population of Systems that do not Disinfect

The Stage 2 DBPR applies only to systems that disinfect their water. Therefore, systems that do not disinfect were removed from the baseline. The inventory is reduced by the percent disinfecting (shown in Exhibit 3.3, column F) to produce the results shown in columns G through K.

The estimate of percent disinfecting in column P is derived in section 3.4.2.1

Step 3: Re-classify Population by Primary Source Water Type

As with the plant baseline, EPA modified population data from SDWIS to represent populations served either by primarily ground or primarily surface water systems. Given that SDWIS does not contain information on whether or not a system is mixed or the relative proportions of surface and ground water flow used, EPA used flow data from the 1995 CWSS to estimate the proportion of surface water and mixed CWSs that received more than 50 percent of their flow from a ground water source (percentages are shown in Exhibit 3.3, column L). This population, originally classified as served by surface water CWSs in SDWIS, was re-assigned to the ground water CWS category. This adjustment was not made for NTNCWSs because these systems are most often a single building or in a small area, and are less likely to be served by more than one source type.

Exhibit 3.3 Derivation of the Stage 2 DBPR Population Baseline

Step 1: Use linked inventory for SW systems					
System Size (population served)	Population Served by Unlinked Systems		Population Served by Linked Systems		Total Population Served
	Public	Private	Public	Private	
	A	B	C	D	E=A+B+C+D
LINKED Surface Water and All Mixed CWSs					
<100	1,124	399	8,260	10,743	20,526
100-499	10,817	5,925	114,084	68,769	199,595
500-999	15,425	7,381	229,498	65,606	317,910
1,000-3,299	107,441	47,998	1,735,746	284,439	2,175,624
3,300-9,999	287,030	76,258	5,746,521	545,907	6,655,716
10,000-49,999	693,894	38,135	22,634,702	2,537,058	25,903,789
50,000-99,999	476,236	0	15,181,764	2,591,527	18,249,527
100,000-999,999	2,432,694	0	63,779,714	9,798,126	76,010,534
1,000,000+	0	0	48,565,698	7,062,250	55,627,948
Total	4,024,661	176,096	157,995,987	22,964,425	185,161,169
Ground Water-Only CWSs					
<100	9,640	6,456	73,773	604,212	694,081
100-499	165,625	64,176	1,180,056	2,054,329	3,464,186
500-999	239,129	70,939	2,022,042	1,111,269	3,443,379
1,000-3,299	594,474	146,219	7,850,024	2,201,328	10,792,045
3,300-9,999	586,870	97,393	11,954,771	2,347,681	14,986,715
10,000-49,999	644,110	82,397	21,421,779	4,180,506	26,328,792
50,000-99,999	87,933	0	7,191,107	1,955,231	9,234,271
100,000-999,999	140,000	0	11,222,309	2,108,763	13,471,072
1,000,000+	0	0	3,933,533	0	3,933,533
Total	2,467,781	467,580	66,849,394	16,563,319	86,348,074
LINKED Surface Water and All Mixed NTNCWSs					
<100	752	1,578	4,285	4,486	11,101
100-499	7,481	9,531	27,491	27,624	72,127
500-999	6,659	8,568	25,534	29,560	70,321
1,000-3,299	29,057	18,649	45,178	60,403	153,287
3,300-9,999	49,231	13,003	24,537	38,642	125,413
10,000-49,999	72,000	43,055	0	13,000	128,055
50,000-99,999	0	0	0	0	0
100,000-999,999	169,846	0	0	0	169,846
1,000,000+	0	0	0	0	0
Total	335,026	94,384	127,025	173,715	730,150
Ground Water-Only NTNCWSs					
<100	545	487	87,724	344,860	433,616
100-499	3,984	3,080	806,717	845,693	1,659,474
500-999	4,510	1,950	824,809	535,712	1,366,981
1,000-3,299	13,823	1,350	657,954	649,238	1,322,365
3,300-9,999	23,800	4,800	145,634	207,114	381,348
10,000-49,999	55,200	0	137,008	36,200	228,408
50,000-99,999	0	0	66,000	0	66,000
100,000-999,999	0	0	0	110,000	110,000
1,000,000+	0	0	0	0	0
Total	101,862	11,667	2,725,846	2,728,817	5,568,192
Grand Total, All Systems	6,929,330	749,727	227,698,252	42,430,276	277,807,585

Sources:
(A-D) for Surface Water CWSs & NTNCWSs: "Linked" system inventory derived from SDWIS 4th Quarter Year 2003 Freeze data. See section 3.4.2.2 for a description of linking methodology.

Exhibit 3.3 Derivation of the Stage 2 DBPR Population Baseline (Continued)

Step 2: Remove population which doesn't disinfect						
System Size (population served)	Percent Disinfecting	Population Served by Remaining Unlinked, Disinfecting Systems		Population Served by Linked, Disinfecting Systems		Total Population Served by Disinfecting Systems
		Public	Private	Public	Private	
	F	G=A*F	H=B*F	I =C*F	J=D*F	K=G+H+I+J
LINKED Surface Water and All Mixed CWSs						
<100	100%	1,124	399	8,260	10,743	20,526
100-499	100%	10,817	5,925	114,084	68,769	199,595
500-999	100%	15,425	7,381	229,498	65,606	317,910
1,000-3,299	100%	107,441	47,998	1,735,746	284,439	2,175,624
3,300-9,999	100%	287,030	76,258	5,746,521	545,907	6,655,716
10,000-49,999	100%	693,894	38,135	22,634,702	2,537,058	25,903,789
50,000-99,999	100%	476,236	0	15,181,764	2,591,527	18,249,527
100,000-999,999	100%	2,432,694	0	63,779,714	9,798,126	76,010,534
1,000,000+	100%	0	0	48,565,698	7,062,250	55,627,948
Total	-	4,024,661	176,096	157,995,987	22,964,425	185,161,169
Disinfecting Ground Water-Only CWSs						
<100	53%	5,090	3,409	38,952	319,024	366,475
100-499	78%	129,022	49,993	919,264	1,600,322	2,698,601
500-999	84%	200,868	59,589	1,698,515	933,466	2,892,438
1,000-3,299	80%	473,796	116,537	6,256,469	1,754,458	8,601,260
3,300-9,999	87%	509,403	84,537	10,376,741	2,037,787	13,008,469
10,000-49,999	97%	621,566	79,513	20,672,017	4,034,188	25,407,284
50,000-99,999	86%	75,886	0	6,205,925	1,687,364	7,969,176
100,000-999,999	96%	134,960	0	10,818,306	2,032,848	12,986,113
1,000,000+	100%	0	0	3,933,533	0	3,933,533
Total	-	2,150,591	393,577	60,919,722	14,399,458	77,863,349
LINKED Surface Water and All Mixed NTNCWSs						
<100	100%	752	1,578	4,285	4,486	11,101
100-499	100%	7,481	9,531	27,491	27,624	72,127
500-999	100%	6,659	8,568	25,534	29,560	70,321
1,000-3,299	100%	29,057	18,649	45,178	60,403	153,287
3,300-9,999	100%	49,231	13,003	24,537	38,642	125,413
10,000-49,999	100%	72,000	43,055	0	13,000	128,055
50,000-99,999	100%	0	0	0	0	0
100,000-999,999	100%	169,846	0	0	0	169,846
1,000,000+	100%	0	0	0	0	0
Total	-	335,026	94,384	127,025	173,715	730,150
Disinfecting Ground Water-Only NTNCWSs						
<100	29%	158	141	25,440	100,009	125,749
100-499	29%	1,155	893	233,948	245,251	481,247
500-999	29%	1,308	566	239,195	155,356	396,424
1,000-3,299	29%	4,009	392	190,807	188,279	383,486
3,300-9,999	29%	6,902	1,392	42,234	60,063	110,591
10,000-49,999	29%	16,008	0	39,732	10,498	66,238
50,000-99,999	29%	0	0	19,140	0	19,140
100,000-999,999	29%	0	0	0	31,900	31,900
1,000,000+	29%	0	0	0	0	0
Total	-	29,540	3,383	790,495	791,357	1,614,776
Grand Total, All Systems	-	6,539,818	667,441	219,833,230	38,328,955	265,369,444

Sources:
(F) Percentage of ground water CWSs that disinfect is estimated using percentage of treatment in place from the Third Edition of the Baseline Handbook (Table B1.3.3), originally derived from the 1995 CWSS.

Exhibit 3.3 Derivation of the Stage 2 DBPR Population Baseline (Continued)

		Baseline Number of People Subject to the Stage 2 DBPR				
Step 3: Re-allocate such that systems are categorized by primary source water type						
System Size (population served)	% SW that are Primarily GW	Population Served by Remaining Unlinked, Disinfecting Systems		Population Served by Linked, Disinfecting Systems		**Total Population Served by Disinfecting Systems**
		Public	Private	Public	Private	
	L	M	N	O	P	**Q=M+N+O+P**
LINKED Primarily Surface Water CWSs						
<100	3.7%	1,082	384	7,954	10,346	**19,767**
100-499	9.6%	9,779	5,356	103,132	62,167	**180,434**
500-999	0.0%	15,425	7,381	229,498	65,606	**317,910**
1,000-3,299	5.9%	101,102	45,166	1,633,337	267,657	**2,047,262**
3,300-9,999	12.0%	252,586	67,107	5,056,938	480,398	**5,857,030**
10,000-49,999	10.0%	624,505	34,322	20,371,232	2,283,352	**23,313,410**
50,000-99,999	8.9%	433,851	0	13,830,587	2,360,881	**16,625,319**
100,000-999,999	14.0%	2,092,117	0	54,850,554	8,426,388	**65,369,059**
1,000,000+	0.0%	0	0	48,565,698	7,062,250	**55,627,948**
Total	-	3,530,447	159,716	144,648,931	21,019,046	**169,358,139**
Disinfecting Primarily Ground Water CWSs						
<100	-	5,132	3,424	39,258	319,421	**367,234**
100-499	-	130,060	50,562	930,216	1,606,924	**2,717,762**
500-999	-	200,868	59,589	1,698,515	933,466	**2,892,438**
1,000-3,299	-	480,135	119,368	6,358,878	1,771,240	**8,729,622**
3,300-9,999	-	543,847	93,688	11,066,324	2,103,296	**13,807,155**
10,000-49,999	-	690,956	83,327	22,935,487	4,287,894	**27,997,663**
50,000-99,999	-	118,271	0	7,557,102	1,918,010	**9,593,384**
100,000-999,999	-	475,537	0	19,747,466	3,404,585	**23,627,588**
1,000,000+	-	0	0	3,933,533	0	**3,933,533**
Total	-	2,644,806	409,957	74,266,779	16,344,837	**93,666,379**
LINKED Primarily Surface Water NTNCWSs						
<100	0.0%	752	1,578	4,285	4,486	**11,101**
100-499	0.0%	7,481	9,531	27,491	27,624	**72,127**
500-999	0.0%	6,659	8,568	25,534	29,560	**70,321**
1,000-3,299	0.0%	29,057	18,649	45,178	60,403	**153,287**
3,300-9,999	0.0%	49,231	13,003	24,537	38,642	**125,413**
10,000-49,999	0.0%	72,000	43,055	0	13,000	**128,055**
50,000-99,999	0.0%	0	0	0	0	**0**
100,000-999,999	0.0%	169,846	0	0	0	**169,846**
1,000,000+	0.0%	0	0	0	0	**0**
Total	-	335,026	94,384	127,025	173,715	**730,150**
Disinfecting Primarily Ground Water NTNCWSs						
<100	-	158	141	25,440	100,009	**125,749**
100-499	-	1,155	893	233,948	245,251	**481,247**
500-999	-	1,308	566	239,195	155,356	**396,424**
1,000-3,299	-	4,009	392	190,807	188,279	**383,486**
3,300-9,999	-	6,902	1,392	42,234	60,063	**110,591**
10,000-49,999	-	16,008	0	39,732	10,498	**66,238**
50,000-99,999	-	0	0	19,140	0	**19,140**
100,000-999,999	-	0	0	0	31,900	**31,900**
1,000,000+	-	0	0	0	0	**0**
Total	-	29,540	3,383	790,495	791,357	**1,614,776**
Grand Total, All Systems	-	6,539,818	667,441	219,833,230	38,328,955	**265,369,444**

Note: Detail may not add due to independent rounding.
Sources:
(L) Percentage of SW systems that are primarily GW from "Geometries and Characteristics of Public Water Supplies" (USEPA 2000c), Exhibit 2.9.
(M) For surface water, M=G*(1-L); For ground water, M=G+((G for SW)*(L for SW)).
(O) For surface water, O=I*(1-L); For ground water, O=I+((I for SW)*(L for SW)).
(P) For surface water, P=J*(1-L); For ground water, P=J+((J for SW)*(L for SW)).

3.4.3 Water Treatment Plant Design and Average Daily Flows

Treatment technology costs depend on the volume of water treated per day. The cost analysis described in Chapter 7 uses two types of treatment plant flow: (1) design flow, which is the maximum capacity at which the plant was intended to operate, expressed in millions of gallons per day (MGD), and (2) average daily flow, which is the flow produced by a treatment plant in one day, an average derived from 365 days of flow measurements, expressed in MGD. Design flows are used to estimate the capital costs of the treatment technology that will be installed to meet the requirements of the Stage 2 DBPR. Average daily flows are used to estimate the annual cost of ongoing operations and maintenance (O&M).

To estimate flows for different sized systems, EPA developed the following regression equations:

Surface Water: Design Flow (MGD) = $0.36971\ X^{0.97757} / 1{,}000$
Average Daily Flow (MGD) = $0.10540\ X^{1.02058} / 1{,}000$

Ground Water: Design Flow (MGD) = $0.39639\ X^{0.97708} / 1{,}000$
Average Daily Flow (MGD) = $0.06428\ X^{1.07652} / 1{,}000$

Where X = mean population served per system.[5]

These equations are based on 1995 CWSS data. Their derivation is presented in detail in the Model Systems Report (USEPA 2000c) and summarized in the Baseline Handbook (USEPA 2001c). The equations are used in this EA to estimate mean flows per plant for each size category, using the mean population served per plant. (The mean population served per plant can be calculated by dividing the total population for a given size category presented in Exhibit 3.3, column Q, by the baseline number of plants in that size category as presented in Exhibit 3.2, column V.). Exhibit 3.4 shows the population per system, the number of plants per system, and the design and average flows per plant.

This EA uses a single regression equation to estimate flows for either public or privately owned systems. There is, however, a slight difference in the flow characteristics for these two ownership types, as discussed in the Model Systems Report (USEPA 2000c). The use of different flow equations for public and private systems would not affect total national costs, although per-household costs may be slightly affected. EPA has evaluated the equations and believes that the differences are small and would have a negligible effect on household costs.

[5] Equations are from the 3rd Edition of the Baseline Handbook as derived in December 2000 Model Systems Report (USEPA 2000c).

Exhibit 3.4 Design Flows and Average Daily Flows per Plant (MGD)

System Size (Population Served)	Average No. of Population Served per System	Average No. of Plants/System	Design Flows (MGD) Per Plant	Average Daily Flow (MGD) Per Plant
LINKED, Primarily Surface Water CWSs				
	X	**Y**	**$Z = 0.36971\ X^{0.97757}/1000Y$**	**$AA = 0.10540\ X^{1.02058}/1000Y$**
<100	55.0	1.0	0.019	0.006
100-499	258.9	1.1	0.077	0.028
500-999	724.2	1.1	0.210	0.079
1,000-3,299	1,994.2	1.1	0.565	0.223
3,300-9,999	6,050.7	1.3	1.415	0.587
10,000-49,999	23,463.6	1.3	5.325	2.340
50,000-99,999	68,866.1	2.4	8.263	3.804
100,000-999,999	278,426.9	2.6	29.886	14.609
1,000,000+	2,418,606.4	3.2	200.952	107.803
Disinfecting Primarily Ground Water CWSs				
	X	**Y**	**$Z = 0.39639\ X^{0.97708}/1000Y$**	**$AA = 0.06428\ X^{1.07652}/1000Y$**
<100	58.3	1.0	0.021	0.005
100-499	235.4	1.3	0.062	0.017
500-999	712.0	1.5	0.162	0.050
1,000-3,299	1,840.9	1.6	0.384	0.131
3,300-9,999	5,654.6	2.1	0.893	0.342
10,000-49,999	20,806.8	4.0	1.642	0.716
50,000-99,999	65,649.2	4.9	4.119	2.012
100,000-999,999	234,214.8	9.1	7.685	4.261
1,000,000+	1,311,177.7	9.1	41.355	27.216
LINKED, Primarily Surface Water NTNCWSs				
	X	**Y**	**$Z = 0.36971\ X^{0.97757}/1000Y$**	**$AA = 0.10540\ X^{1.02058}/1000Y$**
<100	49.1	1.0	0.017	0.006
100-499	231.2	1.0	0.076	0.027
500-999	663.4	1.0	0.212	0.080
1,000-3,299	1,684.5	1.0	0.527	0.207
3,300-9,999	5,016.5	1.0	1.532	0.630
10,000-49,999	25,611.0	1.0	7.541	3.327
50,000-99,999	-	1.0	-	-
100,000-999,999	169,846.0	1.0	47.930	22.937
1,000,000+	-	1.0	-	-
Disinfecting Primarily Ground Water NTNCWSs				
	X	**Y**	**$Z = 0.39639\ X^{0.97708}/1000Y$**	**$AA = 0.06428\ X^{1.07652}/1000Y$**
<100	50.4	1.0	0.018	0.004
100-499	226.1	1.0	0.079	0.022
500-999	672.7	1.0	0.230	0.071
1,000-3,299	1,552.1	1.0	0.520	0.175
3,300-9,999	5,153.4	1.0	1.679	0.637
10,000-49,999	20,764.4	1.0	6.554	2.856
50,000-99,999	66,000.0	1.0	20.286	9.918
100,000-999,999	110,000.0	1.0	33.417	17.188
1,000,000+	-	1.0	-	-

Note: Formulas may not produce exact results due to independent rounding (average people per plant includes fractions).

Source: Equations relating mean population to flow are from the Baseline Handbook (USEPA 2001c).

X is the total population for the size category (Exhibit 3.3, column Q) divided by the total number of systems for the size category (Exhibit 3.2, column V).

Comparable analyses relating average daily and design flow to population was not performed for the NTNCWSs. Other drinking water rules have evaluated flows for NTNCWSs according to service categories (e.g., schools, restaurants, hotels, industry) instead of size. EPA considered using this method for evaluating NTNCWSs for the Stage 2 DBPR, but decided against it for the following reasons:

- Service category flows are based on mean population served for all systems in that category, regardless of source water type. EPA expects that surface water and GWUDI sources would be more prevalent in larger NTNCWSs, but has no basis for developing revised population estimates for each service category by source.

- The prediction of treatment technology selection in Chapter 7 is a function of population served and does not directly apply to service categories that may include a wide range of water system sizes and flows (e.g., schools can be very small local buildings or metropolitan high schools).

EPA, therefore, applied the CWS regression equations to NTNCWSs, recognizing that this may over-estimate flows and, therefore, costs. This over-estimation is addressed as part of the uncertainties summarized in section 3.8. Note that because the ratio of plants per system was assumed to be 1:1 for all NTNCWSs, plant flows equal system flows. Mean plant flows for CWSs and NTNCWSs may differ from each other because of the difference in mean population per plant within each size category.

3.4.4 Number of Households Served

The number of households served by CWSs expected to be subject to the Stage 2 DBPR is estimated by dividing the population for each system size category by the average number of people per household (2.59) (U.S. Census Bureau 2001). As shown in Exhibit 3.5, PWSs serve about 102 million households.

Exhibit 3.5 Number of Households Subject to the Stage 2 DBPR

System Size (Population Served)	Number of Households Served	
	Linked, Primarily Surface Water	Primarily Disinfecting Ground Water
<100	7,632	141,789
100-499	69,666	1,049,329
500-999	122,745	1,116,772
1,000-3,299	790,449	3,370,510
3,300-9,999	2,261,402	5,330,948
10,000-49,999	9,001,317	10,809,909
50,000-99,999	6,419,042	3,704,009
100,000-999,999	25,239,019	9,122,621
1,000,000+	21,477,972	1,518,739
Total	65,389,243	36,164,625
National Total	**101,553,868**	

Note: Detail may not add due to independent rounding.
Source: Calculated by dividing the total population served (Exhibit 3.3, column Q) by 2.59, the average number of people per household (U.S. Census Bureau 2001).

Note: Detail may not add due to independent rounding.

Source: Calculated by dividing the total population served (Exhibit 3.3, column Q) by 2.59, the average number of people per household (U.S. Census Bureau 2001).

3.5 Influent Water Quality Characterization

3.5.1 Summary of Available Influent Water Quality Data

Predictions of compliance forecasts assume that a system will choose a treatment technology for the Stage 2 DBPR that best addresses its water quality improvement needs. The quality of the source water plays a key role in evaluating treatment alternatives to meet regulatory requirements. This section provides an overview of influent water quality on a national level.

Exhibit 3.6 summarizes the influent water quality data that were collected under the ICR for large surface and ground water systems. These data represent the parameters that most affect DBP formation in disinfected waters. The median, 90th percentile, and range provide some insight into the variability in plant means among all large surface and ground water plants.

Monthly plant data collected during the last 12 months of the ICR collection period (January 1998–December 1998) were averaged to estimate a "plant-mean" value for each plant. Only the last 12 months were evaluated because they appear to be of higher quality than data collected during the first 6 months of the survey. In addition, using all 18 months of data could skew results (data from the last 2 quarters of the year would be counted twice).

ICR summary data in Exhibit 3.6 are grouped according to "Ground" or "Surface" water plants types. This designation is based on the source water type reported by the plant for each month from July 1997 to December 1998. The types of sources recorded were surface water, ground water, mixed, or purchased. Most plants reported on one source type for all months, but some plants reported surface water for some months and mixed for others. These plants were considered surface water plants. One ground water plant reported ground water for some months and mixed for others—this plant was considered a ground water. Analyses of all plants includes "blended," "mixed," and "purchased" plant-types from the ICR database. These plant types make up a small portion (less than 10 percent) of the total—most ICR plants are categorized as either surface or ground water plants.

Data for these influent water quality parameters were part of the input data for SWAT. They were also used by the Delphi Group, a group of industry experts gathered to advise EPA on technical issues surrounding the rule, and the small-system experts (both for surface water and ground water) to assess treatment alternatives. For a complete characterization and discussion of these parameters, see Chapter 3 of the Occurrence Assessment (USEPA 2005k).

Exhibit 3.6 ICR Large System Influent Water Quality Parameters—Summary of Pre-Stage 1 Plant-Mean Data

Parameter	Source Type	Number of Plants	Mean of Plant Means	Median of Plant Means	90th Percentile of Plant Means	Range of Plant Means
Alkalinity (mg/L as $CaCO_3$)	Surface	325	81	79	161	2.75 – 272
	Ground	119	160	157	265	1.58 – 415
Bromide (mg/L)	Surface	320	0.055	0.027	0.115	<0.02 – 1.325
	Ground	118	0.103	0.066	0.190	<0.02 – 1.325
pH	Surface	323	7.6	7.7	8.2	6.0 – 8.5
	Ground	118	7.3	7.4	8.0	4.1 – 8.8
Temperature (°C)	Surface	334	16.0	16.1	20.7	3.7 – 27.7
	Ground	121	19.9	20.1	26.3	9.5 – 30.5
Total Hardness (mg/L as $CaCO_3$)	Surface	315	118	110	251	3.1 – 501
	Ground	115	194	197	352	3.6 – 778
Total Organic Carbon (mg/L as C)	Surface	307	3.14	2.71	5.29	<0.7 – 21.4
	Ground	103	1.46	0.18	3.36	<0.7 – 16.1
Turbidity (Nephelometric Turbidity Units)	Surface	316	18.6	6.7	34.1	0.06 – 529
	Ground	115	1.3	0.2	2.6	0.03 – 38.7
UV_{254} Absorbance (cm^{-1})	Surface	306	0.098	0.079	0.176	<0.009 – 0.880
	Ground	104	0.062	0.009	0.266	<0.009 – 0.606

Note: The maximum surface water bromide mean value, 3.13 milligrams per liter (mg/L), is not shown. This value was calculated based on a one-month reported bromide concentration of 28 mg/L, which EPA assumes to be a reporting error. (Laboratories often report bromide values in µg/L, rather than mg/L; this value may not have been converted to mg/L.) All the other values for that plant in the last 12 months of the ICR were below 0.1 mg/L.

Source: ICR AUX1 database (USEPA 2000h). Represents distribution of plant-mean data as calculated using ICR monthly data from the last 12 months of the ICR (January 1998 - December 1998). Only plants with reported data for at least 9 of the 12 months are included in this summary table. Does not include blended, mixed, or purchased plants.

A key influent water quality parameter related to Stage 2 DBPR compliance is TOC. TOC is a measure of organic content in the water and is generally a good indicator of the concentrations of total trihalomethanes (TTHM) and haloacetic acid (HAA5) precursors. The distribution of plant-mean TOC concentrations for plants with surface water sources covers a large range (from 0 to 21.4 mg/L (Exhibit 3.6)); however, 90 percent of the plants had mean TOC concentrations below 5.3 mg/L. Exhibit 3.7 shows the distribution of plant-mean TOC concentrations for surface water and ground water plants for the subset of plants shown in Exhibit 3.6. For ground water plants, 70 percent had mean TOC concentrations below 1 mg/L; the highest values were close to those for surface water plants. A large percentage of ICR ground water plants (approximately 25 percent) are located in Florida, where high levels of TOC occur in ground water.

Bromide in source water can affect the amount and type of DBPs formed, shifting the distribution of DBPs more to the brominated species. Also, bromide can react with ozone and chlorine dioxide to form bromate, another byproduct of concern. As shown in Exhibit 3.6, most of the plant-mean bromide levels are relatively low (the 90th percentiles were 0.122 and 0.190 mg/L for surface water and ground water sources, respectively). Exhibit 3.8 shows the distribution of mean bromide concentrations for large surface water and ground water plants.

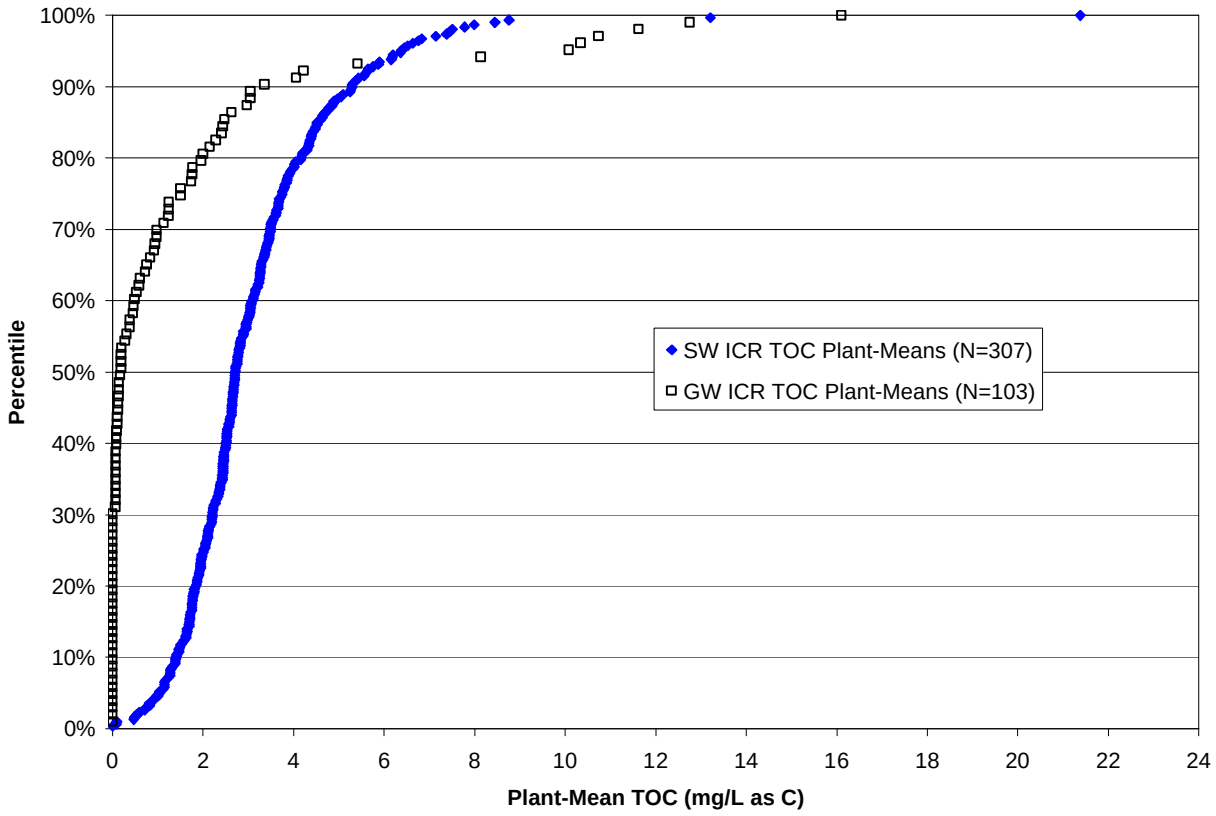
There is no extensive data set similar to the ICR that provides comparable influent water quality data for medium and small systems. Therefore, as noted in section 3.2, several alternative data sources were used to characterize these systems and compare their water quality to the large systems. These data sources include the ICR supplemental survey (ICRSS), NRWA data, AWWA WATER:\Stats data, and data from individual states. The ICRSS is a survey meant to compliment the ICR data set. It is a survey of raw source water quality and DBP concentrations from 40 random plants each from the small, medium, and large size categories. The NRWA surveyed 117 random small plants nationwide and determined treatment process, source water quality, and DBP concentrations. The WATER:\STATS database was compiled by AWWA and contains source water quality, treatment processes, and DBP concentrations for 872 member plants of mostly medium and large size categories. The State data include DBP monitoring data from 10 States representing 562 small surface water systems and 2,336 small ground water systems. The Occurrence Document (USEPA 2005k) provides an overview of each alternative data set and compares source water quality for medium and small systems. Exhibit 3.9 provides a summary of influent water quality data from these sources for medium and small surface and ground water systems. Appendices A and B provide additional detail regarding influent water quality data that are relevant to compliance forecast analyses for surface and ground water systems, respectively.

3.5.2 Regional Differences in Water Quality

EPA evaluated ICR data for surface and ground water systems to determine if there were differences in influent water quality among regions. Exhibits 3.10 and 3.11 show the range of average TOC concentrations by State for surface and ground water systems, respectively, using ICR data. Exhibit 3.12 shows average TOC concentrations by State for ground water systems using Ground Water Supply Survey (GWSS) data. Surface water systems did not exhibit any notable regional trends; however, ICR data and GWSS data show that Florida has very high TOC concentrations compared to other States. Florida also has the largest proportion of large ground water systems of all the States. The ICR Ground Water Delphi Group estimated that, of the large and medium ground water plants that will need to make changes to comply with the Stage 2 DBPR (which includes a requirement for the IDSE),

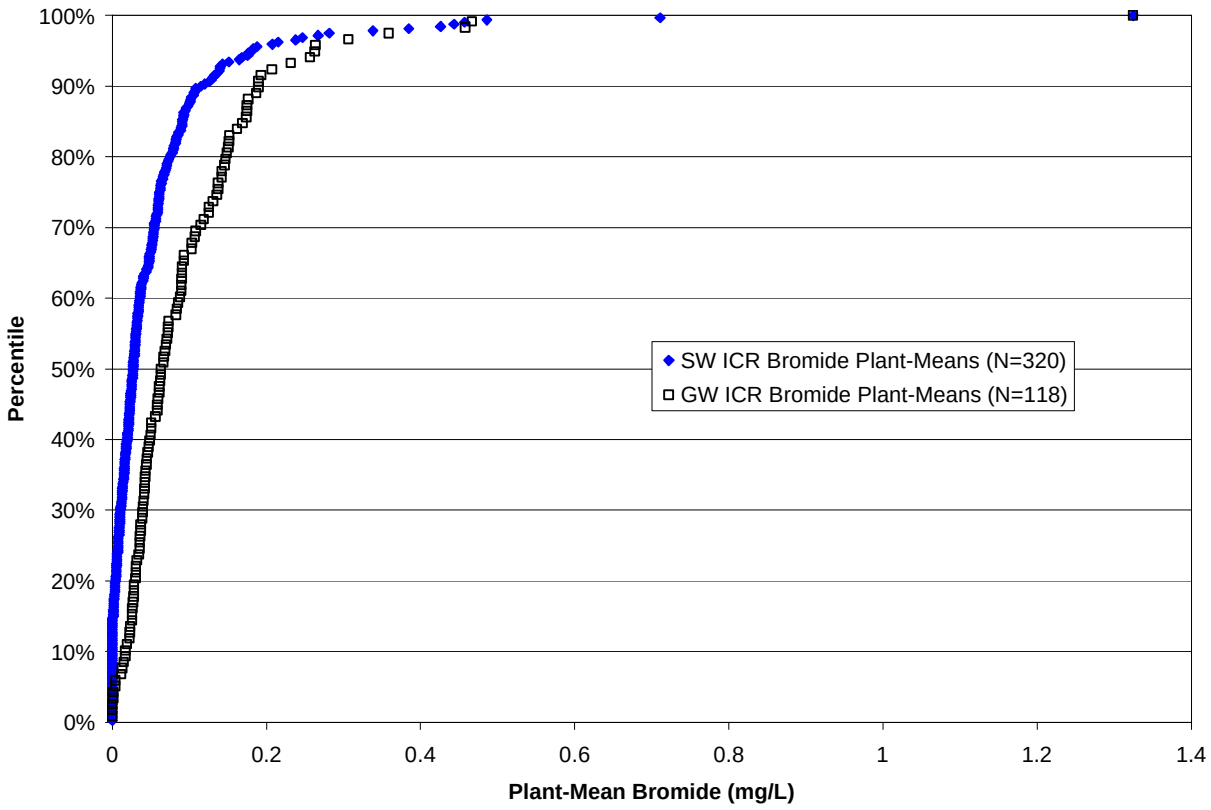
more than 80 percent are in Florida (see Appendix B, Exhibit B.4 for compliance forecast data on ground water systems).

Exhibit 3.7 Cumulative Distribution of TOC in Influent Water of Large System ICR Plant-Mean Data



Source: ICR AUX1 database (USEPA 2000h).

Exhibit 3.8 Cumulative Distribution of Bromide in Influent Water of Large System ICR Plant-Mean Data



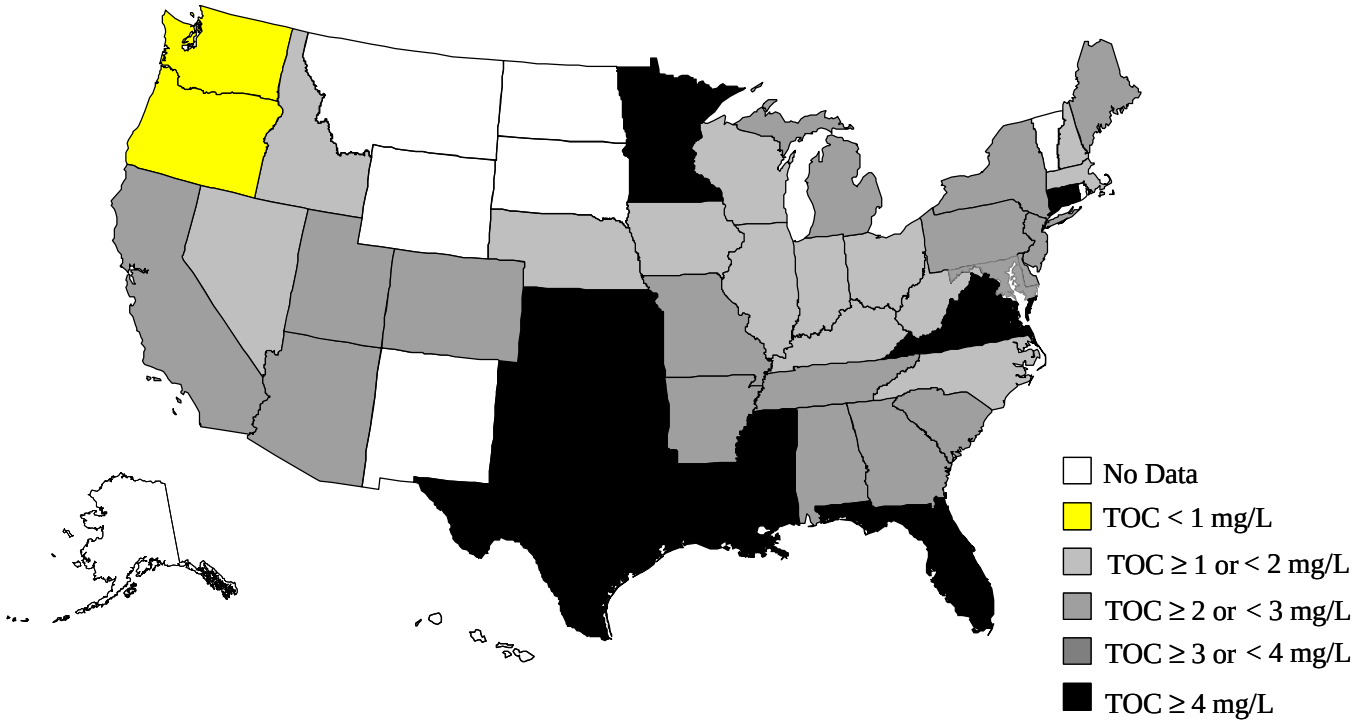
Source: Each data point in the distribution represents the mean value of monthly data collected at a single plant over a 12-month period (January 1998–December 1998). Only plants with reported data for at least 9 of the 12 months are included in this summary table (USEPA 2000h).

Exhibit 3.9 Medium and Small System Influent Water Quality Parameters– Summary of Pre-Stage 1 Plant-Mean Data

Data Source/Size Category	N	Mean of Plant-Means	Median of Plant-Means	90th Percentile of Plant-Means	Range of Plant-Means
Source Water Alkalinity (mg/L as $CaCO_3$)					
NRWA Small Surface Water (SW) Plants	95	81	74	146	0 - 281
ICR Supplemental Survey (ICR SS) Medium SW Plants	40	82	74	159	4.8 - 240
ICR SS Small SW Plants	38	66	55	123	4.4 - 249
Source Water Bromide (mg/L)					
NRWA Small SW Plants	95	0.063	0.021	0.107	0-1.72
ICR SS Medium SW Plants	40	0.050	0.016	0.092	0 - 0.53
ICR SS Small SW Plants	38	0.02	0	0.044	0 - 0.27
Source Water pH					
NRWA Small SW Plants	78	7.3	7.4	8.1	3.8 - 8.8
ICR SS Medium SW Plants	40	7.6	7.6	8.2	5.9 - 8.4
ICR SS Small SW Plants	36	7.3	7.4	8.0	5.8 - 8.3
Source Water TOC (mg/L as C)					
NRWA Small SW Plants	96	3.0	2.6	5.3	0.3 - 9.0
ICR SS Medium SW Plants	40	3.6	3.7	5.5	0.2 - 7.9
ICR SS Small SW Plants	38	2.4	2.1	4.5	0.1 - 7.1
WATER:\STATS Medium SW Plants	102	5.6	3.2	6.4	0 - 200
WATER:\STATS Medium GW Plants	51	2.3	0.79	7.0	0 - 25
Source Water Turbidity (NTU)					
NRWA Small SW Plants	76	7.8	4.1	18	0.1 - 65
ICR SS Medium SW Plants	40	13	5.9	33	1 - 103
ICR SS Small SW Plants	36	6.2	3.5	13	0.3 - 43
Source Water UV-254 (cm^{-1})					
NRWA Small SW Plants	96	0.082	0.075	0.127	0.01 - 0.23
ICR SS Medium SW Plants	40	0.093	0.083	0.171	0.03 - 0.21
ICR SS Small SW Plants	38	0.074	0.051	0.113	0.02 - 0.44

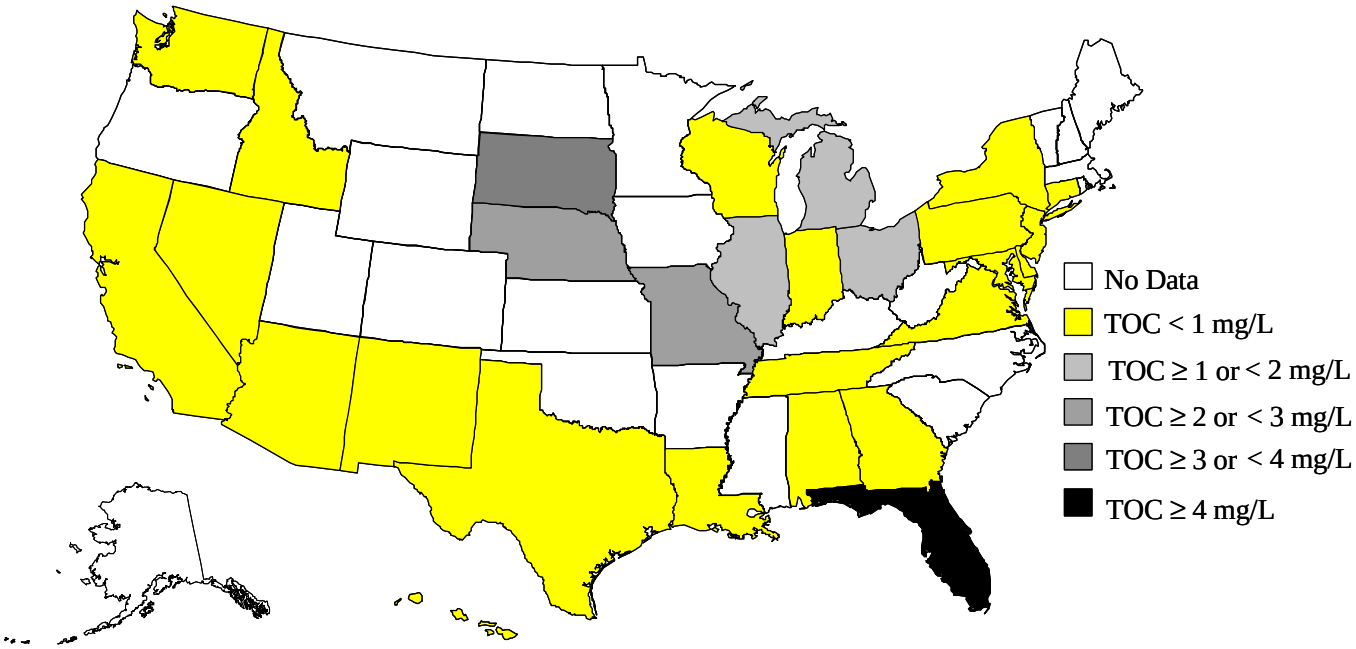
Note: ICR SS data are the plant-means for plants that took at least three-fourths of the total possible samples for each parameter. Only plants that had both a Winter and Summer sample are included in the NRWA data for this analysis.

Exhibit 3.10 Influent Water TOC Distribution for ICR Surface Water Systems



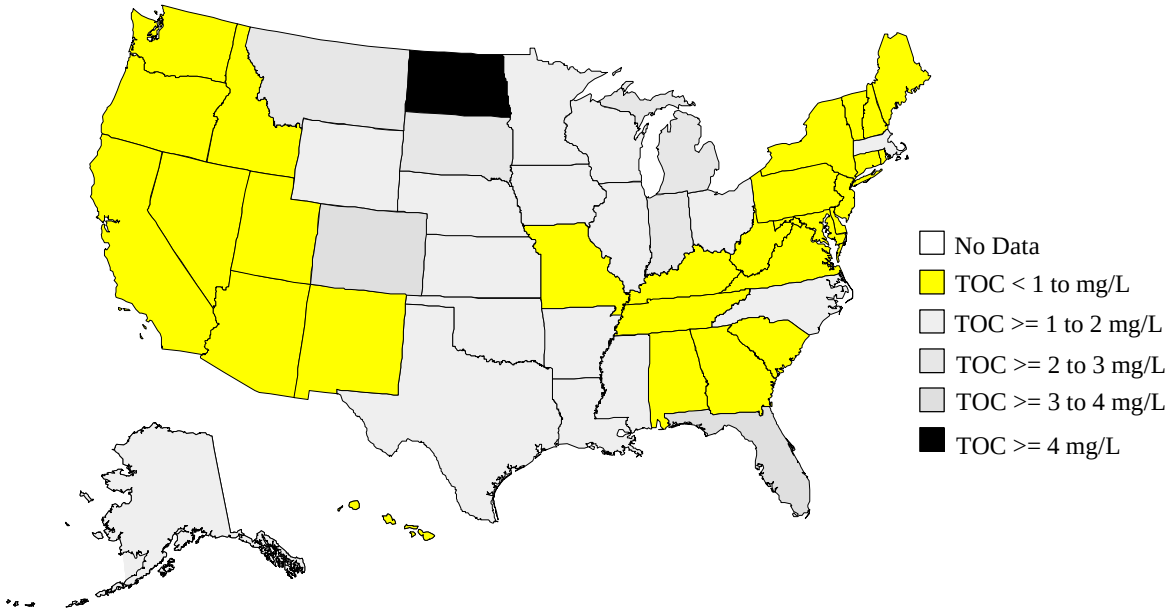
Source: ICR AUX1 Database (USEPA 2000h); mean of all plant-means for each State.

Exhibit 3.11 Influent Water TOC Distribution for ICR Ground Water Systems



Source: ICR AUX1 Database (USEPA 2000h); mean of all plant-means for each State.

Exhibit 3.12 Influent Water TOC Distribution for Ground Water Systems Derived from the Ground Water Supply Survey



Source: Ground Water Supply Survey (USEPA 1983)

3.6 Treatment Characterization for the Pre-Stage 1 Baseline

This section summarizes treatment conditions for the pre-Stage 1 baseline estimate of treatment technologies-in-place for the baseline. Chapter 5 provides further detail on treatment technologies and compliance forecast methodology used in this EA.

Although cost analyses in Chapter 7 are performed for each of the nine system size categories separately, treatment characterizations are predicted according to the following aggregated categories by population served:

- Small systems
    - Serving fewer than 100 people
    - Serving 100 to 999 people
    - Serving 1,000 to 9,999 people
- Medium systems—serving 10,000 to 99,999 people
- Large systems—serving 100,000 or more people

Small systems were stratified by the three population categories shown above to represent differences in the number of systems needing to change treatment technologies and the technology options available to each category. The treatment characterizations presented here and in Chapter 7 show the nine population size categories used for costing, but present one compliance forecast (as a percentage of the total baseline number of plants) for each of the population size categories listed above.

Exhibits 3.13 and 3.14 summarize the pre-Stage 1 DBPR baseline *treatment technologies in place* for surface and ground water treatment plants, respectively[6]. For plants in large and medium ground water systems, ICR treatment data were used to derive the estimated percent of plants using each treatment technology as no other model or data source exists to characterize treatment technologies. For plants in large and medium surface water systems, SWAT-predicted results from the "initial plant run" (USEPA 2001b) are used to characterize the percent of plants using each treatment technology in Exhibit 3.13. SWAT-predicted results were used instead of available ICR-observed data to allow for consistent comparison of pre-Stage 1 data to modeled pre-Stage 2 and post-Stage 2 data. (If observed data were used for pre-Stage 1 treatment technology-in-place estimates, differences between pre-Stage 1 and pre-Stage 2 results would represent potential inconsistencies in observed vs. predicted data, not just the expected treatment technology change from pre-Stage 1 to pre-Stage 2. The SWAT Model uses a subset of the ICR plants, so while percentages are similar, they are not exact.) In addition, the SWAT initial plant run is used to calculate DBP reductions from pre-Stage 1 to post-Stage 1 for use in the benefits models.

For all small systems, the only significant use of advanced treatment technologies was reported in the NRWA database for small surface water systems (approximately 3.6 percent are estimated to be using microfiltration/ultrafiltration (MF/UF), as shown in Exhibit 3.14). The percent using each treatment technology is based on evaluation of CWS data; EPA assumed that NTNCWSs use similar treatment technologies for the size categories shown.

[6]As described in Appendix A, the treatment technologies used to characterize the pre-Stage 1and pre-Stage 2 baselines are different than those presented in the Stage 1 RIA. New tools to characterize treatment technologies-in-place have been made available since the Stage 1 DBPR was promulgated, notably the SWAT Model.

Exhibit 3.13a Pre-Stage 1 DBPR Treatment Technologies-in-Place for CWS Surface Water Plants

System Size (Population Served)	No Advanced Treatment Technologies[1] CL2		No Advanced Treatment Technologies[1] CLM		Chlorine Dioxide				UV				Ozone				MF/UF				GAC10			
					CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM	
	A		B		C		D		E		F		G		H		I		J		K		L	
<100	96.4%	346	0.0%	0													3.6%	13	0.0%	0				
100-499	96.4%	739	0.0%	0	0.0%	0	0.0%	0					0.0%	0	0.0%	0	3.6%	28	0.0%	0				
500-999		466		0		0	0.0%	0						0		0		17		0				
1,000-3,299	96.4%	1,089	0.0%	0	0.0%	0	0.0%	0					0.0%	0	0.0%	0	3.6%	41	0.0%	0				
3,300-9,999		1,213		0		0	0.0%	0						0		0		45		0				
10,000-49,999	53.4%	689	31.6%	408	5.1%	65	3.0%	39					3.2%	42	1.9%	25	0.2%	3	0.1%	2	0.9%	12	0.5%	7
50,000-99,999		309		183		29		17						19		11		1		1		5		3
100,000-999,999	53.4%	326	31.6%	193	5.1%	31	3.0%	18					3.2%	20	1.9%	12	0.2%	1	0.1%	1	0.9%	6	0.5%	3
=1,000,000		39		23		4		2						2		1		0		0		1		0
Total Plants, %	79.6%	5,216	12.3%	808	2.0%	129	1.2%	77					1.3%	82	0.7%	49	2.3%	150	0.1%	3	0.4%	24	0.2%	14

(Population Served)	GAC10 + AD				GAC20				GAC20 + AD				Membranes				TOTAL			
	CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM	
	M		N		O		P		Q		R		S		T		A+C+E+G+I+K+M+O+Q+S		B+D+F+H+J+L+N+P+R+T	
<100					0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	359	0.0%	0
100-499					0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	767	0.0%	0
500-999						0		0		0		0		0		0		483		0
1,000-3,299					0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	1,129	0.0%	0
3,300-9,999						0		0		0		0		0		0		1,258		0
10,000-49,999	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	62.8%	811	37.2%	481
50,000-99,999		0		0		0		0		0		0		0		0		364		216
100,000-999,999	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	62.8%	383	37.2%	227
=1,000,000		0		0		0		0		0		0		0		0		46		27
Total Plants, %	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	85.5%	5,601	14.5%	951

Note: Detail may not add to totals due to independent rounding.

[1]"No Adv" includes conventional, non-conventional, and softening plants.

Source: Surface water systems serving <10,000 people: National Rural Water Survey (USEPA 2001a). Surface water systems serving 10,000 or more people: SWAT initial plant run (USEPA 2001b).

Percentage using chloramine is taken from the Occurrence Document (USEPA 2005k) and ICR AUX1 data (USEPA 2000h).

Exhibit 3.13b Pre-Stage 1 DBPR Treatment Technologies-in-Place for NTNCWS Surface Water Plants

System Size (Population Served)	No Advanced Treatment Technologies[1] CL2		No Advanced Treatment Technologies[1] CLM		Chlorine Dioxide				UV				Ozone				MF/UF				GAC10			
					CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM	
	A		B		C		D		E		F		G		H		I		J		K		L	
<100	96.4%	218	0.0%	0													3.6%	8	0.0%	0				
100-499	96.4%	301	0.0%	0	0.0%	0	0.0%	0					0.0%	0	0.0%	0	3.6%	11	0.0%	0				
500-999		102		0		0	0.0%	0						0		0		4		0				
1,000-3,299	96.4%	89	0.0%	0	0.0%	0	0.0%	0					0.0%	0	0.0%	0	3.6%	3	0.0%	0				
3,300-9,999		24		0		0	0.0%	0						0		0		1		0				
10,000-49,999	53.4%	3	31.6%	2	5.1%	0	3.0%	0					3.2%	0	1.9%	0	0.2%	0	0.1%	0	0.9%	0	0.5%	0
50,000-99,999		0		0		0		0						0		0		0		0		0		0
100,000-999,999	53.4%	1	31.6%	0	5.1%	0	3.0%	0					3.2%	0	1.9%	0	0.2%	0	0.1%	0	0.9%	0	0.5%	0
=1,000,000		0		0		0		0						0		0		0		0		0		0
Total Plants, %	96.1%	737	0.2%	2	0.0%	0	0.0%	0					0.0%	0	0.0%	0	3.6%	27	0.0%	0	0.0%	0	0.0%	0
(Population Served)	GAC10 + AD				GAC20				GAC20 + AD				Membranes				TOTAL							
	CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM		CL2				CLM			
	M		N		O		P		Q		R		S		T		A+C+E+G+I+K+M+O+Q+S				B+D+F+H+J+L+N+P+R+T			
<100					0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	226			0.0%	0		
100-499					0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	312			0.0%	0		
500-999						0		0		0		0		0		0		106				0		
1,000-3,299					0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	92			0.0%	0		
3,300-9,999						0		0		0		0		0		0		25				0		
10,000-49,999	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	62.8%	3			37.2%	2		
50,000-99,999		0		0		0		0		0		0		0		0		0				0		
100,000-999,999	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	62.8%	1			37.2%	0		
=1,000,000		0		0		0		0		0		0		0		0		0				0		
Total Plants, %	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	99.7%	765			0.3%	2		

Note: Detail may not add to totals due to independent rounding.

[1]"No Adv" includes conventional, non-conventional, and softening plants.

The NTNCWS technology distribution is assumed to be the same as the CWS technology distribution presented in Exhibit 3.13a.

Source: Surface water systems serving <10,000 people: National Rural Water Survey (USEPA 2001a). Surface water systems serving 10,000 or more people: SWAT initial plant run (USEPA 2001b).

Percentage using chloramine is taken from the Occurrence Document (USEPA 2005k) and ICR AUX1 data (USEPA 2000h).

Exhibit 3.14a Pre-Stage 1 DBPR Treatment Technologies-in-Place for CWS Ground Water Plants

System Size (Population Served)	No Adv[1] CL2		No Adv[1] CLM		UV CL2		UV CLM		Ozone CL2		Ozone CLM		GAC20 CL2		GAC20 CLM		Membranes CL2		Membranes CLM		TOTAL USING CL2		TOTAL USING CLM	
	A		B		C		D		E		F		G		H		I		J		K = B + D + F + H + J		L = B+D+F+H+J	
<100	100.0%	6,423	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	6,423	0.0%	0
100-499	100.0%	15,242	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	15,242	0.0%	0
500-999		6,093		0		0		0		0		0		0		0		0		0		6,093		0
1,000-3,299	100.0%	7,587	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	7,587	0.0%	0
3,300-9,999		5,030		0		0		0		0		0		0		0		0		0		5,030		0
10,000-49,999	92.3%	4,968	5.4%	290					0.8%	41	0.0%	0	0.0%	0	0.0%	0	1.5%	83	0.0%	0	94.6%	5,093	5.4%	290
50,000-99,999		661		39						6		0		0		0		11		0		677		39
100,000-999,999	92.3%	847	5.4%	49					0.8%	7	0.0%	0	0.0%	0	0.0%	0	1.5%	14	0.0%	0	94.6%	869	5.4%	49
?1,000,000		25		1						0		0		0		0		0		0		26		1
Total Plants	98.9%	46,878	0.8%	379	0.0%	0	0.0%	0	0.1%	54	0.0%	0	0.0%	0	0.0%	0	0.2%	108	0.0%	0	99.2%	47,040	0.8%	379

Note: Detail may not add to totals due to independent rounding

[1]"No Adv" includes conventional, non-conventional, and softening plants.

Source: Ground water systems serving <10,000 people - limited data available. Assumed only cholrine usage and no advanced technologies; Ground water systems serving 10,000 or more people - based on ICR data for 130 large GW plants.

Exhibit 3.14b Pre-Stage 1 DBPR Treatment Technologies-in-Place for NTNCWS Ground Water Plants

System Size (Population Served)	No Adv[1] CL2		No Adv[1] CLM		UV CL2		UV CLM		Ozone CL2		Ozone CLM		GAC20 CL2		GAC20 CLM		Membranes CL2		Membranes CLM		TOTAL USING CL2		TOTAL USING CLM	
	A		B		C		D		E		F		G		H		I		J		K = B + D + F + H + J		L = B+D+F+H+J	
<100	100.0%	2,493	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	2,493	0.0%	0
100-499	100.0%	2,129	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	2,129	0.0%	0
500-999		589		0		0		0		0		0		0		0		0		0		589		0
1,000-3,299	100.0%	247	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	247	0.0%	0
3,300-9,999		21		0		0		0		0		0		0		0		0		0		21		0
10,000-49,999	92.3%	3	5.4%	0					0.8%	0	0.0%	0	0.0%	0	0.0%	0	1.5%	0	0.0%	0	94.6%	3	5.4%	0
50,000-99,999		0		0						0		0		0		0		0		0		0		0
100,000-999,999	92.3%	0	5.4%	0					0.8%	0	0.0%	0	0.0%	0	0.0%	0	1.5%	0	0.0%	0	94.6%	0	5.4%	0
=1,000,000		0		0						0		0		0		0		0		0		0		0
Total Plants	100.0%	5,483	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	100.0%	5,483	0.0%	0

Note: Detail may not add to totals due to independent rounding

The NTNCWS technology distribution is assumed to be the same as the CWS technology distribution presented in Exhibit 3.14a.

[1]"No Adv" includes conventional, non-conventional, and softening plants.

Source: Ground water systems serving <10,000 people - limited data available. Assumed only cholrine usage and no advanced technologies; Ground water systems serving 10,000 or more people - based on ICR data for 130 large GW plants.

3.7 DBP Occurrence for the Pre-Stage 1 Baseline

For pre-Stage 1 DBPR conditions, observed DBP data are available from the ICR for large systems; and from the NRWA survey, WATER:\STATS, and other data sources for medium and small systems (see section 3.2 for a summary of data sources). The pre-Stage 1 DBPR baseline DBP occurrence is also predicted using SWAT. In Chapter 5, SWAT-modeled DBP occurrence is used instead of observed (ICR) values so that any changes shown in the analysis would be a result of treatment technology changes and operating conditions and not differences between observed and modeled data.

Section 3.7.1 provides background information describing the ICR and SWAT DBP data used in this EA. Section 3.7.2 summarizes pre-Stage 1 DBP occurrence data for large surface water systems. Pre-Stage 1 DBPR occurrence levels for large ground water systems are provided in section 3.7.3. DBP occurrence for medium systems is discussed in section 3.7.4, followed by presentation of small system data in section 3.7.5. Section 3.8 describes the uncertainties in observed and predicted DBP data.

3.7.1 Description of ICR and SWAT DBP Data

3.7.1.1 ICR DBP Data

The analysis of ICR DBP data in this EA is consistent with the methodology used in the Occurrence Document (USEPA 2005k), Chapter 5, and Appendix A. A brief description of the data and assumptions used in the analyses are provided below.

Sampling Period

Consistent with the influent water quality date summarized in Section 3.5, DBP data represent that last 12 months (four quarters) of the ICR collection period (January - December, 1998). Data collected appear to be of higher quality than data collected during the first 6 months of the survey. In addition, 6 quarters were not used because 2 quarters would be counted twice and could skew results

Plant Source Water Type

DBP data for ground and surface water plants are analyzed in this section. Consistent with influent water quality data described in Section 3.5, plant-source water type designation is based on the source water type reported by the plant for each month from July 1997 to December 1998. The types of sources recorded were surface water, ground water, mixed, or purchased. Most plants reported on one source type for all months, but some plants reported surface water for some months and mixed for others. These plants were considered surface water plants. One plant reported ground water for some months and mixed for others—this plant was considered a ground water plant.

Distribution System Sampling Locations

Quarterly TTHM and HAA5 data were collected at the following distribution system sampling locations (note that these locations are each associated with one ICR plant):

- *Average 1 (AVG 1) and Average 2 (AVG 2*)—two sample locations in the distribution system, each representing an approximate average residence time, as designated by the water system.

- *Distribution System Maximum (DS Maximum)*—the sample location in the distribution system that has the longest residence time, as designated by the water system.

- *Distribution System Equivalent Location (DSE)*—a sample location in the distribution system that has a known residence time, where no additional disinfectant has been added between the plant and sample location, and where there has been no blending with water from other plants.

Initial Plant Screening

All ICR plants (there are approximately 500 plants in the ICR database) were screened to ensure that at least 3 of 4 quarters have TTHM and HAA5 data for at least 3 of 4 distribution system locations. Note that the total number of plants that meet the minimum screening criteria (311 plants, of which 213 are surface water plants, 83 are ground water plants, and 15 are either blended, mixed, or purchased water plants) represents more than 60 percent of all large plants that participated in the ICR data collection effort.

The initial plant screening was done to minimize biases in RAA and LRAA calculations (e.g., LRAAs could be skewed if data from multiple quarters is missing). While the screening process is intended to reduce biases in data analysis, EPA recognizes that biases in the RAA and LRAA calculations may still exist. First, missing data points from locations may skew the quarterly average. For example, a plant with less than 3 of 4 quarters of data for the maximum residence time location (but having at least 3 of 4 quarters of data for all other locations, allowing it to be included in the analysis) would probably have an RAA that is skewed low. Second, missing quarterly data could skew the yearly average. For example, because higher DBP levels are typically seen during the warmest months, missing data in the warmest quarter may lower the annual average at that location. The screening criteria described above were selected to strike a balance between minimizing biases in RAA and LRAA calculations and maximizing the number of plants evaluated.

3.7.1.2 SWAT DBP Data

SWAT produces monthly estimates of DBP occurrence for surface water plants at two distribution system locations:

- *Distribution System Average (DS Average)*—theoretical location with average residence time (calculated by averaging the residence times reported by the water system for the four locations listed above).

- *Distribution System Maximum (DS Maximum)*—theoretical location with the maximum residence time (highest residence time reported for the four locations above).

Data from these locations are compared and summarized in subsequent sections.

3.7.2 Pre-Stage 1 DBP Occurrence for Large Surface Water Plants

Exhibit 3.15 summarizes the TTHM, HAA5, bromate, and chlorite occurrence for pre-Stage 1 baseline conditions. Pre-Stage 1 occurrence is shown for both observed ICR data and SWAT-predicted data. Exhibits 3.16 through 3.19 show the cumulative distributions of the same plant-mean and individual observations (monthly DBP concentrations) for SWAT data. SWAT plant-mean data represent plant-mean concentrations at the DS Average (average residence time) location. ICR plant-mean data represent the average of four distribution system locations (AVG1, AVG2, DSE, and DS Maximum). Bromate and chlorite data represent finished-water concentrations from both ICR and SWAT data sets, although ICR chlorite data show the maximum finished-water concentration at each plant, rather than the plant-mean. Statistical calculations of individual observations are for SWAT monthly data and ICR quarterly data.

Exhibit 3.15 reveals differences between SWAT-predicted and ICR observed data. Although the predicted SWAT data is calibrated to the national averages reported in the ICR, differences still exist because of differences in calculated versus actual residence times, uncertainty in the SWAT predictive equations, uncertainty in variability in the sampling data, and the fact that SWAT essentially follows a single slug of water through the distribution system, while the ICR measures instantaneous values of different parcels of water. See section 3.8 for a discussion of uncertainty in each data set.

3.7.3 Pre-Stage 1 DBP Occurrence in Large Ground Water Plants

ICR data were the only source of pre-Stage 1 DBP data for large ground water systems. There are limited or no data on bromate and chlorite, since these DBPs were monitored only by plants using ozone or chlorine dioxide, and only one ground water plant in the ICR used these disinfectants (USEPA 2005k). TTHM and HAA5 data for these plants are summarized in Exhibit 3.20. DBP levels in ground water are significantly less than in large surface water plants (see Exhibit 3.15); mean TTHM levels in ground water plants are less than half those in large surface water plants, compared to observed or modeled surface water data. Ground water data are more skewed than surface water data; there is a much bigger difference between the median and the mean values for ground water.

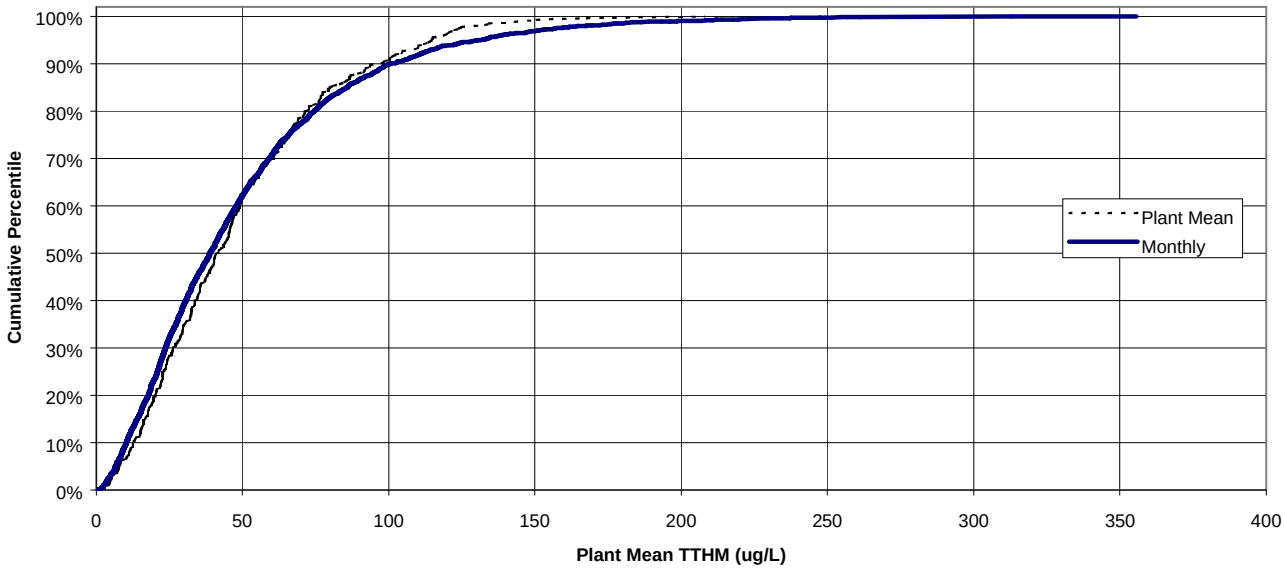
Exhibit 3.15 Summary of Pre-Stage 1 DBP Occurrence for Large Surface Water Plants, DS Average Data

Parameter	Plant-Mean Data					Individual Observations				
	N	Mean	Median	90th %ile	Range	N	Mean	Median	90th %ile	Range
TTHM (µg/L)										
Pre-Stage 1 (ICR)	213	42	40	70	0-117	3083	42	37	78	0-177
Pre-Stage 1 (SWAT)	273	49	44	90	3-207	2784	49	39	100	0-356
HAA5 (µg/L)										
Pre-Stage 1 (ICR)	213	29	24	53	0-116	3083	29	23	55	0-188
Pre-Stage 1 (SWAT)	273	36	29	70	1-146	2784	36	27	77	0-294
Bromate (µg/L) (Ozone plants only)										
Pre-Stage 1 (ICR)	14	2.6	2.2	5.4	0.02-7.2	157	2.6	1.9	6.7	<0.2-14.6
Pre-Stage 1 (SWAT)	15	6.3	1.8	19.6	0.2-28	156	6.1	1.9	18	0.1-62
Chlorite (µg/L) (Chlorine dioxide plants only)										
Pre-Stage 1 (ICR)	18	429	465	701	2.2-1105	192	435	435	830	<20-1719
Pre-Stage 1 (SWAT)	22	663	708	861	10-1483	177	636	700	1309	42-1680

Note: For TTHM and HAA5 data, SWAT data are from the DS Average location and ICR data are the average of four distribution system locations for the last 12 months of the ICR collection period (January 1998-December 1998). For bromate and chlorite data, finished water data from both SWAT and ICR are used. All SWAT data are based on monthly predicted observations, ICR TTHM and HAA5 data are based on quarterly observations, and ICR chlorite and bromate data are based on monthly observations. For ICR data, only individual observations used to calculate plant means are shown. For ICR data, only plants that have data for 3 of the last 4 quarters were included, and, for ICR TTHM and HAA5 data, only plants with at least 3 of the 4 required distribution system samples each quarter were included.

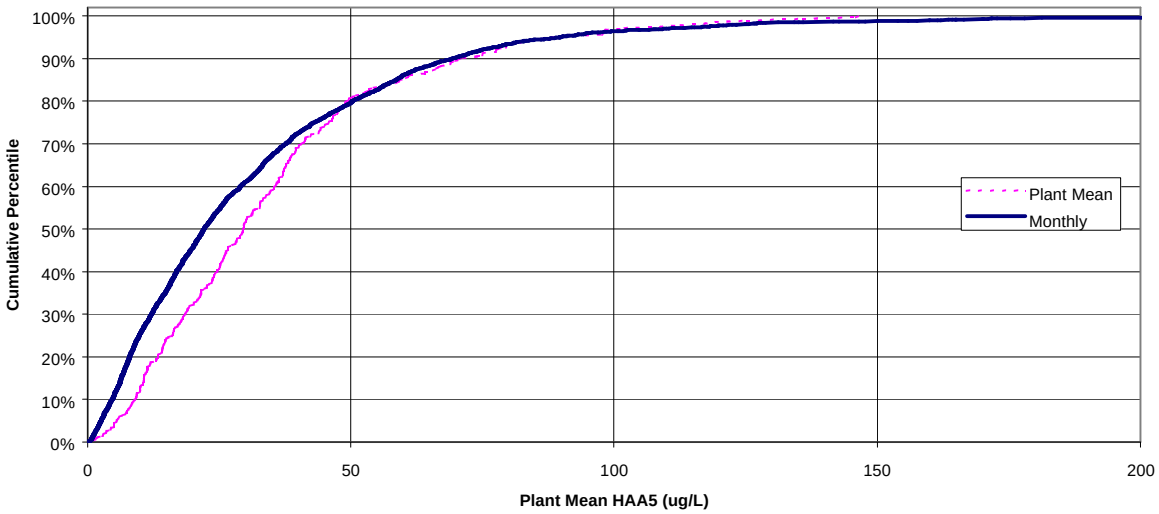
Sources: SWAT Initial Plant Run and Run 300 (USEPA 2001b); ICR AUX1 Database (USEPA 2000h), screened data.

Exhibit 3.16 Cumulative Distributions of TTHM Data Predicted by SWAT, Pre-Stage 1 (DS Average)



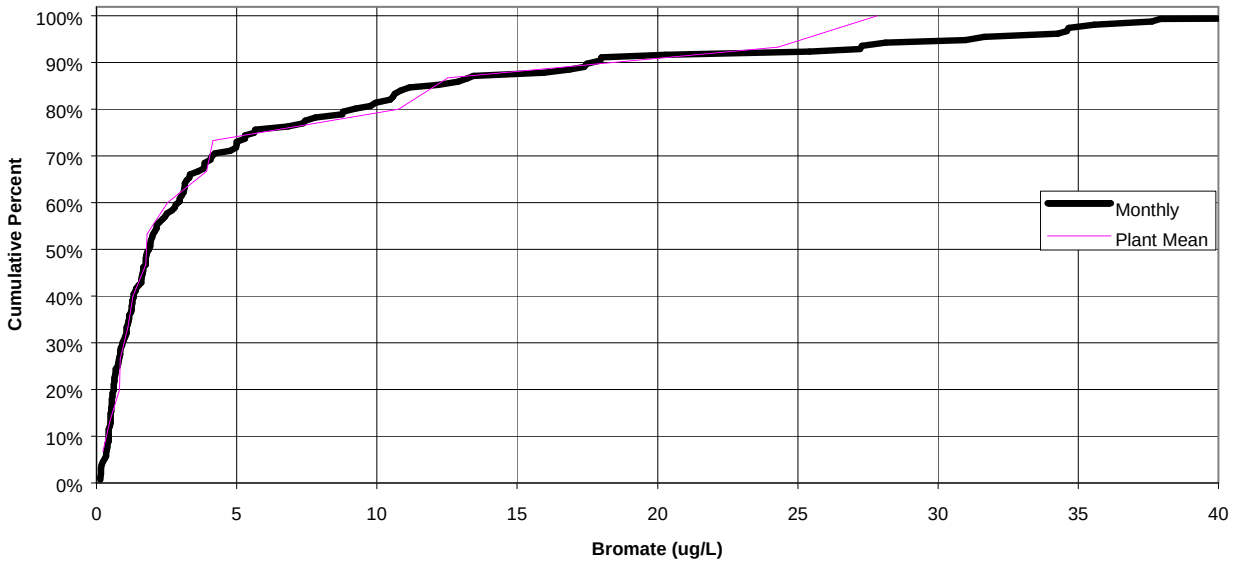
Note: DS Average data from SWAT
Source: SWAT Initial Plant Run (USEPA 2001b).

Exhibit 3.17 Cumulative Distributions of HAA5 Data Predicted by SWAT, Pre-Stage 1 (DS Average)



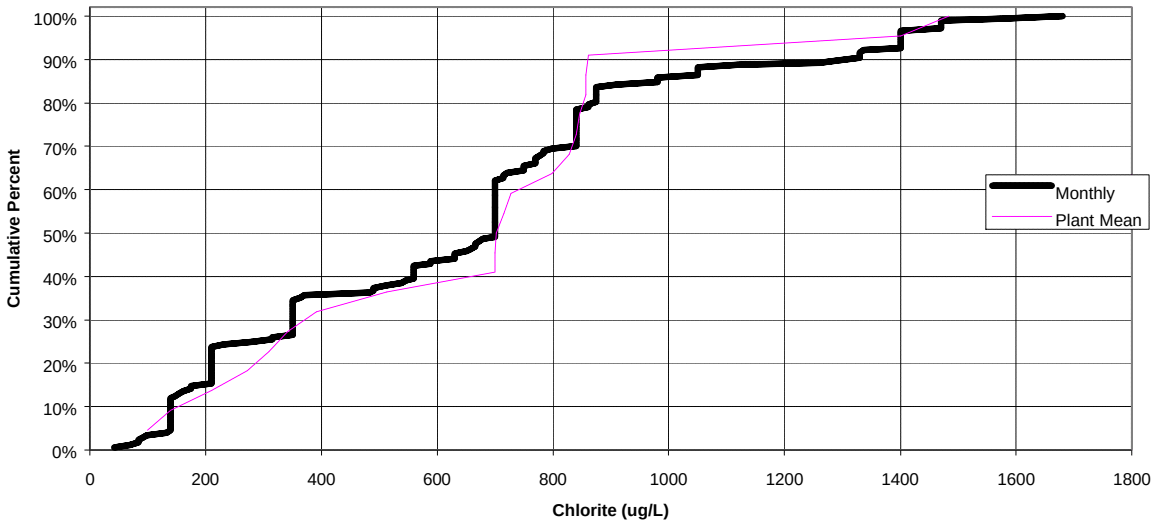
Note: DS Average data from SWAT
Source: SWAT Initial Plant Run (USEPA 2001b)

Exhibit 3.18 Cumulative Distributions of Bromate Data Predicted by SWAT, Pre-Stage 1 (Finished Water)



Note: Finished water data from SWAT for ozone plants only.
Source: SWAT Initial Plant Run (USEPA 2001b).

Exhibit 3.19 Cumulative Distributions of Chlorite Data Predicted by SWAT (Finished Water)



Note: Finished water data from SWAT. Includes chlorine dioxide plants only.
Source: SWAT Initial Plant Run (USEPA 2001b).

Exhibit 3.20 Summary of Pre-Stage 1 DBP Occurrence for Large Ground Water Plants, ICR Data

Parameter	Plant-Mean Data					Individual Observations				
	N	Mean	Median	90th %ile	Range	N	Mean	Median	90th %ile	Range
TTHM (µg/L)										
Pre-Stage 1	96	16.7	7.8	48	0-123	360	16	6.5	47	0-156
HAA5 (µg/L)										
Pre-Stage 1	99	8.9	2.7	25	0-71	373	8.8	2.0	28	0-96

Source: AUX1 database (USEPA 2000h),screened data.

3.7.4 Pre-Stage 1 DBP Occurrence for Medium Surface and Ground Water Plants

DBP occurrence data for medium ground water and surface water plants are limited. Plant-mean data on TTHM are available from WATER:\STATS, a database compiled by the American Water Works Association (AWWA 2000). Graphs of WATER:\STATS data in Appendix A show that DBP levels and water quality parameter levels are similar in medium and large surface water plants. Graphs for ground water in the Occurrence Document (USEPA 2005k) also show similarities between medium and large ground water plants. Therefore, EPA assumed that DBP occurrence for medium surface water and ground water plants is roughly equivalent to DBP occurrence for large surface water and ground water plants, respectively.

3.7.5 Pre-Stage 1 DBP Occurrences for Small Surface and Ground Water Plants

The small-system experts used NRWA survey data and TTHM data submitted to EPA from eight States to assess pre-Stage 1 DBP occurrence levels for small surface and ground water plants. Exhibit 3.21 summarizes the TTHM and HAA5 data from these two data sets.

Although Exhibit 3.21 shows that TTHM levels from the State data set are higher than the levels from the NRWA data set, NRWA data are considered more reliable and representative of national pre-Stage 1 DBP occurrence than the State surface water data. (For further characterization of small surface and ground water plant data sets, refer to Chapter 3 of the Occurrence Document (USEPA 2005k)). Therefore, NRWA observed data were used to describe occurrence for small surface water plants.

Exhibit 3.21 Summary of Pre-Stage 1 DBP Occurrence Data for Small Systems, DS Average Data

Parameter (source)	Plant-Mean Data					Individual Observations				
	N	Mean	Median	90th %ile	Range	N	Mean	Median	90th %ile	Range
TTHM (µg/L)										
Pre-Stage 1 (NRWA survey, SW systems)	96	83	62	168	0-328	192	83	63	162	0-446
Pre-Stage 1 (State data, SW systems)	562	99	66	215	0-687	N/A	N/A	N/A	N/A	N/A
Pre-Stage 1 (State data, GW systems)	2336	17	3	46	0-655	N/A	N/A	N/A	N/A	N/A
HAA5 (µg/L)										
Pre-Stage 1 (NRWA survey, SW systems)	96	45	35	83	0-262	192	45	34	88	0-381

Source: Pre-Stage 1 data: NRWA data (USEPA 2001a) are weighted averages of data at locations having average and maximum residence times in the distribution system. Average residence time data are weighted three times more than maximum residence time data to make data equivalent to DS Averages calculated for ICR TTHM and HAA5. NRWA plant-mean data include only those plants that had data for both sampling periods and for both distribution system locations. Only those individual observations that were used to calculate plant-mean data are shown here. State data (USEPA 2005k) are a mixed data set from eight States for surface water and seven States for ground water; N/A indicates no individual observations were available for this data set.

3.8 Uncertainties in Development of the Pre-Stage 1 Baseline

There is uncertainty in this baseline analysis due to measurement error and incomplete information that could result in either an over-estimate or under-estimate of the benefits and/or costs as presented in Chapters 6 and 7. These uncertainties were not modeled as the impacts of these uncertainties is unknown and EPA believes these uncertainties have less of an effect than those which are modeled in Chapters 6 and 7.

Exhibit 3.22 presents key uncertainties and an estimate of the effects that each may have on subsequent analyses. Note the effects on benefits and costs is unknown for most of the uncertainties listed in Exhibit 3.22. A detailed discussion of each uncertainty follows the exhibit.

Exhibit 3.22 Summary of Uncertainties Affecting Stage 2 DBPR Baseline Estimates

Uncertainty	Section Where Estimates are Presented	Effect on Benefit Estimate			Effect on Cost Estimates		
		Under-estimate	Over-estimate	Unknown Impact	Under-estimate	Over-estimate	Unknown Impact
Uncertainty in baseline data inputs used to generate the industry baseline (SDWIS and 1995 CWSS data)	3.4			X			X
CWS flow equations for NTNCWSs	3.4.3	No impact on benefits				X	
Uncertainty in use of chloramines and advanced treatment technologies	3.6			X			X
Uncertainty in observed data and predictive tools used to characterize DBP occurrence for the pre-Stage 1 baseline	3.7			X			X

Uncertainty in the Industry Baseline

EPA recognizes that there is uncertainty related to the various data sources used to define the system inventory for the Stage 2 DBPR. The uncertainty in the system inventory data inputs is not quantified in this EA; however, a qualitative discussion of the identified uncertainties is provided below.

As noted above, SDWIS and the 1995 CWSS are the primary sources of system inventory data. SDWIS is EPA's primary drinking water database, containing data for over 170,000 PWSs. SDWIS stores State-reported information on each water system, including name, ID number, number of people served, type of system (year-round or seasonal), and source of water (ground water or surface water), along with monitoring and violation information. In 1998, EPA began a major effort to assess the quality of its drinking water data in SDWIS. The results, published in *Data Reliability Analysis of the EPA Safe Drinking Water Information System/Federal Version*, found that the quality of the required inventory data was high (USEPA 2000e). Thus, EPA believes that uncertainty in the system inventory data from SDWIS with respect to numbers of systems, source information, and size classification is low.

The 1995 CWSS was developed to gather data on water systems in the United States. A total of 3,681 systems covering a range of source water types and system sizes were statistically selected to receive the main survey questionnaire. Of these, 1,980 systems responded. These responses were

weighted to maintain statistical representation of the total universe of CWSs. The EPA report *Community Water System Survey* (USEPA 1997c) provides information on the 1995 CWSS survey design and data evaluation.

The 1995 CWSS was the primary data source used to develop the following industry baseline characteristics:

- Percent of ground water systems that disinfect
- Percent of SDWIS surface water systems that use primarily ground water
- Treatment plants per system
- Average and design flow based on population served (presented in section 3.4.3)

Because the CWSS is a survey of CWSs, estimates based on the data will contain uncertainty because of sampling errors. To help define these uncertainties, the CWSS report provides the confidence intervals on certain parameters. The report does not, however, contain data for percent disinfecting, percent of SDWIS surface water systems providing ground water, and treatment plants per system that are used in this EA. The confidence intervals for similar parameters can provide some information on uncertainty. For example, an analysis of the percent of ground water systems with no treatment (which uses similar data to the analysis of percent disinfecting), yielded 95 percent confidence intervals of less than $\pm$ 10 percent.

For average and design flow regression equations, one measure of uncertainty is the R-value for the regressions. The regressions both for average daily flow and for design flow had very high R-values (0.97 and 0.90, respectively), indicating a low level of uncertainty.

Uncertainties in Flow Equations for NTNCWs

As noted in Section 3.4.3, the relationship between population served and average daily flow and design flow was not modeled for NTNCWSs. As a surrogate, the population-flow equations derived for CWSs based on data collected during the 1995 CWSS were used. EPA recognizes that the CWS flow equations likely overestimate average daily and design flows for NTNCWSs since NTNCWSs generally only operate for part of the day and may not have high volume water uses such as showering or washing clothes. This overestimation could lead to an overestimation in treatment technology costs and therefore, national costs of the rule. The number of NTNCWSs relative to CWSs, however, is small, so EPA anticipates that the impact of this overestimate will be minor.

Uncertainties in pre-Stage 1 Use of Advanced Treatment Technology

The estimated use of chloramines and advanced treatment technologies prior to the implementation of the Stage 1 DBPR is based on different data sources depending on system size. For large surface and ground water systems, use of treatment technologies is based on ICR data. EPA expects that the treatment technology characterization for large systems has a relatively high degree of certainty because the ICR database represents a census of all plants serving more than 100,000 people. For medium and small systems, use of chloramines or advanced treatment technologies is based on data gathered during the 1995 CWSS. As described earlier in this section, the CWSS is a statistically designed

survey and is expected to contain sample error. Thus, the estimated pre-Stage 1 treatment technologies in place for medium and small systems are less certain than the estimated pre-Stage 1 treatment technologies in place for large systems.

Uncertainties in ICR DBP Data

The are several sources of uncertainty in the DBP data collected under the ICR. The American Water Works Association Research Foundation (AWWARF) has compiled a thorough description of the ICR data collection challenges and ultimate quality of the data in a publication, *Information Collection Rule Data Analysis* (the AWWARF ICR Report) (McGuire et al. 2002). Data quality controls were developed by a group of industry experts and strictly enforced; thus, EPA believes that the data quality in the ICR database is very high.

One key area of uncertainty that is addressed in the AWWARF ICR Report relates to the representativeness of all data collected during the ICR. The authors try to answer the question, how does the water quality during the year of ICR data collection (1998) represent past years and adequately be used to predict future DBP occurrence? Weather and rainfall during the ICR sample period were compared to historical data to make this assessment.

On a nationwide basis, 1998 was hotter and wetter than normal. Approximately 75 percent of the country experienced warmer than usual temperatures during 1998. Overall it was also a very wet year with an average rainfall of 32.6 inches compared to the average of 27.2 inches. Twenty-two percent of the country experienced wetter-than-normal conditions. Increased rainfall could bias the results, increasing levels of constituents that derive mainly from runoff such as TOC. Other constituent could be lower than normal such as bromide, which tends to rise during droughts. It should also be noted that these trends are for the national data and that on a regional basis the trends may be different. For example, even though 1998 was a very wet year on a national basis several mid-Atlantic states experienced severe droughts during the summer of 1998. Chapter 3 of the AWWARF ICR Report (McGuire et al. 2002) provides additional details for this assessment.

It is unknown how year-to-year variability in source water quality will affect estimated DBP occurrence. The year of data collection (1998) could represent a worst-case, best-case, or typical year depending on water-quality trends for a given plant. It is likely that some plants may experience higher DBP occurrence in future years than what is represented in the ICR database.

Because of the nature of distribution system monitoring, the representativeness of a single grab sample is uncertain. Pereira et al. (2004) showed that DBP levels can fluctuate even on a daily basis. Over a 1 week sampling period where samples were taken every 6 hours that the coefficient of variability ranged from 6 to 20 percent depending on the DBP measured and the sampling location. One grab sample collected at a discreet point in time for the ICR does not represent this potential variability. In addition to hourly variations, the ICR data were not required to be collected at evenly spaced intervals. Thus, there is uncertainty in assuming that a single data point represents typical occurrence over the entire quarter.

Based on comparisons of ICR and historical DBP databases, researchers suspect that plants changed their treatment technology in anticipation of the Stage 1 DBPR prior to the ICR data collection period (McGuire et al. 2002). The ICR then is not likely the true pre-Stage 1 baseline. EPA believes,

however, that because costs and benefits for the Stage 2 DBPR are based on treatment technology changes from a predicted pre-Stage 2 baseline, the impact of this uncertainty is small.

Uncertainties in SWAT Predictions

Part II of Appendix A is dedicated to the discussion of uncertainties in the SWAT model. Major areas of uncertainty in the SWAT predictions for the pre-Stage 1 baseline are (1) the uncertainty in ICR observed data, upon which the SWAT model is based, (2) uncertainty in predictive equations for DBP formation, (3) uncertainty in the SWAT compliance determination, and (4) uncertainty in SWAT treatment technology selection. See Appendix A for a detailed discussion of uncertainties and information on how the SWAT model was validated.

4. Consideration of Regulatory Alternatives

4.1 Introduction

To address the public health concerns presented in Chapter 2 and discussed in more detail in Chapter 6, the Environmental Protection Agency (EPA) convened the Microbial-Disinfectants / Disinfection Byproducts (M-DB\P) Advisory Committee under the Federal Advisory Committees Act (FACA) to explore a number of regulatory alternatives for the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR). The M-DBP Advisory Committee was composed of representatives from the following groups:

All Indian Pueblo Council, Pueblo Office of Environmental Protection
American Water Works Association
Association of Metropolitan Water Agencies
Association of State Drinking Water Administrators
Chlorine Chemistry Council
Clean Water Action
Conservation Law Foundation
Environmental Council of the States
International Ozone Association
National Association of County and City Health Officials
National Association of People with AIDS
National Association of Regulatory Utility Commissioners
National Association of State Utility Consumer Advocates
National Association of Water Companies
National Environmental Health Association
National League of Cities
National Resources Defense Council
National Rural Water Association
Physicians for Social Responsibility
Unfiltered Systems
U.S. Environmental Protection Agency
Water and Wastewater Equipment Manufacturers Association

M-DBP deliberations began the Spring of 1999 and culminated in December 2000 and are documented on EPA's website in the form of meeting summaries (USEPA 2000n).

This chapter describes the process for developing regulatory alternatives, then summarizes the four Stage 2 DBPR regulatory alternatives considered in this Economic Analysis (EA). Among the four alternatives is the Preferred Alternative, which represents the recommendation of the M-DBP Advisory Committee.

4.2 Process for Development of Regulatory Alternatives

The process that led to the development of the Stage 2 DBPR began with the initiation of a negotiated rulemaking by EPA in 1992 to address public health concerns related to disinfectants, disinfection byproducts (DBPs), and microbial pathogens. The Regulatory Negotiation Committee met from November 1992 through June 1993. The Committee included representatives of State and local public health and regulatory agencies, public water systems, elected officials, consumer groups, and environmental groups. As a result of its deliberations, the Committee recommended the development of three sets of rules:

- A two-stage approach for regulations to control risks from DBPs.
- A two-stage approach for regulations to control risks from microbial contaminants (the Interim Enhanced Surface Water Treatment Rule (IESWTR) and the Long Term Enhanced Surface Water Treatment Rule).
- An information collection rule to support the above.

The Information Collection Rule (ICR) was promulgated in May 1996. The DBP and microbial regulatory process recommendations of the Committee were subsequently incorporated into the 1996 Safe Drinking Water Act (SDWA) Amendments as statutory requirements. The Stage 1 DBPR and the IESWTR were both promulgated by EPA in December 1998.

Results from the 1996 ICR, which were gathered between July 1997 and December 1998, provided the M-DBP Advisory Committee and EPA with a wealth of information on large water systems, their treatment processes, and the quality of their source and finished waters. This information was used to develop and run the Surface Water Analytical Tool (SWAT) (a model that uses a series of algorithms and decision rules to predict treatment technology changes and DBP occurrence for regulatory alternatives; see Appendix A). The output from SWAT formed much of the basis for estimates of national cost and exposure to DBPs for the regulatory alternatives under consideration. Additional data were obtained from a survey conducted by the National Rural Water Association (NRWA) of 120 smaller systems—serving fewer than 10,000 people—as well as from a variety of State data sources.

The M-DBP Advisory Committee considered several key questions during the negotiation process, including:

- What health effects will the Stage 2 DBPR address?
- Should disinfectants and DBPs not regulated under the Stage 1 DBPR now be regulated?
- Should standards for disinfectants and DBPs set under the Stage 1 DBPR be amended?
- Should monitoring requirements under the Stage 1 DBPR be amended?
- Should compliance standards be calculated differently than those in the Stage 1 DBPR?
- What are the risk tradeoffs that need to be considered?

EPA used SWAT to develop rough estimates of costs and exposure reductions for over a hundred possible rule alternatives. Of these, the M-DBP Advisory Committee focused its attention on those alternatives that would reduce peaks in DBPs that may occur throughout the distribution system.

4.3 Regulatory Alternatives Considered

Four Stage 2 DBPR regulatory options are considered in this EA. They include what is referred to as the Preferred Alternative, representing the recommendation of the M-DBP Advisory Committee, and three other alternatives studied by the Committee, but not selected for reasons noted below. Though not selected as a preferred option, the Committee considered each of those other three options as alternatives worth careful consideration; EPA carried them through the benefits and cost calculations for comparison with the Preferred Alternative. EPA chose the least-cost alternative that targets the highest risks as the Preferred Alternative.

The goal of the M-DBP Advisory Committee was to increase the stringency of the total trihalomethanes (TTHM) and haloacetic acids (HAA5) compliance standards by reducing peak concentrations of DBPs in distribution systems. The Advisory Committee debated three different compliance determination approaches. The first, a running annual average (RAA), bases compliance on the average of all samples taken over a 12-month period, and allows certain monitoring locations to have DBP levels higher than the maximum contaminant level (MCL) as long as the average does not exceed the MCL. The second approach, a locational running annual average (LRAA), bases compliance on the average of all samples taken at each specific monitoring location over a 12-month period, and requires the average of all samples at individual monitoring locations to be no higher than the MCL. The third, a single highest (SH) value, bases compliance on each individual sample meeting the MCL, and requires all monitoring locations never to have DBP levels higher than the MCL. Compared to RAA compliance options, the options involving LRAA and SH compliance measures focus on reducing peak exposures—and the potential inequalities in exposure resulting from them—to customers served in some parts of distribution systems. The LRAA has the added benefit of reducing average DBP exposures.

The following discussion provides details of the four main regulatory alternatives considered.

Preferred Alternative

The Stage 1 DBPR set MCLs for total TTHM at 80 µg/L and HAA5 at 60 µg/L, each measured as a RAA based on quarterly averages of all samples taken. The Stage 2 Preferred Alternative retains these MCL values, but modifies how compliance is determined for TTHM and HAA5 under the Stage 1 DBPR. Its components include:

- MCL of 80 micrograms per liter (µg/L) TTHM measured as an LRAA
- MCL of 60 µg/L HAA5 measured as an LRAA
- MCL of 10 µg/L bromate measured as an RAA, based on monthly samples taken at the finished water point (no change from the Stage 1 DBPR)

- Compliance monitoring preceded by the Initial Distribution System Evaluation (IDSE)

Under the Preferred Alternative for the Stage 2 DBPR, systems are required to identify the compliance monitoring sites that best represent high TTHM and HAA5 levels through the IDSE and to monitor at these locations. The purpose of this alternative is to control the levels of TTHM and HAA5 at locations in the distribution system with the highest levels of these DBPs in order to meet the MCLs throughout the entire distribution system.

Alternative 1

This alternative has the same TTHM and HAA5 requirements as the Preferred Alternative, but **has a lower MCL for bromate**. Its components include:

- MCL of 80 µg/L TTHM measured as an LRAA
- MCL of 60 µg/L HAA5 measured as an LRAA
- MCL of 5 µg/L bromate measured as an RAA, based on monthly samples taken at the finished water point

Members of the M-DBP Advisory Committee did not favor this alternative because they were concerned that lowering the bromate level to 5 µg/L could have adverse effects on microbial protection. In addition, the more stringent bromate standard led to estimated costs that are approximately three times those for the Preferred Alternative. Alternative 1 would probably cause some systems to stop using ozone or not consider ozone for microbial protection—developments that the M-DBP Advisory Committee and EPA did not want to encourage because ozone is more effective than chlorine against *Cryptosporidium* (Clark et al. 1994).

Alternative 2

This alternative measures TTHM and HAA5 concentrations as a **SH value for the MCL** and maintains the MCL for bromate. Its components include:

- MCL of 80 µg/L TTHM measured as the SH value for any sample taken
- MCL of 60 µg/L HAA5 measured as the SH value for any sample taken
- MCL of 10 µg/L bromate measured as an RAA (no change from the Stage 1 DBPR)

This alternative is more stringent than the Preferred Alternative and Alternative 1. Under Alternative 2, no TTHM or HAA5 sample can exceed the MCL. EPA has estimated that a large portion of the surface water systems covered by the rule would have to switch from their current treatment practice to more expensive advanced treatment technologies to comply with this alternative. The M-DBP Advisory Committee did not favor this alternative because it believed that the health effects data are not certain enough to warrant such a drastic shift in the Nation's drinking water treatment practices. In addition, Alternative 2 does not include the risk targeting strategy of the Preferred Alternative.

Alternative 3

This alternative **reduces MCLs for TTHM and HAA5** and maintains the MCL for bromate, but does not modify how compliance is measured under the Stage 1 DBPR. Its components include:

- MCL of 40 µg/L TTHM measured as an RAA
- MCL of 30 µg/L HAA5 measured as an RAA
- MCL of 10 µg/L bromate measured as an RAA (no change from Stage 1 DBPR MCL)

This alternative reduces the average level of TTHM and HAA5 in the distribution system, but does not necessarily reduce peaks in the distribution system as an LRAA compliance strategy is expected to do. As with Alternative 2, a large portion of the surface water systems covered by the rule would have to switch from their current treatment practices to expensive advanced treatment technologies to comply with this alternative. Similarly, the M-DBP Advisory Committee did not favor this alternative because it believed that the health effects data are not certain enough to warrant such a drastic shift in the Nation's drinking water treatment practices and because it does not include the risk targeting strategy of the Preferred Alternative.

Exhibit 4.1 shows how compliance would be determined for the Stage 1 DBPR and for each of the Stage 2 regulatory alternatives described above when applied to a hypothetical large surface water system. This hypothetical system has one treatment plant and measures TTHM in the distribution system in four locations per quarter (the calculations shown would be the same for HAA5). Note that the measured concentrations of TTHM and HAA5 are the same in all cases. In this example, the system is in compliance with the Stage 1 DBPR, but would be in violation of all four Stage 2 DBPR regulatory options.

In addition to the four regulatory options addressed above, the M-DBP Advisory Committee considered other changes in the approach to regulating DBPs to be worth noting. Both the current Stage 1 DBPR and the Stage 2 DBPR alternatives considered in this analysis use TTHM and HAA5 as the specific chlorination DBPs measured for compliance. The M-DBP Advisory Committee determined that TTHM and HAA5 are reliable indicators for all halogenated DBPs that exist in chlorinated drinking water, including known DBPs that are unmeasurable and others that have yet to be identified. The Committee considered having EPA modify the group of indicators to include a total of six haloacetic acids (HAA6), a total of nine haloacetic acids (HAA9), or other chlorination DBPs. However, the M-DBP advisory committee did not recommend that EPA expand the DBP indicators to include HAA6 or HAA9. Fewer plants measured for HAA9 under the ICR because of analytical method problems for detecting HAA9 (USEPA 1999c).

The Stage 1 DBPR also set a bromate MCL at 10 µg/L measured as an RAA, based on monthly measurements for ozone systems and a chlorite MCL at 1.0 mg/L based on measurements required for chlorine dioxide systems. The M-DBP Advisory Committee debated whether the bromate MCL should be lowered (Regulatory Alternative 1). The Stage 1 DBPR set the MCL for bromate at 10 µg/L partly because that was the limit of EPA's analytical capability at that time. New methods now exist to measure lower concentrations of bromate, which would allow a lower limit to be set. However, the Committee was concerned that a lower bromate MCL might discourage systems from switching to (or

continuing to use) ozone to increase microbial protection. Unlike chlorine, ozone is effective in the disinfection of *Cryptosporidium*—a focus of the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). Therefore, the M-DBP Advisory Committee recommended that EPA not change the bromate MCL. The M-DBP Advisory Committee did not discuss the chlorite standard, and EPA does not believe it needs to be revised.

Last, it should be noted that reductions in exposure to DBPs could also be achieved through treatment techniques in lieu of or in addition to setting MCLs. For example, reducing organic precursor compounds, measured as Total Organic Carbon (TOC), by such means as enhanced coagulation has been shown to lower DBP formation. The M-DBP Advisory Committee considered regulatory alternatives for reducing precursors and determined that the Stage 1 DBPR reduced TOC to a sufficient degree. Further, removing ever-smaller quantities of these compounds will be more difficult, less efficient, and increasingly costly. While analysis of ICR data shows that some systems could improve performance in this way (and SWAT incorporated that into its decision tree), a regulatory requirement for reducing TOC levels was deemed unnecessary.

Exhibit 4.1 Comparison of Hypothetical Compliance Calculations for Stage 1 and Stage 2 Regulatory Alternatives

Basis of Compliance

Violation of MCL

Stage 1 DBPR
TTHM MCL = 80 µg/L measured as an RAA
No exceedance of MCL

	Loc. 1	Loc. 2	Loc. 3	Loc. 4	Qtrly Avg.
Q1	100	40	50	50	60
Q2	75	50	40	100	66
Q3	55	45	55	110	66
Q4	60	55	40	75	58
				RAA	63

Preferred Stage 2 DBPR Alternative and Alternative 1*
TTHM MCL = 80 µg/L measured as an LRAA
LRAA at Location 4 exceeds MCL

	Loc. 1[1]	Loc. 2[1]	Loc. 3[1]	Loc. 4[1]
Q1	100	40	50	50
Q2	75	50	40	100
Q3	55	45	55	110
Q4	60	55	40	75
LRAA	73	48	46	84

*The Preferred Alternative and Alternative 1 have the same TTHM MCL; they differ only in regard to the bromate MCL.

Footnote 1: Based on the IDSE, new locations targeted for high DBPs.

Alternative 2
TTHM MCL = 80 µg/L measured as a single highest value
Three samples at Locations 1 and 4 exceed MCL

	Loc. 1	Loc. 2	Loc. 3	Loc. 4
Q1	100	40	50	50
Q2	75	50	40	100
Q3	55	45	55	110
Q4	60	55	40	75

Alternative 3
TTHM MCL = 40 µg/L measured as an RAA
RAA exceeds MCL

	Loc. 1	Loc. 2	Loc. 3	Loc. 4	Qtrly Avg.
Q1	100	40	50	50	60
Q2	75	50	40	100	66
Q3	55	45	55	110	66
Q4	60	55	40	75	58
				RAA	63

5. Compliance Forecast and Consequent Reduction in Chlorination DBPs

5.1 Introduction

The compliance forecast represents the changes system are predicted to make in treatment technologies to comply with a new drinking water regulation. Treatment technology changes to meet the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR) result in costs incurred by the water systems as well as reductions in concentrations of disinfection byproducts (DBPs) that determine the benefits achieved by the rule.

Section 5.2 provides an overview of the methodologies used to develop the compliance forecasts and consequent reduction in the levels of DBPs. Section 5.3 provides details on the derivation of the compliance forecast, and Section 5.4 presents the forecast results for the Stage 1 DBPR and the Stage 2 DBPR Preferred Alternative (forecasts for the other regulatory alternatives are presented in Appendix C). Predicted reductions in the levels of two key classes of DBPs, total trihalomethane (TTHM) and five haloacetic acids (HAA5), are discussed in Sections 5.5 and 5.6. Uncertainties in the compliance forecast and DBP reduction estimates are summarized in Section 5.7.

In support of this chapter:

- Appendices A and B explain the derivation of the compliance forecasts (i.e., the number of plants making treatment technology changes and which treatment technologies they select) for surface water and disinfecting ground water systems, respectively.

- Appendix C provides supplemental compliance forecasts for the Stage 1 DBPR and Stage 2 DBPR regulatory alternatives.

Note that "compliance forecast" and "technology selection forecast" are used interchangeably in this Economic Analysis (EA) to denote the overall percentage of plants predicted to change treatment technology, along with the specific technologies those plants are predicted to select to achieve compliance with the Stage 1 or Stage 2 DBPRs.

5.2 Overview of Methodologies used in the Primary Analysis

Changes in concentrations of DBPs are the direct result of changes in treatment technologies. Therefore, it is important that EPA use consistent methodologies for forecasting treatment technology changes and predicting reductions in DBPs (specifically, the reductions in TTHM and HAA5 concentrations that are used in the benefits analysis). This section summarizes the tools used and key assumptions for the Stage 2 DBPR compliance forecasts and the consequent reductions in TTHM and HAA5 concentrations.

Since the rule was proposed, EPA has modified the compliance forecast methodology in an attempt to quantify uncertainties in the analysis. Specifically, EPA has developed a second method to predict the number of surface water plants making treatment technology changes and consequent reductions in TTHM and HAA5 concentration, which supplements the Surface Water Analytical Tool (SWAT) predictions. EPA has also quantified uncertainty in the potential impacts of the Initial Distribution System Evaluation (IDSE). Uncertainties are characterized using Monte Carlo simulation in the cost and benefits models.

Predictive Tools Used to Develop the Compliance Forecast

EPA uses different methods for different system sizes and source water types to develop the compliance forecasts, as shown in Exhibit 5.1. Because extensive data were available from the Information Collection Request (ICR), detailed analysis tools were used to develop compliance forecasts for large surface and ground water systems. For large surface water systems, EPA used two different methodologies, both drawing from ICR data: the Surface Water Analytical Tool (SWAT) and the ICR Matrix Method. The ICR Matrix Method uses TTHM and HAA5 distribution system data from the ICR to predict how many plants will need to change technology for a specific regulatory alternative. SWAT uses a series of decision rules and algorithms to predict (1) which surface water plants need to change treatment technology to meet a specific regulatory alternative, (2) which treatment technology those plants will select based on a least cost decision tree. The ICR Matrix Method and SWAT produce different results; thus, both are incorporated into a Monte Carlo simulation model to account for uncertainties in both methods. The forecast for large ground water systems was generated using the ICR Ground Water Delphi process, which convened a group of experts to evaluate plant configurations and predict treatment technology selections for ground water plants that did not meet rule requirements. Compliance forecasts for large surface and ground water systems were used to generate forecasts for medium and small systems, making adjustments to account for operational and water quality characteristics in medium and small systems that differ from those in large systems.

Exhibit 5.1 Tools Used to Develop the Stage 2 DBPR Compliance Forecasts

System Size (Population Served)	Source Water Category		
	Surface Water		Disinfecting Ground Water
Large (≥ 100,000 people)	The Surface Water Analytical Tool (SWAT) (Appendix A)	ICR Matrix Method (Section 5.5)	ICR Ground Water Delphi Group (Appendix B)
Medium (10,000 to 99,999 people)	Extrapolation from SWAT (Appendix A)	Extrapolation from ICR Matrix Method (Section 5.5)	Extrapolation from large ground water system results (Appendix B)
Small (<10,000 people)	Extrapolation from SWAT, adjusted to deal with small system-specific issues (Appendix A)	Extrapolation from ICR Matrix Method (Section 5.5)	Extrapolation from large ground water system results, adjusted to deal with small system-specific issues (Appendix B)

Tools Used to Predict Changes in DBP Levels

For the benefits analysis, EPA needs information on the changes in both average and peak TTHM and HAA5 levels that result from implementation of the Stage 2 DBPR. Estimates of bladder cancer cases avoided are based on reductions in average levels, while the illustrative analysis of potential developmental and reproductive health benefits is based on reductions in occurrences of peak concentrations.

To predict changes in average TTHM and HAA5 levels for surface water systems, EPA uses two methods: the ICR Matrix Method and SWAT. As noted in the previous section, the ICR Matrix Method evaluates distribution system data to identify plants that would need to make treatment technology changes to meet a specific regulatory alternative. To predict average DBP concentrations occurring after treatment technology changes, EPA used TTHM and HAA5 occurrence data for those surface water plants already using chloramines and/or advanced technologies at the time of the ICR. The predicted average TTHM and HAA5 levels for all surface water plants is a weighted average for plants that do and do not change treatment technology.

SWAT is a model that uses a series of decision rules and algorithms to predict (1) which surface water plants need to change treatment technology to meet a specific regulatory alternative, (2) which treatment technology those plants will select based on a least cost decision tree, and (3) resulting changes in the national average TTHM and HAA5 levels in distribution systems. As with the compliance forecast, SWAT and the ICR Matrix Method produce different results; thus, both are incorporated into a Monte Carlo simulation model to account for uncertainties in both methods.

ICR ground water plant data were not robust enough to develop a ground water model similar to SWAT; therefore, the ICR Matrix Method is the only approach used to predict reductions in average TTHM and HAA5 levels for these systems.

To predict changes in the occurrence of peak TTHM and HAA5 concentrations, EPA used only the ICR Matrix Method[1]. Similar to the way in which it is used to evaluate changes in average TTHM and HAA5 concentrations, the ICR Matrix Method evaluates distribution system data to identify plants that would need to make treatment technology changes to meet a specific regulatory alternative. To predict occurrence of peaks after treatment technology changes, EPA analyzed TTHM and HAA5 occurrence data for those surface water plants already using chloramines and/or advanced technologies at the time of the ICR. The predicted occurrence of peaks for all plants is a weighted average for plants that do and do not make treatment technology changes.

Accounting for the Stage 1 DBPR

For cost and benefit analyses, the compliance forecast and consequent reduction in DBPs needs to represent treatment technology changes from the pre-Stage 2 baseline (i.e., after implementation of the Stage 1 DBPR). The best data available to characterize large plants are from the ICR, which were collected before the Stage 1 DBPR compliance deadlines and likely represent pre-Stage 1 conditions[2]. The compliance forecast, therefore, needs to account for treatment technology changes as a result of the Stage 1 DBPR before predicting changes that are needed for the Stage 2 DBPR. Similarly, the post-Stage 2 TTHM and HAA5 predictions need to take into account changes as a result of the Stage 1 DBPR before predicting reductions that will occur as a result of the Stage 2 DBPR.

EPA uses a "delta" compliance forecast method that was developed by the Microbial / Disinfection Byproducts (M-DBP) Technical Working Group (TWG). The method has four steps. First, EPA characterizes treatment technologies and TTHM and HAA5 occurrence for the Pre-Stage 1 baseline. Secondly, EPA predicts treatment technology changes and subsequent reduction in TTHM and HAA5 levels from Pre-Stage 1 baseline to post-Stage 1 DBPR conditions. Thirdly, treatment technology changes and subsequent reductions in TTHM and HAA5 levels are predicted from pre-Stage 1 baseline to post-Stage 2 DBPR conditions. Lastly, results from step 2 are subtracted from step 3 to calculate the incremental treatment technology change and TTHM/HAA5 reduction from post-Stage 1 DBPR to post-Stage 2 DBPR conditions.

[1] Although the SWAT model was calibrated to national average TTHM and HAA5 concentrations in distribution systems and validated against industry treatment technology predictions, it was not calibrated to plant-level DBP predictions and, thus, could not be used to assess changes in occurrence of peak levels. See Appendix A for more information on SWAT.

[2] There is uncertainty in using the ICR data to represent pre-Stage 1 conditions because some plants may have begun making changes prior to the ICR in anticipation of the Stage 1 DBPR (McGuire et al., 2002). See Section 3.8 for a full discussion of uncertainties in ICR data.

This delta method was selected by the M-DBP TWG over a more direct, two step approach (i.e., predict pre-Stage 2 conditions and then use the pre-Stage 2 conditions to predict impacts for Stage 2) because modeling tools are not able to predict the treatment technology selection or TTHM, HAA5, bromate, and chlorite levels at the plant level. The delta approach allows for potential errors in treatment technology selection and TTHM and HAA5 levels to be cancelled out for national level estimates. The TWG believed that using the delta approach reduces the impact of uncertainty in SWAT predictive equations for TTHM and HAA5. The delta approach is used with both the ICR Matrix Method and SWAT analyses.

Accounting for *the IDSE*

Because the purpose of the IDSE is to identify Stage 2 compliance monitoring locations with high DBP levels, it is possible that systems may measure higher DBP levels at Stage 2 compliance monitoring sites than were measured under the ICR. This suggests that the number of plants predicted to make treatment technology changes, the level of treatment they select, and the resulting reductions in TTHM and HAA5 levels, all based on ICR data, could be underestimated.

The M-DBP TWG recommended that the Stage 1 and Stage 2 compliance forecast methodology incorporate an operational safety margin of 20 percent to represent the operational level (i.e., 80 percent of the MCL) at which systems typically take some action to ensure consistent compliance with a new drinking water standard and the level at which systems target new treatment technologies to meet the standard. EPA believes that this safety margin already accounts for the impacts of the IDSE for some systems, including small systems, ground water systems, and those using chloramines[3]. EPA believes, however, that the 20 percent safety margin is not sufficient to account for the potential impacts of the IDSE on large and medium surface water systems because spatial variability of DBP levels and distribution system complexity are greatest in these systems. Since the proposal, EPA developed a methodology that analyzed ICR data from surface water plants to assess the extent of spatial variability of TTHM and HAA5 levels and used this as a basis for quantifying the impacts of the IDSE for large and medium surface water systems.

5.3 Compliance Forecast Methodology

This section summarizes the tools used for the compliance forecast and provides details on how EPA accounted for the Stage 1 DBPR and potential impacts of the IDSE on the compliance forecast. Section 5.4 presents the results of the compliance forecast.

[3]EPA believes that the 20 percent safety margin accounts for potential impacts of the IDSE for small systems because their distributions are not as complex when compared to large systems. EPA also believes that the safety margin accounts for the IDSE for ground water systems because the year-to-year variability in source water quality (and thus, TTHM and HAA5 formation) is low. Chloramine systems generally observe lower spatial and temporal variability in TTHM and HAA5 distribution system levels (USEPA 2005k); thus, EPA believes the 20 percent safety margin accounts for potential impacts of the IDSE for these systems.

5.3.1 Tools for Surface and Ground Water Systems

EPA uses several tools to predict changes in treatment technology that will result from the Stage 2 DBPR. For surface water systems, EPA used results from both SWAT and the ICR Matrix Method. For ground water systems, predictions were made using the ICR Ground Water Delphi Process. Exhibit 5.1 summarizes the tools used to develop the compliance forecasts. Detailed information on these methodologies can be found in the referenced sections and appendices.

Surface Water Systems

The two tools used to predict changes in treatment technology and the resulting reductions in DBP levels for surface water systems are SWAT and the ICR Matrix Method. SWAT is a modeling tool developed by EPA during the M-DBP Federal Advisory Committee Act (FACA) process to evaluate regulatory alternatives. SWAT uses source water and treatment data from the ICR along with a series of empirical equations developed by researchers to model TTHM and HAA5 levels in distribution systems. For each plant, SWAT predicts TTHM, HAA5, chlorite, and bromate levels and compares them to MCLs for a given regulatory alternative. If the plant does not meet the MCLs, SWAT modifies the plant's treatment until it can achieve compliance. SWAT uses a decision tree, arranged from lowest-cost to the highest-cost treatment technology, to determine which new technology is selected for the plant. A total of 273 of the 350 ICR surface water plants had sufficient data to allow for modeling in SWAT. (For characterization of the 273 modeled plants, see Appendix A.)

The ICR Matrix Method evaluates TTHM and HAA5 distribution system data from the ICR to identify plants that would need to make treatment technology changes to meet specific regulatory alternatives. ICR plants are first screened to ensure that there are enough TTHM and HAA5 distribution system data so as not to skew the analysis. (See chapter 3 for a discussion of the screening process, including a discussion of data representativeness.) The method then places the screened plants into "bins" based on their running annual average (RAA) and locational running annual average (LRAA) TTHM and HAA5 concentrations. Plants in bins that are non-compliant with Stage 1 are moved into compliant bins[4]. The remaining plants that are non-compliant with Stage 2 regulatory alternatives are moved into compliant bins. The ICR Matrix Method is limited in that it does not predict the specific technologies plants will select; this information is only available from SWAT.

Results from both SWAT and the ICR Matrix Method are used in the primary analysis for all regulatory alternatives. Section 5.3.6 compares the results and explains how they are incorporated into the cost and benefits model.

SWAT and ICR Matrix Method compliance forecast results for large surface water systems were applied directly to medium surface water systems, as the two size categories share similar source

[4]As will be explained in Sections 5.5 and 5.6, revised TTHM and HAA5 levels for these plants are based on an analysis of ICR data for plants that are Stage 2 compliant and already use chloramines and/or advanced technologies prior to the ICR.

types and operational capabilities. Adjustments were made to the forecasts for small surface water systems to account for differences in water quality and operational constraints.

Ground Water Systems

The compliance forecasts for large ground water systems were generated using the ICR Ground Water Delphi Process, which convened a group of experts to determine the treatment technology changes that would be needed by systems that were not in compliance with the Stage 1 and Stage 2 DBPR. The results were stratified based on plant location (Florida or Non-Florida) and extrapolated to national levels. Because large and medium ground water systems are similar with respect to treatment configurations and the well fields from which they draw, the compliance forecasts for large ground water systems were also used for medium ground water systems (the ratio of Florida to Non-Florida ground water systems was considered similar enough to allow for this extrapolation; see Appendix B for more details). The compliance forecast for small ground water plants was based on results of the ICR Ground Water Delphi process, but was adjusted to account for differences in total organic carbon (TOC), softening use, and the ratio of Florida to Non-Florida ground water systems.

5.3.2 Accounting for the Stage 1 DBPR

For cost and benefit analyses, the compliance forecast needs to represent treatment technology changes from the pre-Stage 2 baseline (i.e., after implementation of the Stage 1 DBPR). The best data available to characterize large plants are from the ICR, which were collected before the Stage 1 DBPR compliance deadlines and likely represent pre-Stage 1 conditions[5]. The compliance forecast, therefore, needs to account for treatment technology changes as a result of the Stage 1 DBPR before predicting changes that are needed for the Stage 2 DBPR.

The Stage 1 Regulatory Impact Analysis (RIA) (USEPA 1998a) includes a prediction of chloramine and advanced technology use that will result from the Stage 1 DBPR. EPA did not use this prediction as the post-Stage 1 baseline in this EA because new data and tools became available since the Stage 1 RIA was developed (namely ICR and SWAT) that provide better characterization of plants and allow for better prediction of treatment technology changes.

For surface water systems, a straightforward, 2-step approach for generating the Stage 2 DBPR compliance forecast was originally considered during the M-DBP FACA deliberations. Under this approach, SWAT would be used to predict treatment technology use and TTHM or HAA5 levels for each plant for post-Stage 1 conditions (i.e., after plants make changes to comply with Stage 1). Then SWAT would evaluate post-Stage 1 conditions for each plant to predict treatment technology changes needed to comply with the Stage 2 DBPR. In other words, SWAT would assess each plant for

[5] There is uncertainty in using the ICR data to represent pre-Stage 1 conditions because some plants may have begun making changes prior to the ICR in anticipation of the Stage 1 DBPR (McGuire 2003). See Section 3.8 for a full discussion of uncertainties in ICR data.

compliance with Stage 1, make a treatment technology change if needed to comply with Stage 1, then evaluate post-Stage 1 TTHM and HAA5 levels to determine if further changes are needed for Stage 2.

The M-DBP TWG identified a problem with this approach. SWAT predictive equations for TTHM and HAA5 were calibrated by comparing the ICR-observed values to the SWAT-predicted values for the 273 plants used by the SWAT model. While the national average TTHM and HAA5 levels predicted by SWAT and observed by the ICR had good agreement, differences between SWAT and ICR data were large for some plants. Thus, although national predictions were considered dependable, SWAT-predicted TTHM and HAA5 data for individual plants were uncertain. Because of this uncertainty, the M-DBP TWG decided that it was inappropriate to evaluate SWAT-predicted post-Stage 1 TTHM and HAA5 occurrence for each plant separately to assess compliance with the Stage 2 DBPR.

To minimize the impacts of uncertainty in SWAT plant-level predictions on the Stage 2 DBPR compliance forecast, the M-DBP FACA developed a four-step, or "delta," approach for SWAT:

- Step 1: Model TTHM and HAA5 occurrence for the pre-Stage 1 baseline conditions (for SWAT, predict using the model; for the ICR Matrix Method, use observed data).

- Step 2: Predict treatment technology changes from the pre-Stage 1 DBPR baseline to post-Stage 1 DBPR conditions.

- Step 3: Predict treatment technology changes from the pre-Stage 1 DBPR baseline to post-Stage 2 DBPR conditions.

- Step 4: Take the difference, or delta, between the results from Steps 2 and 3 to calculate the incremental treatment technology selection forecast and TTHM and HAA5 reduction for Stage 2 (from post-Stage 1 conditions).

Because the same pre-Stage 1 baseline was used to evaluate compliance with both Stage 1 and Stage 2, potential errors in selection of treatment technology and changes in TTHM and HAA5 levels are cancelled out for national level estimates in Step 4. The TWG believed that using the delta approach reduces the impact of uncertainty in SWAT's predictive equations for TTHM and HAA5. The delta approach was used for both SWAT and the ICR Matrix Method.

A similar delta approach was developed and used for ground water plants. Because ICR data for ground water plants were not robust enough to allow for modeling in SWAT, ICR observed data were used as the pre-Stage 1 baseline. Using the ICR Ground Water Delphi results, EPA calculated the percent of plants exceeding Stage 1 and Stage 2 MCLs from the Pre-Stage 1 baseline and took the difference as the percent of plants needing to change treatment technologies from post-Stage 1 to Stage 2.

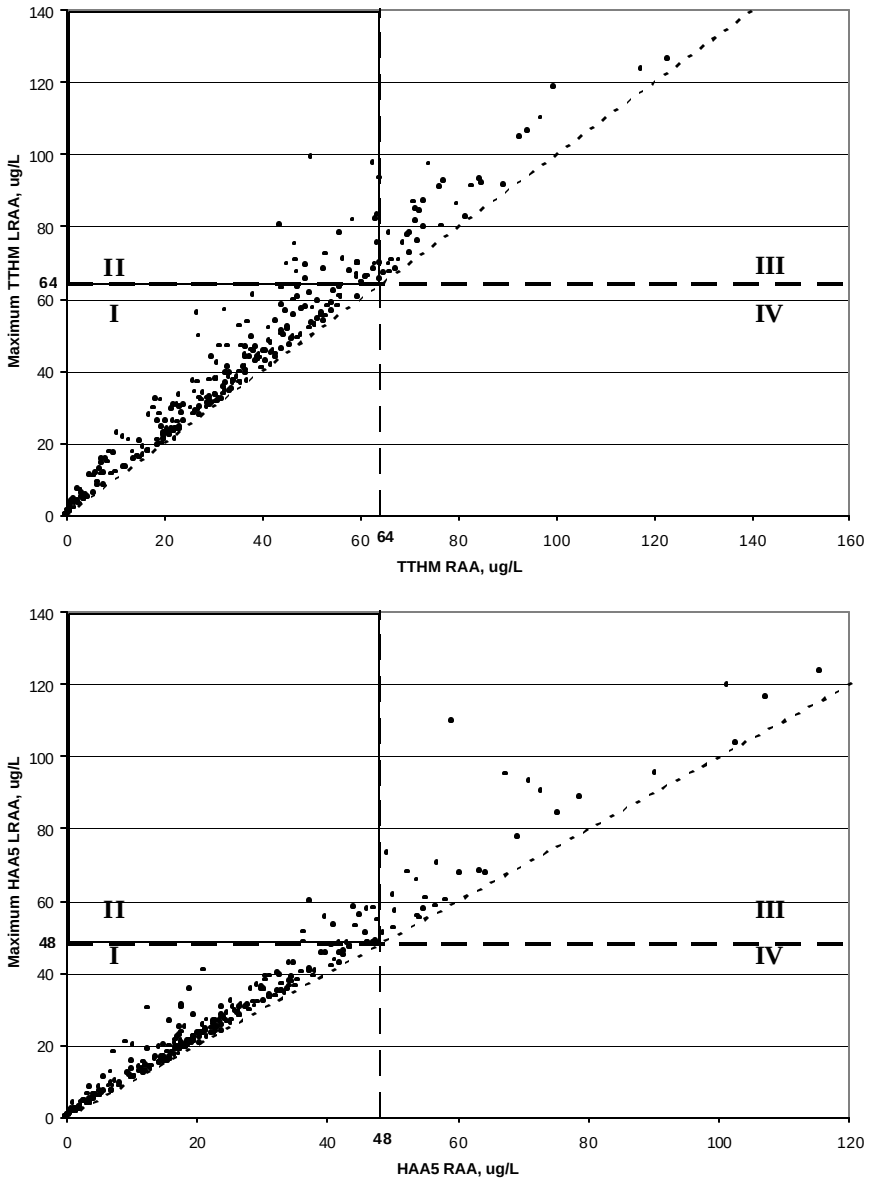
An uncertainty in the delta approach is the implicit assumption that plants making treatment technology changes to comply with the Stage 1 DBPR also meet the Stage 2 DBPR MCLs (Stage 1 forecasts are subtracted from Stage 2; only the delta is considered for costs and benefits). To illustrate the mechanisms of the delta approach and this uncertainty, consider the plots of the maximum locational

running annual average (LRAA) and running annual average (RAA) for each plant in Exhibit 5.2. Quadrant I contains those plants in compliance with both Stage 1 and Stage 2 considering a 20 percent safety margin. Quadrant II contains plants that are in compliance with Stage 1, but not Stage 2. Plants in Quadrant III are those that exceed the MCLs for both Stage 1 and Stage 2. With the delta approach, plants in Quadrant III that make a treatment technology change to meet the Stage 1 DBPR move to Quadrant I (i.e., they are Stage 2-compliant). Although EPA recognizes this uncertainty, the Agency believes this the delta approach is reasonable for the following reasons:

- The Stage 2 DBPR is a required rule in the Safe Drinking Water Act (SDWA) Amendments of 1996. Details of the Stage 2 DBPR were published in the Agreement in Principle, which includes the Stage 2 MCLs, in December 2000, which is well before the Stage 1 compliance deadlines. It is less costly and, therefore, in a water system's best interest to develop a comprehensive treatment strategy to achieve simultaneous compliance with both Stage 1 and Stage 2.

- A large portion of systems use chloramines to achieve compliance with the Stage 1 DBPR. Chloramines generally result in lower spatial and temporal variability of TTHM and HAA5 concentrations in distribution systems compared to chlorine, as discussed in Section 5.3.6 and shown in Exhibit 5.8a. Therefore, systems that have switched to chloramines to comply with Stage 1 DBPR will likely have LRAA values already below 80 µg/L for TTHM and 60 µg/L for HAA5 and will not need to make a second treatment technology change to comply with the Stage 2 DBPR.

Exhibit 5.2 Compliance Evaluation of Screened ICR Surface and Ground Water Plants



Note: Each point on the graph represents one plant

MCL (with 20% Safety Factor)
RAA = LRAA representation
Plants under the Stage 1 DBPR, but above the Stage 2 DBPR compliance targets

Source: analysis of ICR screened ground and surface water plants (N = 311)

One disadvantage of the delta approach is that compliance forecasts for the Stage 2 DBPR do not take into account the specific advanced treatment technologies predicted for Stage 1. In some cases, a more advanced treatment technology can be predicted for a plant to meet Stage 1 requirements as compared to Stage 2. There are two reasons this can happen:

- A plant is allowed to use chloramines in the Stage 2 model run, but not for the Stage 1 run. For all SWAT model runs, 77 percent of plants were allowed to convert from free chlorine to chloramines to comply with DBP rules. The 77 percent cap on chloramine conversion was developed during the M-DBP FACA deliberations to represent site-specific circumstances and other local factors that would preclude chloramine usage for reasons other than technical suitability. The percentage is applied to each plant randomly by a Monte Carlo simulation model. Because the number is assigned randomly, the situation can (and does) occur where a plant is not allowed to use chloramines for Stage 1 compliance, but is allowed to use it for Stage 2 compliance.

- EPA considered ultraviolet (UV) an available technology for meeting Stage 2 requirements, but not Stage 1 requirements, when developing the compliance forecasts. UV is an emerging technology that has just recently been shown to be an effective disinfectant for many microorganisms of concern in drinking water. Since the model starts with the same pre-Stage 1 baseline, some plants that are predicted to use more expensive technologies, such as ozone, microfiltration/ultrafiltration (MF/UF), or granular activated carbon (GAC), to comply with Stage 1 can achieve compliance with UV once it is included in the Stage 2 runs.

The first factor (randomness in chloramine use) has a relatively small impact on the compliance forecast. The second factor, assumptions for UV availability, however, causes the delta from Stage 1 to Stage 2 to be negative for some advanced technologies. EPA developed an approach to adjust the technology selection forecast to correct for the negatives (called the "adjustment for negatives" step). In summary, plants selecting UV for the Stage 2 DBPR were reallocated to advanced technologies (ozone, MF/UF, and GAC-10-Minute Contact Time (GAC10)) when overall predictions were lower for Stage 2 than for Stage 1. Details on the adjustment-for-negatives step, including flow charts and sample calculations, are provided in Appendices A and B.

5.3.3 Operational Safety Margins

The M-DBP TWG recommended that a 20 percent operational safety margin be used for DBP MCLs (TTHM, HAA5, bromate, and chlorite) when evaluating Stage 1 and all Stage 2 regulatory alternatives. This safety margin is intended to represent the level (i.e., 80 percent of the MCL) at which systems typically take some action to ensure consistent compliance with a new drinking water standard and the level at which systems target new treatment technologies to meet the standard. In addition to representing industry practices, the safety margin also is intended to account for year-to-year fluctuations in DBP levels. (ICR data are limited to 1 year and might not represent the highest DBP concentrations that occur in a system.) Individual systems may use higher or lower safety margins based on system-specific conditions. Use of a safety margin is consistent with prior DBP regulatory development efforts.

5.3.4 Accounting for the IDSE

For most systems, compliance monitoring for the Stage 2 DBPR is preceded by an IDSE. The purpose of the IDSE is to identify Stage 2 DBPR compliance monitoring sites that represent high TTHM and HAA5 concentrations in the distribution system. Not all systems must perform an IDSE. Nontransient noncommunity water system (NTNCWSs) serving fewer than 10,000 people are not required to conduct an IDSE. Other systems may not need to perform the IDSE if they demonstrate low historic DBP distribution system concentrations or if they serve fewer than 500 people. For systems that conduct the IDSE it is expected that most will conduct standard monitoring for 1 year.

There are several reasons why Stage 2 compliance monitoring sites identified by the IDSE may have higher TTHM and HAA5 levels than data collected under the ICR. First, monitoring under the IDSE includes more sites, and samples are taken more frequently than the ICR. In addition, sites are selected to represent both high TTHM and high HAA5 levels. Whether an individual system finds sites with higher TTHM and HAA5 levels than those reported in the ICR depends on a number of factors, including but not limited to:

- Spatial variability in TTHM and HAA5 levels. The more variability in a system, the more likely the system will find higher LRAAs during the IDSE. Spatial variability is influenced by residual disinfectant type (free chlorine versus chloramines).

- Temporal variability in TTHM and HAA5 levels. Seasonal variability related to increased temperature and changes in source water quality may be better characterized during the IDSE because they take more frequent samples (for large systems, 6 per year for the IDSE compared to 4 per year required for the Stage 1 DBPR). Temporal variability is a much larger factor for surface water systems than for ground water systems.

- Number of plants per system. Systems with a higher than average number of plants are already sampling at many locations under the Stage 1 DBPR and thus have most likely already captured much of the spatial variability of DBP levels in their distribution systems. Conversely, systems with a lower than average number of plants have collected fewer samples under Stage 1 and are thus more likely to find higher LRAAs when monitoring for the IDSE.

- System configuration. Systems having more complicated distribution systems (e.g., well-looped systems with several large users, systems with multiple storage facilities, and systems with pumping stations) are more likely to find higher LRAAs during their IDSE. Complexity of the system generally decreases with system size.

- Technical resources used to select ICR and/or Stage 1 sites. Systems with extensive residual data, extensive DBP data, hydraulic models, and those that have performed tracer studies should already have well-defined maximum residence time sites. These systems are less likely to see significantly higher LRAAs as a result of their IDSE.

The IDSE can potentially affect the compliance forecast in two ways. First, systems that appear to be in compliance with the Stage 2 DBPR based on an evaluation of their ICR data might find increased DBP concentrations at their new Stage 2 DBPR monitoring locations (post-IDSE), high enough to cause them to make treatment technology changes. Secondly, systems that expect to be out of compliance with the Stage 2 DBPR based on an evaluation of their ICR data may need to use more advanced technology changes to meet rule requirements at new sites identified during the IDSE.

One limitation of EPA's compliance forecast methodology is the use of ICR data as model inputs; ICR data are the best available data, but they may not represent Stage 2 DBPR compliance monitoring results due to systems conducting the IDSE. This limitation is, in part, accounted for by the use of a 20 percent safety margin. EPA believes that the 20 percent safety margin accounts for potential impacts of the IDSE for small surface water systems because their distribution systems are not usually as complex as large systems. For ground water systems, EPA believes that a 20 percent safety margin already accounts for the IDSE because the year-to-year variability in source water quality (and TTHM and HAA5 levels) is low. Similarly, chloramine systems generally observe lower spatial and temporal variability in TTHM and HAA5 distribution system levels (USEPA 2005k); thus, EPA believes the 20 percent safety margin accounts for potential impacts of the IDSE for these systems.

EPA believes, however, that the 20 percent safety margin is not sufficient to account for the potential impacts of the IDSE on large and medium surface water systems because spatial variability of DBP levels and distribution system complexity are greatest in these systems. Since the proposal, EPA developed a methodology to quantify the potential impacts of the IDSE on these systems.

5.3.4.1 Analysis of Spatial Variability in Large and Medium Surface Water Systems

ICR screened data, consisting of data from 213 surface water plants, were used to assess spatial variability of DBPs in distribution systems of large and medium surface water systems. See section 3.7.1 for a description of the ICR data set and the screening method. (Only those plants with 3 of 4 quarters of data that have TTHM and HAA5 data for at least 3 of 4 distribution system locations are considered in the analysis.)

EPA began with the simplifying assumption that the spatial variability in the ICR data represents the variability that systems can find through IDSE monitoring. That is, all plants can find post-IDSE maximum LRAA values according to the following formula[6]:

$$\text{post-IDSE LRAA}_{max} = \text{ICR LRAA}_{max} + (\text{ICR LRAA}_{max} - \text{ICR LRAA}_{2ndHi}) \qquad \text{(Equation 5.1)}$$

Where:

[6]This method was selected over other alternatives since the highest location in the ICR data was not always at the maximum residence time location. In addition, this approach more conservatively predicts spatial variability, as it represents the highest two locations, and thus the smallest difference between two ICR-observed locations.

post-IDSE $LRAA_{max}$ = the maximum LRAA value found after the system has conduced the IDSE

ICR $LRAA_{max}$ = the maximum LRAA value as reported for the last four quarters of the ICR

ICR $LRAA_{2ndHi}$ = the second highest LRAA as reported for the last four quarters of the ICR

Exhibit 5.3 predicts the potential increase in the percent of plants making treatment technology changes from Stage 1 to Stage 2 by assuming that the Stage 2-compliant ICR surface water plants have post-IDSE LRAAs according to Equation 5.1. Exhibit 5.4a characterizes the difference between the ICR $LRAA_{max}$ and ICR $LRAA_{2ndHi}$ for those surface water plants that are predicted to make treatment technology changes for Stage 1 and Stage 2, including those plants that are predicted to make treatment technology changes if Equation 5.1 was applied. Note that the average difference between the ICR $LRAA_{max}$ and ICR $LRAA_{2ndHi}$ is 12.7 µg/L for TTHM and 4.4 µg/L for HAA5. The cumulative distribution for ICR $LRAA_{max}$ - $LRAA_{2ndHi}$ for TTHM and HAA5 are shown in Exhibits 5.4b and 5.4c, respectively.

Exhibit 5.3 Predicted Increase in Percent Making Treatment Technology Changes based on Spatial Variability Analysis

Disinfectant Type	Number of Screened ICR Surface Water Plants	S1-Compliant Plants that are already S2 Non-Compliant		S2-Compliant Plants that will be S2 Non-Compliant after the IDSE based on $LRAA_{MAX}$ + ($LRAA_{MAX}$ - $LRAA_{2ndHI}$)	
		Number	Percent of All Plants	Number	Percent of All Plants
	A	B	C = B / A	D	E = D / A
CL2	133	29	21.8%	11	8.3%
CLM	80	7	8.8%	4	5.0%
All	**213**	**36**	**16.9%**	**15**	**7.0%**

Notes: CL2 = free chlorine, CLM = chloramines

$LRAA_{MAX}$ = the maximum LRAA value for each plant.

$LRAA_{2ndHI}$ = the second highest LRAA value for each plant.

Sources: A) See Section 3.7.1 for a detailed description of the ICR data set and screening method.

B) & D) Stage 1 and Stage 2 compliance is based on an assessment of ICR TTHM and HAA5 occurrence data applying a 20 percent safety margin.

Exhibit 5.4a Analysis of Variability for Stage 2 Non-Compliant Plants

	TTHM			HAA5		
	CL2	CLM	All	CL2	CLM	All
Number of Screened Stage 2 non-compliant Plants [1]	40	11	51	40	11	51
Average of $LRAA_{MAX}$	64.50	57.63	63.02	37.57	38.97	37.87
Average of $LRAA_{2ndHI}$	49.79	52.31	50.33	32.93	35.58	33.50
Average of ($LRAA_{MAX}$ - $LRAA_{2ndHI}$)	14.71	5.31	**12.68**	4.64	3.39	**4.37**
Max of ($LRAA_{MAX}$ - $LRAA_{2ndHI}$)	38.37	17.70	38.37	21.08	12.73	21.08

Notes

[1]Represents all screened ICR SW plants that are in compliance with Stage 1 but have Post-IDSE LRAAmax values > 64 ug/L for TTHM or 48 ug/L for HAA5.

See Section 3.7.1 for a detailed description of the ICR data set and screening method.

CL2 = free chlorine, CLM = chloramines

$LRAA_{MAX}$ = the maximum LRAA value for each plant.

$LRAA_{2ndHI}$ = the second highest LRAA value for each plant.

Exhibit 5.4b Cumulative Distribution of ICR $LRAA_{max}$ - ICR $LRAA_{2ndHi}$ for Stage 2 Non-Compliant Plants (TTHM data)

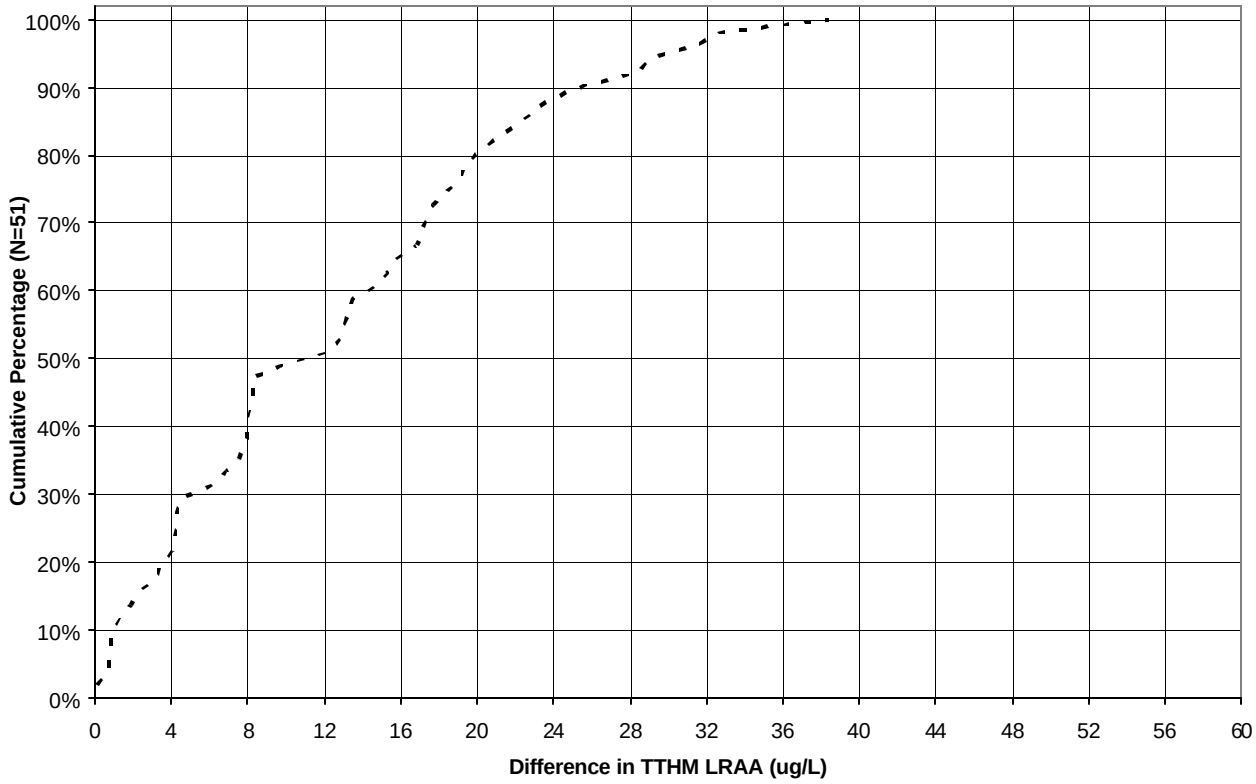
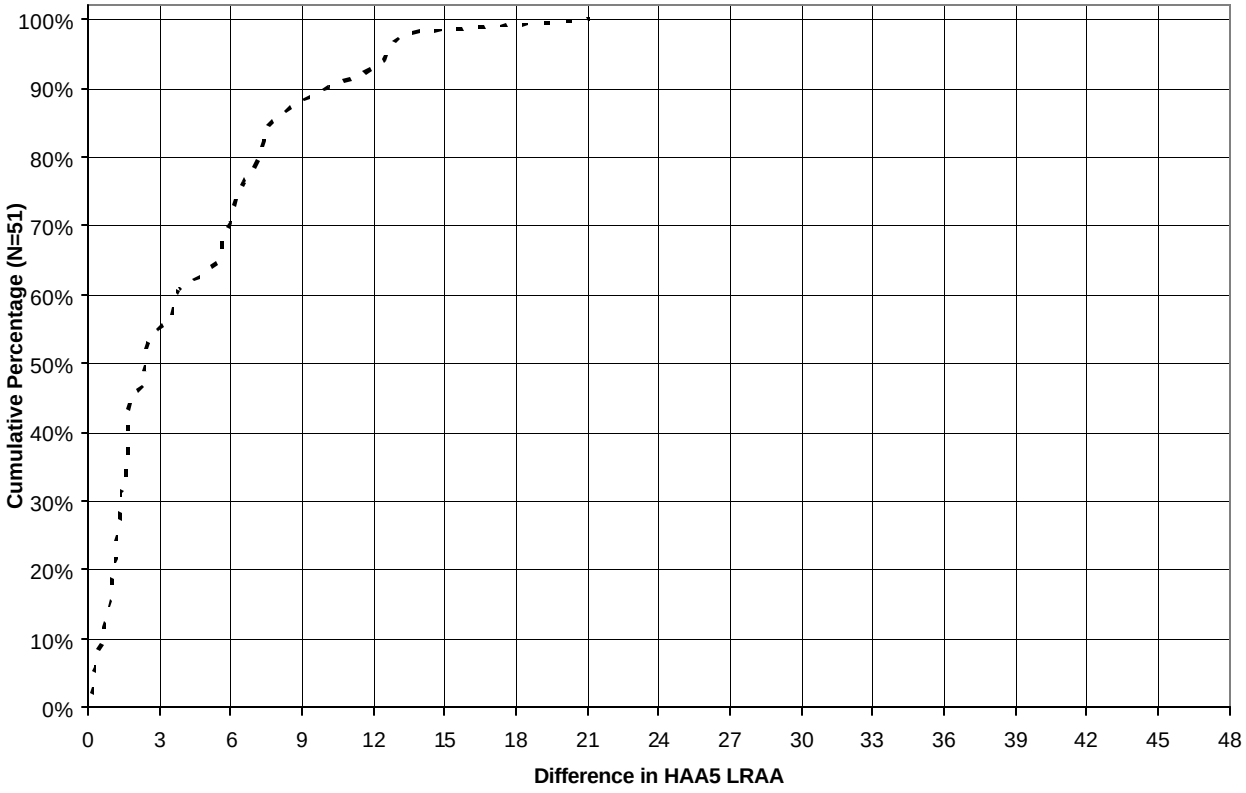


Exhibit 5.4c Cumulative Distribution of ICR $LRAA_{max}$ - ICR $LRAA_{2ndHi}$ for Stage 2 Non-Compliant Plants (HAA5 Data)



EPA believes this analysis of spatial variability over-predicts the potential impacts of the IDSE for three reasons. First, the calculation is generally based on the difference between a calculated LRAA from a maximum residence time and an average residence site. Because sampling was required at only one maximum residence time site for the ICR, EPA is not able to compare two or more LRAA results from maximum residence time sites. Secondly, this calculation assumes all plants find sites with higher DBP levels during the IDSE and does not take into account other factors, such as the use of advanced tools to locate maximum residence time sites prior the ICR. Systems that used advanced tools are not expected to find drastic differences between their ICR $LRAA_{max}$ and their post-IDSE $LRAA_{max}$. Thirdly, systems using chloramines for residual disinfection generally find less spatial and temporal variability in distribution system DBP data as compared to systems using chlorine. This statement is supported by results in Exhibit 5.4a, which presents the difference in between the $LRAA_{max}$ and the $LRAA_{2ndHi}$ for screened ICR surface water plants that are in compliance with Stage 1 but out of compliance with Stage 2, based on the post-IDSE $LRAA_{max}$ calculation (see equation 5.1). The average between the TTHM $LRAA_{max}$ and TTHM $LRAA_{2ndHi}$ for chlorine plants is 14.7 µg/L, whereas the average difference for chloramine plants is 5.3 µg/L. Even though EPA believes that the analysis of spatial variability in this section over-predicts the potential impacts of the IDSE for reasons described above, the Agency believes that it has value in informing an upper-end estimate.

5.3.4.2 Modifying the Operational Safety Margin

The next step in the process of quantifying the potential impacts of the IDSE is applying the results in the previous section to the large and medium surface water compliance forecast methodology. Changes to the compliance forecast must take into account:

- The potential changes in the number of systems making treatment technology changes
- The potential treatment technology changes selected by all systems
- The resulting reduction in TTHM and HAA5 concentrations

EPA determined that the most effective way to revise the compliance forecast was to modify the operational safety margin. A larger safety margin would affect the compliance forecasts of both SWAT and the ICR Matrix Method (i.e., cause more plants to make treatment technology changes). A larger safety margin would also impact the distribution of treatment technologies predicted by SWAT. (SWAT re-evaluates compliance with the Stage 2 DBPR by considering the safety margin after evaluating each treatment type in the decision tree.) Lastly, an increased safety margin could result in plants predicted to install higher-cost treatment technologies to meet compliance with a lower numeric MCL value. The decrease in TTHM and HAA5 levels resulting from the additional plants making treatment technology changes and more advanced treatment technologies being selected would be automatically calculated by SWAT.

To identify the most appropriate safety margin, EPA compared the results in Exhibits 5.3 and 5.4 to the compliance assessment in Exhibit 5.5. The variability analysis in Exhibit 5.3 predicts that an additional 7 percent of all plants could make treatment technology changes as a result of the IDSE. This prediction falls in between the compliance analysis of ICR for a 25 and a 30 percent safety margin (compare to column E in Exhibit 5.5). Because EPA believes the analysis of spatial variability produces an overestimate of potential impacts as discussed previously, a safety margin of 25 percent was chosen to model the impacts of the IDSE. Although the true magnitude of the influence of the IDSE is unknown, EPA believes that the compliance forecast based on analysis of spatial variability provides a plausible prediction.

Exhibit 5.5 Compliance Analysis of ICR Screened Plants at Different Operational Safety Margins

Plant Subset	TTHM/HAA5 LRAA Values	Number of Plants	Percent of All Plants	Delta from Stage 1 to Stage 2	Incremental Percent More Plants Compared to 20 Percent SM for Stage 2	Ratio of Additional Plants to the 20 Percent SM for Stage 2
	A	B	C = B / 213	D = C - 19.2%	E = D - 16.9%	F = D/16.9%
All Screened Plants		213				
Stage 1 non-compliant at 20% SM		41	19.2%			
Stage 2 non-compliant at 20% SM	64 / 48	77	36.2%	**16.9%**		
Stage 2 non-compliant at 25% SM	60 / 45	88	41.3%	**22.1%**	**5.2%**	**1.3**
Stage 2 non-compliant at 30% SM	56 / 42	95	44.6%	**25.4%**	**8.5%**	**1.5**

Sources:
A. MCL * (1 - safety margin)
B. Assessment of ICR screened DBP dataset for surface water systems. See section 3.7.1 for a description of the dataset and screening process

5.3.4.3 Incorporating Potential Impacts of the IDSE into the Compliance Forecast

EPA believes that the 20 percent operational safety margin already accounts for the impacts of the IDSE for some systems, including small systems, ground water systems, and those using chloramines. As discussed earlier, EPA believes that the 20 percent safety margin accounts for potential impacts of the IDSE for small systems because their distribution systems are less complex than those of large systems. EPA also believes that the safety margin accounts for the IDSE for ground water systems because the year-to-year variability in source water quality (and thus, TTHM and HAA5 formation) is low. Chloramine systems generally observe lower spatial and temporal variability in TTHM and HAA5 distribution system levels (USEPA 2005k); thus, EPA believes the 20 percent safety margin accounts for potential impacts of the IDSE for these systems.

EPA believes that the compliance forecast for some large and medium surface water systems using a 20 percent safety margin is already conservative because the treatment technology decision tree (see Appendix A) does not include distribution system operational improvements that systems are more likely to use for compliance with Stage 2 as compared to Stage 1. However, for the reasons given in Section 5.3.4, EPA believes that a compliance forecast based on a safety margin of 25 percent also provides a plausible prediction for some large and medium surface water systems. Because both operational safety margins are considered plausible, EPA's compliance forecast for large and medium surface water systems assigns equal probability to the 20 and 25 percent safety margins. Compliance forecast results in this chapter reflect this assumption.

Although the magnitude of the impacts of the IDSE is uncertain, it is important to note that the IDSE will affect costs and benefits similarly. If higher DBPs are identified through the IDSE, more systems make treatment technology changes and more advanced treatment technologies are selected, increasing both costs and benefits. A sensitivity analysis in Chapter 9 reveals that cost predictions are affected less than benefits predictions. As the safety margin for large and medium surface systems

increases, the net benefit (benefits minus costs) also increases. Therefore, an under prediction of the impact of the IDSE also leads to an under prediction on net benefits.

5.3.5 Methodology for Incorporating SWAT and ICR Matrix Method Results into the Compliance Forecast

As described in Section 5.3.1, EPA uses two tools to predict changes in treatment technology and resulting reductions in DBP levels: SWAT and the ICR Matrix Method. Exhibit 5.6 compares the SWAT and ICR Matrix Method predictions of plants changing treatment technology for Stage 1 and Stage 2. (Comparisons of the predicted reductions in TTHM and HAA5 concentrations are presented in Sections 5.6 and 5.7.) Exhibit 5.6 shows that although the total predicted percentages of plants making treatment technology changes for Stage 2 are similar for both methods, the percent of plants making treatment technology changes to comply with Stage 1 differ between the ICR Matrix Method and SWAT by more than 10 percentage points. Such differences are expected given the inherent differences in the two methods and uncertainties associated with each[7].

Because both SWAT and the ICR Matrix Method have associated uncertainty, results from both are used to generate the compliance forecast for surface water systems. The ICR Matrix Method does not predict the specific treatment technologies that plants will install. Thus, results from the ICR matrix method are incorporated by comparing the predicted percent of plants making treatment technology changes with SWAT results to create a ICR Matrix Method-to-SWAT multiplier, shown in Exhibit 5.6, column G. EPA generated a uniform distribution with 1.0 as the 5th percentile value and the ICR Matrix Method-to-SWAT multiplier for plants making treatment technology changes as the 95th percentile value. Two separate distributions were used, one for the 20 percent safety margin and one for the 25 percent safety margin, as shown in Exhibit 5.6. Exhibit 5.7 provides a graphical depiction of the two uniform distributions for the Preferred Alternative.

[7]One possible explanation for this difference is that the maximum residence time reported in the ICR is not consistent with the maximum TTHM and HAA5 value reported for the system. As shown in Section A.6.4, the maximum TTHM and HAA5 LRAAs often occur at locations other than the one designated as the maximum residence time location (MAX). Uncertainty, and especially underestimates, of the maximum residence time may result in a lower percent of plants predicted by SWAT to make treatment technology changes for Stage 2, but not Stage 1. The average residence time in SWAT is deemed to be more certain because it is based on the mean of the four distribution system residence times reported in the ICR (for the distribution system equivalent sample point (DSE), average sample point number 1 (AVE1), average sample point number 2 (AVE2), and MAX locations).

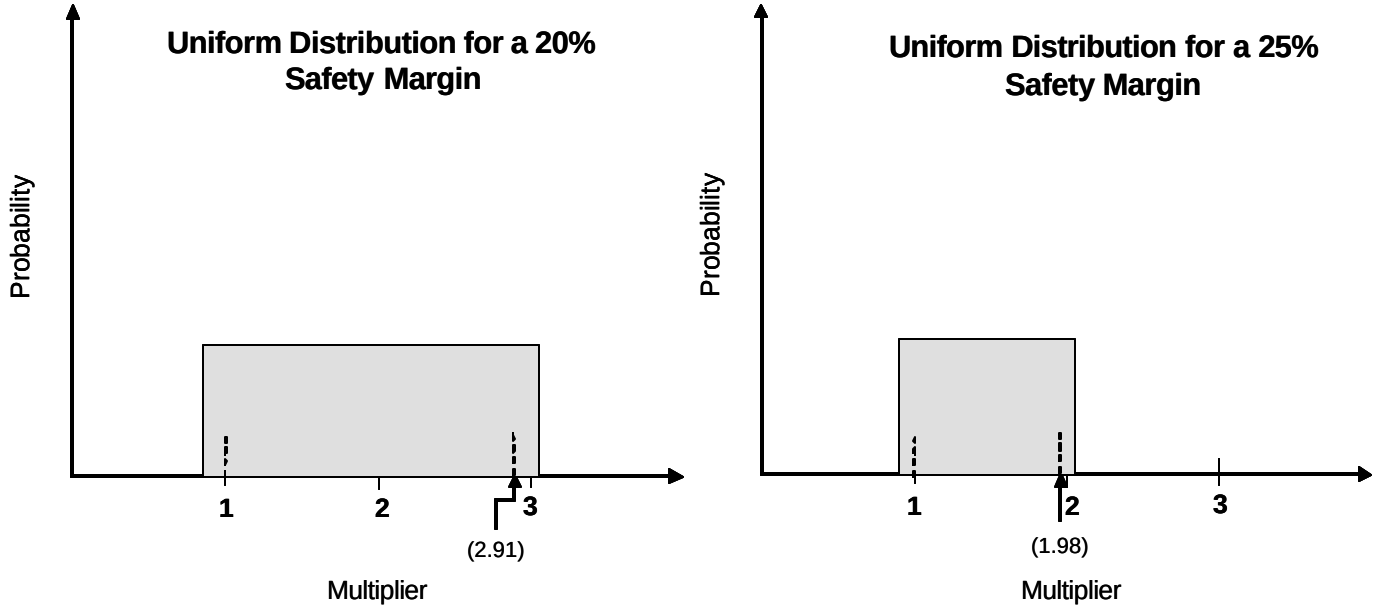
Exhibit 5.6 Predicted Percent of Plants Making Treatment Technology Changes to Meet Stage 1 and Stage 2 Regulatory Alternatives for the ICR Matrix Method and SWAT

Regulatory Alternative	ICR Matrix Method			SWAT			ICR Matrix Method-to-SWAT Multiplier
	% Changing from pre-S1 to pre-S2	% Changing fom pre-S1 to post-S2	% Changing from pre-S2 to post-S2	% Changing from pre-S1 to pre-S2	% Changing fom pre-S1 to post-S2	% Changing from pre-S2 to post-S2	
	A	B	C = B - A	D	E	F = E - D	**G = C / F**
Preferred Reg. Alternative (80/60 LRAA, IDSE), 20% SM	19.2%	36.2%	16.9%	32.5%	38.3%	5.8%	2.91
Preferred Reg. Alternative (80/60 LRAA, IDSE), 25% SM	19.2%	41.3%	22.1%	32.5%	43.7%	11.2%	1.98
Reg. Alternative 1 (Bromate = 5), 20% SM	19.2%	36.2%	16.9%	32.5%	38.6%	6.1%	2.77
Reg. Alternative 2 (80/60 Single High), 20% SM	19.2%	58.2%	39.0%	32.5%	61.2%	28.7%	1.36
Reg. Alternative 3 (40/30 RAA), 20% SM	19.2%	72.8%	53.5%	32.5%	70.4%	37.9%	1.41

Notes: 1) The operational safety margin for Stage 1 is 20 percent for all analyses.

Sources: SWAT run summaries (USEPA 2001b), ICR Matrix Method results (USEPA 2005a).
(A) Percent of plants changing from bin B2 from Exhibit 5.19a. ICR Matrix Method results for Reg. Alternative 1 are the same as for the Preferred Alternative, assuming a 20 percent safety margin.
(B) The sum of percent of plants changing in bins B2 and A2 from Exhibits 5.19b through 5.19d. ICR Matrix Method results for Reg. Alternative 1 are the same as for the Preferred Alternative, 20 percent safety margin.
(D) and (E) SWAT run summaries (USEPA 2001b).

Exhibit 5.7 Uniform Distributions for Incorporating Results from SWAT and the ICR Matrix Method into the Compliance Forecast for Surface Water Systems



Note: The uniform distribution is used when generating the Stage 2 DBPR compliance forecasts for surface water systems for the Preferred Alternative. The same method is applied to the other regulatory alternatives using the multipliers in Exhibit 5.6.

Source: Exhibit 5.6.

5.3.6 Compliance Forecast Simulation Model

To include results from two surface water compliance forecast tools and to account for uncertainty in the potential impacts of the IDSE in the compliance forecast, EPA developed a Monte Carlo simulation model. The model follows three basic steps:

- Step 1: For large and medium surface water systems, the model randomly selects the predicted treatment technology selection delta for either the 20 or 25 percent safety margin runs. Each safety margin has an equal (50 percent) chance of being selected. For small surface water systems and all ground water systems, the treatment technology selection delta for the 20 percent safety margin is always selected.

- Step 2: For large, medium, and small surface water systems, the model randomly selects the ICR-to-SWAT multiplier from the appropriate uniform distribution from Exhibit 5.7 for the safety margin selected in Step 1.

- Step 3: For large, medium, and small surface water systems, the model multiplies the result from Step 2 by the treatment technology selection delta results identified in Step 1 to calculate the percent and number of plants making treatment technology changes from Stage 1 to Stage 2. For ground water systems, the treatment technology selection delta for a 20 percent safety margin is always used to calculate the percent of plants changing from Stage 1 to Stage 2.

The process is repeated 10,000 times to produce a distribution of plants making treatment technology changes from Stage 1 to Stage 2 (results from Step 3). This distribution is carried through the cost model, as described in Chapter 7. Note that for large and medium surface water systems, only the treatment technology selection delta for the 20 percent safety margin is used in Step 1 for Regulatory Alternatives 1, 2, and 3 as the IDSE is not a component of these alternatives.

5.4 Compliance Forecast Results

Three types of compliance forecasts are presented in this EA:

1) **Treatment Technologies-in-Place** forecasts show the number and percent of plants that are using a given treatment technology either before or after rule implementation. For pre-Stage 2 and post-Stage 2 treatment technologies-in-place, the calculated number and percent of plants represents plants predicted to make treatment technology changes to comply with the rule, added to the number and percent of plants already using the treatment technology before rule promulgation.

2) **Treatment Technology Selection** forecasts show the number and percent of plants that are predicted to add a given treatment technology to comply with the Stage 1 DBPR or Stage 2 DBPR regulatory alternatives. These results include only the number of plants that exceed the rule's MCLs and that therefore must make treatment technology changes to comply with the rule. Treatment technology selection results are always based on pre-Stage 1 conditions.

3) **Treatment Technology Selection Delta** forecasts show the incremental number and percent of plants that must add a given treatment technology following the Stage 1 DBPR to meet Stage 2 DBPR MCLs. Treatment technology selection deltas are calculated by subtracting the Stage 1 DBPR treatment technology selection from the Stage 2 DBPR treatment technology selection. These treatment technology selection delta are used for costing.

Note that all forecast results in subsequent sections have the same formatting, with system size down the left hand column and treatment technology across the top. Exhibit 5.8 provides the exhibit numbers for the compliance forecasts for the Stage 2 DBPR Preferred Alternative. Exhibit 5.9 summarizes compliance forecast results for community water systems (CWSs) and NTNCWSs for all regulatory alternatives. Surface water system results in Exhibit 5.9 represent the mean values from the

Monte Carlo simulation model. The results with 90 percent confidence intervals and further population breakouts are shown in Exhibit 7.3.

Exhibit 5.8 Compliance Forecast Exhibits for the Stage 2 DBPR Preferred Alternative

Compliance Forecast Type	Exhibit Containing Results for the Preferred Alternative [1]
Pre-Stage 1 Treatment Technologies-in-Place	Exhibits 3.13 and 3.14
Stage 1 DBPR Treatment Technology Selection	Exhibits C.1 and C.2
Pre-Stage 2 Treatment Technologies-in-Place	Exhibit 5.10 and 5-13
Stage 2 DBPR Treatment Technology Selection Delta	Exhibits 5.11 and 5.14[2]
Post-Stage 2 Treatment Technologies-in-Place	Exhibits 5.12 and 5.15

Notes:
1. The first exhibit contains results for surface water plants, the second for ground water plants.
2. Treatment technology selection delta tables are used for costing.

Surface Water Systems

Section 3.6.2 describes how predictions of pre-Stage 1 treatment technologies-in-place were developed. The pre-Stage 1 baseline for surface water systems is shown in Exhibit 3.13.

Exhibit 5.10 shows the predicted treatment technologies-in-place for surface water plants following the Stage 1 DBPR (i.e., the pre-Stage 2 DBPR baseline). The treatment technologies-in-place for small surface and ground water systems can be derived by adding the treatment technology selection for the Stage 1 DBPR (Exhibit C.1a for CWS, C.1b for NTNCWS) to the treatment technologies-in-place for the pre-Stage 1 baseline (Exhibit 3.13). This is not true, however, for plants in large and medium systems. EPA assumes that pre-Stage 2, only medium and large systems employ advanced treatment technologies. Therefore, the SWAT program produces a different type of result, called "ending technologies," that accounts for these plants that already have an advanced treatment technology but must select another to meet the rule alternative.

Exhibits 5.11a through 5.11d present the treatment technology selection deltas, as a percentage (5.11a for CWS, 5.11c for NTNCWS) and as the number of plants (5.11b for CWS, 5.11d for NTNCWS), for the Stage 2 DBPR Preferred Alternative for surface water systems. These exhibits are used to predict costs for surface water systems. As described in Section 5.3, technology selection deltas for surface water systems incorporate two compliance forecast methods: SWAT and the ICR Matrix Method. For the Preferred Alternative, the Stage 2 treatment technology selection deltas for large and medium surface water systems represents equal probability of a 20 and 25 percent safety margin to model the potential impact of the IDSE.

Exhibits 5.12a through 5.12d present the final post-Stage 2 treatment technologies-in-place for surface water systems under the Stage 2 DBPR Preferred Alternative.

Ground Water Systems

Exhibit 3.14 summarizes the pre-Stage 1 DBPR baseline treatment technologies-in-place for ground water treatment plants. The derivation of this baseline is discussed in Section 3.6.2. For plants in large and medium ground water systems, ICR treatment data were used to derive the predicted percent of plants using each treatment technology. The percentage of small ground water plants using each treatment technology is based on evaluation of CWS data; EPA assumed that NTNCWSs use similar treatment technologies for the size categories shown.

Exhibit 5.13 shows the predicted treatment technologies-in-place for ground water plants following the Stage 1 DBPR (pre-Stage 2 DBPR baseline). The treatment technologies-in-place for the pre-Stage 2 baseline can be derived by adding the treatment technology selection for the Stage 1 DBPR (Exhibit C.2a for CWS, C.2b for NTNCWS) to the treatment technologies-in-place for the pre-Stage 1 baseline (Exhibit 3.14a for CWS, 3.14b for NTNCWS).

Exhibits 5.14a through 5.14d present the treatment technology selection deltas for ground water systems. EPA used these deltas to predict the costs to ground water systems of complying with the Stage 2 DBPR. Exhibits 5.15a through 5.15d present EPA's prediction of treatment technologies that will be employed after systems comply with the Stage 2 DBPR. For all plants, post-Stage 2 treatment technologies-in-place can be derived by adding the predicted pre-Stage 2 treatment technologies-in-place (Exhibit 5.13) to the treatment technology selections in Exhibit 5.14.

Exhibit 5.9 Plants in CWSs and NTNCWSs Making Treatment Technology Changes From Stage 1 For Stage 2 DBPR Regulatory Alternatives

System Size and Type	Baseline Number of CWS and NTNCWS Plants	Mean Estimate of Plants Changing Treatment Technology from Stage 1 to Stage 2 (including CLM)	
		Number	Percent
	A	B	C = B / A
Preferred Regulatory Alternative			
SW > 10K	2,561	409	16.0%
SW < 10K	4,757	461	9.7%
GW > 10K	7,048	145	2.1%
GW < 10K	45,855	1,323	2.9%
All Plants	**60,221**	**2,338**	**3.9%**
Alternative 1 (BR 5)			
SW > 10K	2,561	331	12.9%
SW < 10K	4,757	456	9.6%
GW > 10K	7,048	145	2.1%
GW < 10K	45,855	1,327	2.9%
All Plants	**60,221**	**2,259**	**3.8%**
Alternative 2 (80/60 SH)			
SW > 10K	2,561	926	36.2%
SW < 10K	4,757	1,093	23.0%
GW > 10K	7,048	488	6.9%
GW < 10K	45,855	2,374	5.2%
All Plants	**60,221**	**4,881**	**8.1%**
Alternative 3 (40/30 RAA)			
SW > 10K	2,561	1,226	47.9%
SW < 10K	4,757	1,341	28.2%
GW > 10K	7,048	334	4.7%
GW < 10K	45,855	1,610	3.5%
All Plants	**60,221**	**4,511**	**7.5%**

Notes: Uncertainty in the impacts of the IDSE for SW systems serving >10,000 people are reflected in estimates for the Preferred Regulatory Alternative only. Estimates for all SW systems are the averages of the results of two methods: SWAT and the ICR Matrix Method.

Sources: (A) Baseline Number of CWS and NTNCWS plants from Chapter 3, Exhibit 3.2.

(B) Exhibits 5.11 and 5.14 for the Preferred Regulatory Alternative, Exhibits C.3 and C.4 for Alternative 1, Exhibits C.7 and C.8 for Alternative 2, and Exhibits C.11 and C.12 for Alternative 3

Exhibit 5.10a Pre-Stage 2 DBPR Treatment Technologies-in-Place for CWS Surface Water Plants (Percent and Number of Plants by Residual Disinfection Type)

System Size (Population Served)	No Advanced Treatment Technologies1 CL2		No Advanced Treatment Technologies1 CLM		Chlorine Dioxide				UV				Ozone				MF/UF				GAC10			
					CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM	
	A		B		C		D		E		F		G		H		I		J		K		L	
	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#
<100	41.8%	150	29.7%	107													14.5%	52	7.1%	26				
100-499	35.6%	273	35.4%	272	1.0%	7	0.9%	7					5.1%	39	4.6%	35	8.9%	68	4.8%	37				
500-999		172		171		5		4						24		22		43		23				
1,000-3,299	33.4%	378	41.3%	467	1.9%	22	2.1%	24					4.0%	45	4.5%	51	6.2%	70	2.9%	32				
3,300-9,999		421		520		24		27						50		56		78		36				
10,000-49,999	35.0%	452	39.0%	504	3.3%	42	3.7%	47					6.1%	78	6.8%	87	0.9%	11	1.0%	12	1.0%	13	1.2%	15
50,000-99,999		203		226		19		21						35		39		5		6		6		7
100,000-999,999	35.0%	213	39.0%	238	3.3%	20	3.7%	22					6.1%	37	6.8%	41	0.9%	5	1.0%	6	1.0%	6	1.2%	7
>=1,000,000		26		29		2		3						4		5		1		1		1		1
Total Plants, %	34.9%	2,287	38.7%	2,534	2.2%	141	2.4%	155					4.8%	314	5.1%	337	5.1%	333	2.7%	179	0.4%	27	0.5%	30

System Size (Population Served)	GAC10 + AD				GAC20				GAC20 + AD				Membranes				TOTAL			
	CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM	
	M		N		O		P		Q		R		S		T		U = A+C+E+G+I+K+M+O+Q+S		V = B+D+F+H+J+L+N+P+R+T	
	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#
<100					2.0%	7	1.3%	5	0.0%	0	0.0%	0	2.1%	8	1.4%	5	60.4%	217	39.6%	142
100-499					1.1%	8	1.0%	7	0.5%	4	0.4%	3	0.5%	3	0.4%	3	52.5%	403	47.5%	364
500-999						5		5		2		2		2		2		254		229
1,000-3,299					1.0%	12	1.2%	13	0.5%	6	0.6%	7	0.2%	2	0.2%	2	47.3%	534	52.7%	596
3,300-9,999						13		15		7		7		2		2		595		664
10,000-49,999	0.5%	7	0.6%	7	0.2%	2	0.2%	2	0.0%	0	0.0%	0	0.3%	4	0.4%	5	47.3%	610	52.7%	681
50,000-99,999		3		3		1		1		0		0		2		2		274		306
100,000-999,999	0.5%	3	0.6%	4	0.2%	1	0.2%	1	0.0%	0	0.0%	0	0.3%	2	0.4%	2	47.3%	288	52.7%	322
>=1,000,000		0		0		0		0		0		0		0		0		35		39
Total Plants, %	0.2%	13	0.2%	15	0.8%	49	0.8%	49	0.3%	18	0.3%	19	0.4%	26	0.4%	25	49.0%	3,209	51.0%	3,342

Note: Detail may not add to totals due to independent rounding

[1]"No Adv" includes conventional, non-conventional, and softening plants.

Source: Surface water systems serving <10,000 people: Add Treatment Technologies-in-Place for the Pre-Stage 1 DBPR Baseline (Exhibit 3.13a) to Stage 1 Treatment Technology Selection (Exhibit C.1a).
Surface water systems serving 10,000 or more people: Use ending Treatment Technology predictions from SWAT (FACA Screen Series3 v3.0 Database) (USEPA, 2001e).

Exhibit 5.10b Pre-Stage 2 DBPR Treatment Technologies-in-Place for NTNCWS Surface Water Plants (Percent and Number of Plants by Residual Disinfection Type)

System Size (Population Served)	No Advanced Treatment Technologies1 CL2		No Advanced Treatment Technologies1 CLM		Chlorine Dioxide				UV				Ozone				MF/UF				GAC10			
					CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM	
	A		B		C		D		E		F		G		H		I		J		K		L	
	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#
<100	41.8%	95	29.7%	67													14.5%	33	7.1%	16				
100-499	35.6%	111	35.4%	111	1.0%	3	0.9%	3					5.1%	16	4.6%	14	8.9%	28	4.8%	15				
500-999		38		38		1		1						5		5		9		5				
1,000-3,299	33.4%	31	41.3%	38	1.9%	2	2.1%	2					4.0%	4	4.5%	4	6.2%	6	2.9%	3				
3,300-9,999		8		10		0		1						1		1		2		1				
10,000-49,999	35.0%	2	39.0%	2	3.3%	0	3.7%	0					6.1%	0	6.8%	0	0.9%	0	1.0%	0	1.0%	0	1.2%	0
50,000-99,999		0		0		0		0						0		0		0		0		0		0
100,000-999,999	35.0%	0	39.0%	0	3.3%	0	3.7%	0					6.1%	0	6.8%	0	0.9%	0	1.0%	0	1.0%	0	1.2%	0
>=1,000,000		0		0		0		0						0		0		0		0		0		0
Total Plants, %	37.1%	285	34.7%	266	0.8%	6	0.8%	6					3.4%	26	3.2%	25	10.1%	77	5.2%	40	0.0%	0	0.0%	0

System Size (Population Served)	GAC10 + AD				GAC20				GAC20 + AD				Membranes				TOTAL			
	CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM		CL2		CLM	
	M		N		O		P		Q		R		S		T		U = A+C+E+G+I+K+M+O+Q+S		V = B+D+F+H+J+L+N+P+R+T	
	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#
<100					2.0%	4	1.3%	3	0.0%	0	0.0%	0	2.1%	5	1.4%	3	60.4%	137	39.6%	89
100-499					1.1%	3	1.0%	3	0.5%	2	0.4%	1	0.5%	1	0.4%	1	52.5%	164	47.5%	148
500-999						1		1		1		0		0		0		56		50
1,000-3,299					1.0%	1	1.2%	1	0.5%	0	0.6%	1	0.2%	0	0.2%	0	47.3%	43	52.7%	49
3,300-9,999						0		0		0		0		0		0		12		13
10,000-49,999	0.5%	0	0.6%	0	0.2%	0	0.2%	0	0.0%	0	0.0%	0	0.3%	0	0.4%	0	47.3%	2	52.7%	3
50,000-99,999		0		0		0		0		0		0		0		0		0		0
100,000-999,999	0.5%	0	0.6%	0	0.2%	0	0.2%	0	0.0%	0	0.0%	0	0.3%	0	0.4%	0	47.3%	0	52.7%	1
>=1,000,000		0		0		0		0		0		0		0		0		0		0
Total Plants, %	0.0%	0	0.0%	0	1.3%	10	1.1%	8	0.3%	3	0.3%	3	0.9%	7	0.7%	5	54.0%	414	46.0%	353

Note: Detail may not add to totals due to independent rounding

[1]"No Adv" includes conventional, non-conventional, and softening plants.

Source: Surface water systems serving <10,000 people: Add Treatment Technologies-in-Place for the Pre-Stage 1 DBPR Baseline (Exhibit 3.13b) to Stage 1 Treatment Technology Selection (Exhibit C.1b).
Surface water systems serving 10,000 or more people: Use ending Treatment Technology predictions from SWAT (FACA Screen Series3 v3.0 Database) (USEPA, 2001e).

Exhibit 5.11a
Stage 2 DBPR Treatment Technology Selection Deltas for CWS Surface Water Plants (Percent of Plants by Residual Disinfection Type)
Preferred Alternative

System Size (Population Served)	Converting to CLM Only			Chlorine Dioxide						UV						Ozone						MF/UF						GAC10					
				CL2			CLM			CL2			CLM			CL2			CLM			CL2			CLM			CL2			CLM		
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	A			B			C			D			E			F			G			H			I			J			K		
<100	2.1%	1.1%	3.1%							4.5%	2.3%	6.6%	3.3%	1.7%	4.9%							0.0%	0.0%	0.0%	0.0%	0.0%	0.0%						
100-499	4.5%	2.3%	6.6%	0.1%	0.1%	0.2%	0.4%	0.2%	0.6%	1.3%	0.7%	2.0%	1.4%	0.7%	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%						
500-999	4.5%	2.3%	6.6%	0.1%	0.1%	0.2%	0.4%	0.2%	0.6%	1.3%	0.7%	2.0%	1.4%	0.7%	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%						
1,000-3,299	4.6%	2.4%	6.9%	0.2%	0.1%	0.3%	1.0%	0.5%	1.5%	1.0%	0.5%	1.5%	1.4%	0.7%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%						
3,300-9,999	4.6%	2.4%	6.9%	0.2%	0.1%	0.3%	1.0%	0.5%	1.5%	1.0%	0.5%	1.5%	1.4%	0.7%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%						
10,000-49,999	9.5%	4.9%	13.7%	0.0%	0.0%	0.0%	0.4%	0.5%	0.1%	3.1%	0.7%	6.6%	0.9%	0.2%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
50,000-99,999	9.5%	4.9%	13.7%	0.0%	0.0%	0.0%	0.4%	0.5%	0.1%	3.1%	0.7%	6.6%	0.9%	0.2%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100,000-999,999	9.5%	4.9%	13.7%	0.0%	0.0%	0.0%	0.4%	0.5%	0.1%	3.1%	0.7%	6.6%	0.9%	0.2%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
>=1,000,000	9.5%	4.9%	13.7%	0.0%	0.0%	0.0%	0.4%	0.5%	0.1%	3.1%	0.7%	6.6%	0.9%	0.2%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total %	6.4%	3.3%	9.3%	0.1%	0.0%	0.1%	0.6%	0.4%	0.7%	2.1%	0.7%	3.9%	1.3%	0.6%	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

System Size (Population Served)	GAC10 + Advanced Disinfectants						GAC20						GAC20 + Advanced Disinfectants						Membranes						Total Converting to CLM			Plants Making Treatment Technology Changes					
	CL2			CLM			CL2			CLM			CL2			CLM			CL2			CLM											
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	L			M			N			O			P			Q			R			S			T=A+C+E+G+I+K+M+O+Q+S			L = SUM(A:S)					
<100							0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.4%	1.1%	0.5%	0.3%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.9%	3.1%	8.8%	11.2%	5.8%	16.5%			
100-499							0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.3%	0.9%	0.8%	0.4%	1.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	7.1%	3.7%	10.5%	9.2%	4.8%	13.6%			
500-999							0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.3%	0.9%	0.8%	0.4%	1.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	7.1%	3.7%	10.5%	9.2%	4.8%	13.6%	9.6%	5.0%	14.2%
1,000-3,299							0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.3%	0.8%	0.9%	0.5%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.9%	4.1%	11.7%	9.7%	5.0%	14.3%			
3,300-9,999							0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.3%	0.8%	0.9%	0.5%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.9%	4.1%	11.7%	9.7%	5.0%	14.3%			
10,000-49,999	1.3%	0.6%	2.0%	0.5%	0.2%	0.8%	0.3%	0.0%	0.8%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.3%	5.8%	16.8%	16.0%	7.0%	26.1%			
50,000-99,999	1.3%	0.6%	2.0%	0.5%	0.2%	0.8%	0.3%	0.0%	0.8%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.3%	5.8%	16.8%	16.0%	7.0%	26.1%	16.0%	7.0%	26.1%
100,000-999,999	1.3%	0.6%	2.0%	0.5%	0.2%	0.8%	0.3%	0.0%	0.8%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.3%	5.8%	16.8%	16.0%	7.0%	26.1%			
>=1,000,000	1.3%	0.6%	2.0%	0.5%	0.2%	0.8%	0.3%	0.0%	0.8%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.3%	5.8%	16.8%	16.0%	7.0%	26.1%			
Total %	0.5%	0.2%	0.8%	0.2%	0.1%	0.3%	0.1%	0.0%	0.3%	0.0%	0.0%	0.1%	0.4%	0.2%	0.5%	0.5%	0.3%	0.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	9.0%	4.6%	13.3%	12.1%	5.8%	18.9%	12.1%	5.8%	18.9%

Note: Detail may not add to totals due to independent rounding

Source: Treatment Technology Selection for the Preferred Alternative minus the Stage 1 Treatment Technology Selection from Appendix C, Exhibit C.1a.

Exhibit 5.11b
Stage 2 DBPR Treatment Technology Selection Deltas for CWS Surface Water Plants (Number of Plants by Residual Disinfection Type)
Preferred Alternative

System Size (Population Served)	Converting to CLM Only			Chlorine Dioxide						UV						Ozone						MF/UF						GAC10					
				CL2			CLM			CL2			CLM			CL2			CLM			CL2			CLM			CL2			CLM		
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	A			B						C						D						E						F					
<100	7	4	11							16	8	24	12	6	18							0	0	0	0	0	0						
100-499	34	18	51	1	1	1	3	2	5	10	5	15	11	6	16	0	0	0	0	0	0	0	0	0	0	0	0						
500-999	22	11	32	1	0	1	2	1	3	6	3	10	7	4	10	0	0	0	0	0	0	0	0	0	0	0	0						
1,000-3,299	52	27	78	2	1	3	11	6	17	12	6	17	16	8	23	0	0	0	0	0	0	0	0	0	0	0	0						
3,300-9,999	58	30	87	2	1	4	12	6	18	13	7	19	17	9	26	0	0	0	0	0	0	0	0	0	0	0	0						
10,000-49,999	122	64	177	0	0	0	5	6	1	40	8	85	11	2	24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50,000-99,999	55	29	80	0	0	0	2	3	1	18	4	38	5	1	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100,000-999,999	58	30	84	0	0	0	2	3	1	19	4	40	5	1	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>=1,000,000	7	4	10	0	0	0	0	0	0	2	0	5	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Plants	416	216	609	6	3	9	38	27	45	138	47	253	84	36	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

System Size (Population Served)	GAC10 + Advanced Disinfectants						GAC20						GAC20 + Advanced Disinfectants						Membranes						Total Converting to CLM			Plants Making Treatment Technology Changes					
	CL2			CLM			CL2			CLM			CL2			CLM			CL2			CLM											
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	G						H						I						J						Q+S			L = SUM(A:S)					
<100							0	0	0	0	0	0	3	1	4	2	1	3	0	0	0	0	0	0	21	11	32	40	21	59			
100-499							0	0	0	0	0	0	5	2	7	6	3	9	0	0	0	0	0	1	55	28	81	71	36	104			
500-999							0	0	0	0	0	0	3	2	4	4	2	5	0	0	0	0	0	0	34	18	51	44	23	66	386	200	572
1,000-3,299							0	0	0	0	0	0	6	3	9	10	5	15	0	0	0	0	0	0	89	46	132	109	57	162			
3,300-9,999							0	0	0	0	0	0	7	3	10	11	6	17	0	0	0	0	0	0	100	52	147	122	63	180			
10,000-49,999	17	8	26	7	3	10	3	0	10	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	146	75	217	206	91	338			
50,000-99,999	8	3	12	3	1	5	1	0	5	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	66	34	97	93	41	151	408	180	668
100,000-999,999	8	4	12	3	1	5	2	0	5	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	69	35	102	98	43	160			
>=1,000,000	1	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	4	12	12	5	19			
Total Plants	33	15	51	13	6	21	6	0	20	3	1	6	23	12	34	33	17	49	0	0	0	1	0	1	588	303	872	795	380	1,240	795	380	1,240

Note: Detail may not add to totals due to independent rounding

Source: Above table with Treatment Technologies switching from an advanced Treatment Technology with Cl2 to the same advanced Treatment Technology with CLM being moved into the CLM only column

Exhibit 5.11c

Stage 2 DBPR Treatment Technology Selection Deltas for NTNCWS Surface Water Plants (Percent of Plants by Residual Disinfection Type)

Preferred Alternative

System Size (Population Served)	Converting to CLM Only			Chlorine Dioxide						UV						Ozone						MF/UF						GAC10					
				CL2			CLM			CL2			CLM			CL2			CLM			CL2			CLM			CL2			CLM		
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	A			B			C			D			E			F			G			H			I			J			K		
<100	2.1%	1.1%	3.1%							4.5%	2.3%	6.6%	3.3%	1.7%	4.9%							0.0%	0.0%	0.0%	0.0%	0.0%	0.0%						
100-499	4.5%	2.3%	6.6%	0.1%	0.1%	0.2%	0.4%	0.2%	0.6%	1.3%	0.7%	2.0%	1.4%	0.7%	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%						
500-999	4.5%	2.3%	6.6%	0.1%	0.1%	0.2%	0.4%	0.2%	0.6%	1.3%	0.7%	2.0%	1.4%	0.7%	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%						
1,000-3,299	4.6%	2.4%	6.9%	0.2%	0.1%	0.3%	1.0%	0.5%	1.5%	1.0%	0.5%	1.5%	1.4%	0.7%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%						
3,300-9,999	4.6%	2.4%	6.9%	0.2%	0.1%	0.3%	1.0%	0.5%	1.5%	1.0%	0.5%	1.5%	1.4%	0.7%	2.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%						
10,000-49,999	9.5%	4.9%	13.7%	0.0%	0.0%	0.0%	0.4%	0.5%	0.1%	3.1%	0.7%	6.6%	0.9%	0.2%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
50,000-99,999	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100,000-999,999	9.5%	4.9%	13.7%	0.0%	0.0%	0.0%	0.4%	0.5%	0.1%	3.1%	0.7%	6.6%	0.9%	0.2%	1.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
>=1,000,000	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total %	3.8%	2.0%	5.7%	0.1%	0.1%	0.1%	0.4%	0.2%	0.5%	2.2%	1.1%	3.3%	2.0%	1.0%	2.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

System Size (Population Served)	GAC10 + Advanced Disinfectants						GAC20						GAC20 + Advanced Disinfectants						Membranes						Total Converting to CLM			Plants Making Treatment Technology Changes					
	CL2			CLM			CL2			CLM			CL2			CLM			CL2			CLM											
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	L			M			N			O			P			Q			R			S			T=A+C+E+G+I+K+M+O+Q+S			L = SUM(A:S)					
<100							0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.7%	0.4%	1.1%	0.5%	0.3%	0.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	5.9%	3.1%	8.8%	11.2%	5.8%	16.5%			
100-499							0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.3%	0.9%	0.8%	0.4%	1.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	7.1%	3.7%	10.5%	9.2%	4.8%	13.6%			
500-999							0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.3%	0.9%	0.8%	0.4%	1.1%	0.0%	0.0%	0.0%	0.1%	0.0%	0.1%	7.1%	3.7%	10.5%	9.2%	4.8%	13.6%	10.1%	5.2%	15.0%
1,000-3,299							0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.3%	0.8%	0.9%	0.5%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.9%	4.1%	11.7%	9.7%	5.0%	14.3%			
3,300-9,999							0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.5%	0.3%	0.8%	0.9%	0.5%	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	7.9%	4.1%	11.7%	9.7%	5.0%	14.3%			
10,000-49,999	1.3%	0.6%	2.0%	0.5%	0.2%	0.8%	0.3%	0.0%	0.8%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.3%	5.8%	16.8%	16.0%	7.0%	26.1%			
50,000-99,999	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	16.0%	7.0%	26.1%
100,000-999,999	1.3%	0.6%	2.0%	0.5%	0.2%	0.8%	0.3%	0.0%	0.8%	0.1%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	11.3%	5.8%	16.8%	16.0%	7.0%	26.1%			
>=1,000,000	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%			
Total %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.6%	0.3%	0.9%	0.7%	0.4%	1.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	6.9%	3.6%	10.3%	9.9%	5.1%	14.7%	9.9%	5.1%	14.7%

Note: Detail may not add to totals due to independent rounding

Source: Treatment Technology Selection for the Preferred Alternative minus the Stage 1 Treatment Technology Selection from Appendix C, Exhibit C.1b.

Exhibit 5.11d

Stage 2 DBPR Treatment Technology Selection Deltas for NTNCWS Surface Water Plants (Number of Plants by Residual Disinfection Type)

Preferred Alternative

System Size (Population Served)	Converting to CLM Only			Chlorine Dioxide						UV						Ozone						MF/UF						GAC10					
				CL2			CLM			CL2			CLM			CL2			CLM			CL2			CLM			CL2			CLM		
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	A			B						C						D						E						F					
<100	5	2	7							10	5	15	8	4	11							0	0	0	0	0	0						
100-499	14	7	21	0	0	1	1	1	2	4	2	6	4	2	6	0	0	0	0	0	0	0	0	0	0	0	0						
500-999	5	2	7	0	0	0	0	0	1	1	1	2	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0						
1,000-3,299	4	2	6	0	0	0	1	0	1	1	0	1	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0						
3,300-9,999	1	1	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0						
10,000-49,999	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50,000-99,999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100,000-999,999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>=1,000,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Plants	29	15	44	1	0	1	3	1	4	17	9	26	15	8	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

System Size (Population Served)	GAC10 + Advanced Disinfectants						GAC20						GAC20 + Advanced Disinfectants						Membranes						Total Converting to CLM			Plants Making Treatment Technology Changes					
	CL2			CLM			CL2			CLM			CL2			CLM			CL2			CLM											
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	G						H						I						J						Q+S			L = SUM(A:S)					
<100							0	0	0	0	0	0	2	1	2	1	1	2	0	0	0	0	0	0	13	7	20	25	13	37			
100-499							0	0	0	0	0	0	2	1	3	2	1	4	0	0	0	0	0	0	22	11	33	29	15	43			
500-999							0	0	0	0	0	0	1	0	1	1	0	1	0	0	0	0	0	0	8	4	11	10	5	14	75	39	111
1,000-3,299							0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	7	4	11	9	5	13			
3,300-9,999							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	3	2	1	4			
10,000-49,999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1			
50,000-99,999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
100,000-999,999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
>=1,000,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
Total Plants	0	0	0	0	0	0	0	0	0	0	0	0	5	3	7	6	3	8	0	0	0	0	0	0	53	27	79	76	39	113	76	39	113

Note: Detail may not add to totals due to independent rounding

Source: Above table with Treatment Technologies switching from an advanced Treatment Technology with Cl2 to the same advanced Treatment Technology with CLM being moved into the CLM only column

Exhibit 5.12a
Post-Stage 2 DBPR Treatment Technologies-in-Place for CWS Surface Water Plants (Percent of Plants by Residual Disinfection Type)
Preferred Alternative

System Size (Population Served)	No Advanced Treatment Technology CL21			No Advanced Treatment Technology CLM1			Chlorine Dioxide CL2			Chlorine Dioxide CLM			UV CL2			UV CLM			Ozone CL2			Ozone CLM			MF/UF CL2			MF/UF CLM			GAC 10 CL2			GAC 10 CLM		
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	A			B			C			D			E			F			G			H			I			J			K			L		
<100	30.7%	25.3%	36.1%	31.8%	30.8%	32.8%							4.5%	2.3%	6.6%	3.3%	1.7%	4.9%							14.5%	14.5%	14.5%	7.1%	7.1%	7.1%						
100-499	26.4%	22.0%	30.8%	39.9%	37.7%	42.1%	1.1%	1.0%	1.2%	1.3%	1.1%	1.5%	1.3%	0.7%	2.0%	1.4%	0.7%	2.1%	5.1%	5.1%	5.1%	4.6%	4.6%	4.6%	8.9%	8.9%	8.9%	4.8%	4.8%	4.8%						
500-999	26.4%	22.0%	30.8%	39.9%	37.7%	42.1%	1.1%	1.0%	1.2%	1.3%	1.1%	1.5%	1.3%	0.7%	2.0%	1.4%	0.7%	2.1%	5.1%	5.1%	5.1%	4.6%	4.6%	4.6%	8.9%	8.9%	8.9%	4.8%	4.8%	4.8%						
1,000-3,299	23.8%	19.1%	28.4%	46.0%	43.8%	48.2%	2.1%	2.0%	2.2%	3.1%	2.6%	3.6%	1.0%	0.5%	1.5%	1.4%	0.7%	2.0%	4.0%	4.0%	4.0%	4.5%	4.5%	4.5%	6.2%	6.2%	6.2%	2.9%	2.9%	2.9%						
3,300-9,999	23.8%	19.1%	28.4%	46.0%	43.8%	48.2%	2.1%	2.0%	2.2%	3.1%	2.6%	3.6%	1.0%	0.5%	1.5%	1.4%	0.7%	2.0%	4.0%	4.0%	4.0%	4.5%	4.5%	4.5%	6.2%	6.2%	6.2%	2.9%	2.9%	2.9%						
10,000-49,999	29.3%	25.5%	33.2%	41.2%	41.0%	41.4%	2.7%	2.3%	3.0%	3.7%	3.5%	4.0%	1.1%	0.3%	1.9%	1.6%	0.4%	2.9%	5.3%	5.1%	5.5%	7.5%	7.3%	7.7%	0.8%	0.7%	0.8%	1.1%	1.0%	1.1%	0.9%	0.9%	0.9%	1.3%	1.2%	1.3%
50,000-99,999	29.3%	25.5%	33.2%	41.2%	41.0%	41.4%	2.7%	2.3%	3.0%	3.7%	3.5%	4.0%	1.1%	0.3%	1.9%	1.6%	0.4%	2.9%	5.3%	5.1%	5.5%	7.5%	7.3%	7.7%	0.8%	0.7%	0.8%	1.1%	1.0%	1.1%	0.9%	0.9%	0.9%	1.3%	1.2%	1.3%
100,000-999,999	29.3%	25.5%	33.2%	41.2%	41.0%	41.4%	2.7%	2.3%	3.0%	3.7%	3.5%	4.0%	1.1%	0.3%	1.9%	1.6%	0.4%	2.9%	5.3%	5.1%	5.5%	7.5%	7.3%	7.7%	0.8%	0.7%	0.8%	1.1%	1.0%	1.1%	0.9%	0.9%	0.9%	1.3%	1.2%	1.3%
>=1,000,000	29.3%	25.5%	33.2%	41.2%	41.0%	41.4%	2.7%	2.3%	3.0%	3.7%	3.5%	4.0%	1.1%	0.3%	1.9%	1.6%	0.4%	2.9%	5.3%	5.1%	5.5%	7.5%	7.3%	7.7%	0.8%	0.7%	0.8%	1.1%	1.0%	1.1%	0.9%	0.9%	0.9%	1.3%	1.2%	1.3%
Total %	26.8%	22.5%	31.2%	42.2%	40.8%	43.5%	2.0%	1.8%	2.2%	2.8%	2.5%	3.1%	1.3%	0.6%	2.0%	1.6%	0.7%	2.5%	4.5%	4.4%	4.6%	5.4%	5.3%	5.5%	5.0%	5.0%	5.1%	2.8%	2.8%	2.8%	0.4%	0.3%	0.4%	0.5%	0.5%	0.5%

System Size (Population Served)	GAC10 + AD CL2			GAC10 + AD CLM			GAC20 CL2			GAC20 CLM			GAC20 + AD CL2			GAC20 + AD CLM			Membranes CL2			Membranes CLM			TOTAL CL2			TOTAL CLM		
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	M			N			O			P			Q			R			S			T			U = A+C+E+G+I+K+M+O+Q+S			V = B+D+F+H+J+L+N+P+R+T		
<100							2.0%	2.0%	2.0%	1.3%	1.3%	1.3%	0.7%	0.4%	1.1%	0.5%	0.3%	0.8%	2.1%	2.1%	2.1%	1.4%	1.4%	1.4%	54.5%	46.6%	62.4%	45.5%	42.6%	48.4%
100-499							1.1%	1.1%	1.1%	1.0%	1.0%	1.0%	1.1%	0.8%	1.4%	1.2%	0.8%	1.6%	0.5%	0.5%	0.5%	0.5%	0.4%	0.5%	45.4%	40.0%	50.8%	54.6%	51.2%	58.0%
500-999							1.1%	1.1%	1.1%	1.0%	1.0%	1.0%	1.1%	0.8%	1.4%	1.2%	0.8%	1.6%	0.5%	0.5%	0.5%	0.5%	0.4%	0.5%	45.4%	40.0%	50.8%	54.6%	51.2%	58.0%
1,000-3,299							1.0%	1.0%	1.0%	1.2%	1.2%	1.2%	1.1%	0.8%	1.3%	1.5%	1.0%	1.9%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	39.3%	33.8%	44.9%	60.7%	56.8%	64.5%
3,300-9,999							1.0%	1.0%	1.0%	1.2%	1.2%	1.2%	1.1%	0.8%	1.3%	1.5%	1.0%	1.9%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	39.3%	33.8%	44.9%	60.7%	56.8%	64.5%
10,000-49,999	0.9%	0.8%	1.0%	1.3%	1.0%	1.5%	0.2%	0.1%	0.3%	0.3%	0.2%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	41.6%	36.1%	47.1%	58.4%	56.1%	60.7%
50,000-99,999	0.9%	0.8%	1.0%	1.3%	1.0%	1.5%	0.2%	0.1%	0.3%	0.3%	0.2%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	41.6%	36.1%	47.1%	58.4%	56.1%	60.7%
100,000-999,999	0.9%	0.8%	1.0%	1.3%	1.0%	1.5%	0.2%	0.1%	0.3%	0.3%	0.2%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	41.6%	36.1%	47.1%	58.4%	56.1%	60.7%
>=1,000,000	0.9%	0.8%	1.0%	1.3%	1.0%	1.5%	0.2%	0.1%	0.3%	0.3%	0.2%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	41.6%	36.1%	47.1%	58.4%	56.1%	60.7%
Total %	0.4%	0.3%	0.4%	0.5%	0.4%	0.6%	0.8%	0.7%	0.8%	0.8%	0.8%	0.8%	0.6%	0.5%	0.8%	0.8%	0.6%	1.0%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	42.2%	36.6%	47.8%	57.8%	54.7%	60.9%

Note: Detail may not add to totals due to independent rounding

[1]No advanced Treatment Technologies includes conventional, non-conventional, and softening plants.

Source: Surface water systems serving <10,000 people: Add Treatment Technologies-in-Place for the Pre-Stage 2 Baseline (Exhibit 6.14a) to the Treatment Technology Selection Delta for the Preferred Alternative. Surface water systems serving 10,000 or more people: Use ending Treatment Technology predictions from SWAT (FACA Screen Series3 v3.0 Database) for the Preferred Alternative.

Exhibit 5.12b
Post-Stage 2 DBPR Treatment Technologies-in-Place for CWS Surface Water Plants (Number of Plants by Residual Disinfection Type)
Preferred Alternative

System Size (Population Served)	No Advanced Treatment Technology CL21			No Advanced Treatment Technology CLM1			Chlorine Dioxide CL2			Chlorine Dioxide CLM			UV CL2			UV CLM			Ozone CL2			Ozone CLM			MF/UF CL2			MF/UF CLM			GAC 10 CL2			GAC 10 CLM		
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	A			B			C			D			E			F			G			H			I			J			K			L		
<100	110	91	130	114	111	118							16	8	24	12	6	18							52	52	52	26	26	26						
100-499	202	168	236	306	289	323	8	8	9	10	8	11	10	5	15	11	6	16	39	39	39	35	35	35	68	68	68	37	37	37						
500-999	127	106	149	193	182	203	5	5	6	6	5	7	6	3	10	7	4	10	24	24	24	22	22	22	43	43	43	23	23	23						
1,000-3,299	268	216	321	519	494	545	24	23	25	35	30	41	12	6	17	16	8	23	45	45	45	51	51	51	70	70	70	32	32	32						
3,300-9,999	299	240	358	579	551	607	26	25	28	39	33	45	13	7	19	17	9	26	50	50	50	56	56	56	78	78	78	36	36	36						
10,000-49,999	379	329	429	532	529	534	35	30	39	48	45	51	14	4	25	21	5	37	69	66	72	97	94	99	10	9	10	14	13	14	12	11	12	17	16	17
50,000-99,999	170	147	193	239	237	240	15	14	17	22	20	23	6	2	11	9	2	17	31	30	32	43	42	45	4	4	5	6	6	6	5	5	6	7	7	8
100,000-999,999	179	155	203	251	250	253	16	14	18	23	21	24	7	2	12	10	3	17	33	31	34	46	44	47	5	4	5	7	6	7	6	5	6	8	8	8
>=1,000,000	22	19	24	30	30	30	2	2	2	3	3	3	1	0	1	1	0	2	4	4	4	6	5	6	1	1	1	1	1	1	1	1	1	1	1	1
Total Plants	1,757	1,472	2,043	2,763	2,674	2,852	132	120	143	186	166	205	86	38	134	104	43	165	295	290	301	356	350	361	330	329	331	181	181	182	23	22	24	33	32	34

System Size (Population Served)	GAC10 + AD CL2			GAC10 + AD CLM			GAC20 CL2			GAC20 CLM			GAC20 + AD CL2			GAC20 + AD CLM			Membranes CL2			Membranes CLM			TOTAL CL2			TOTAL CLM		
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	M			N			O			P			Q			R			S			T			U = A+C+E+G+I+K+M+O+Q+S			V = B+D+F+H+J+L+N+P+R+T		
<100							7	7	7	5	5	5	3	1	4	2	1	3	8	8	8	5	5	5	196	167	224	163	153	174
100-499							8	8	8	7	7	7	8	6	11	9	6	12	3	3	3	4	3	4	348	307	390	419	392	445
500-999							5	5	5	5	5	5	5	4	7	6	4	8	2	2	2	2	2	2	219	193	246	264	247	280
1,000-3,299							12	12	12	13	13	13	12	9	15	17	12	22	2	2	2	2	2	2	444	382	507	685	642	728
3,300-9,999							13	13	13	15	15	15	13	10	17	19	13	24	2	2	2	2	2	2	495	426	565	763	715	811
10,000-49,999	12	10	13	17	13	20	3	2	4	4	3	5	0	0	0	0	0	0	4	4	4	6	5	6	537	466	608	755	725	784
50,000-99,999	5	5	6	7	6	9	1	1	2	2	1	2	0	0	0	0	0	0	2	2	2	2	2	3	241	209	273	339	325	352
100,000-999,999	6	5	6	8	6	9	1	1	2	2	1	3	0	0	0	0	0	0	2	2	2	3	3	3	254	220	287	357	343	371
>=1,000,000	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	31	27	35	43	41	45
Total Plants	23	20	26	33	27	39	51	49	53	52	50	55	41	30	53	52	36	68	25	25	26	26	26	27	2,765	2,396	3,134	3,787	3,584	3,989

Note: Detail may not add to totals due to independent rounding

[1]No advanced Treatment Technologies includes conventional, non-conventional, and softening plants.

Source: Surface water systems serving <10,000 people: Add Treatment Technologies-in-Place for the Pre-Stage 2 Baseline (Exhibit 6.14a) to the Treatment Technology Selection Delta for the Preferred Alternative. Surface water systems serving 10,000 or more people: Use ending Treatment Technology predictions from SWAT (FACA Screen Series3 v3.0 Database) for the Preferred Alternative.

Exhibit 5.12c
Post-Stage 2 DBPR Treatment Technologies-in-Place for NTNCWS Surface Water Plants (Percent of Plants by Residual Disinfection Type)
Preferred Alternative

System Size (Population Served)	No Advanced Treatment Technology CL21			No Advanced Treatment Technology CLM1			Chlorine Dioxide CL2			Chlorine Dioxide CLM			UV CL2			UV CLM			Ozone CL2			Ozone CLM			MF/UF CL2			MF/UF CLM			GAC 10 CL2			GAC 10 CLM		
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	A			B			C			D			E			F			G			H			I			J			K			L		
<100	30.7%	25.3%	36.1%	31.8%	30.8%	32.8%							4.5%	2.3%	6.6%	3.3%	1.7%	4.9%							14.5%	14.5%	14.5%	7.1%	7.1%	7.1%						
100-499	26.4%	22.0%	30.8%	39.9%	37.7%	42.1%	1.1%	1.0%	1.2%	1.3%	1.1%	1.5%	1.3%	0.7%	2.0%	1.4%	0.7%	2.1%	5.1%	5.1%	5.1%	4.6%	4.6%	4.6%	8.9%	8.9%	8.9%	4.8%	4.8%	4.8%						
500-999	26.4%	22.0%	30.8%	39.9%	37.7%	42.1%	1.1%	1.0%	1.2%	1.3%	1.1%	1.5%	1.3%	0.7%	2.0%	1.4%	0.7%	2.1%	5.1%	5.1%	5.1%	4.6%	4.6%	4.6%	8.9%	8.9%	8.9%	4.8%	4.8%	4.8%						
1,000-3,299	23.8%	19.1%	28.4%	46.0%	43.8%	48.2%	2.1%	2.0%	2.2%	3.1%	2.6%	3.6%	1.0%	0.5%	1.5%	1.4%	0.7%	2.0%	4.0%	4.0%	4.0%	4.5%	4.5%	4.5%	6.2%	6.2%	6.2%	2.9%	2.9%	2.9%						
3,300-9,999	23.8%	19.1%	28.4%	46.0%	43.8%	48.2%	2.1%	2.0%	2.2%	3.1%	2.6%	3.6%	1.0%	0.5%	1.5%	1.4%	0.7%	2.0%	4.0%	4.0%	4.0%	4.5%	4.5%	4.5%	6.2%	6.2%	6.2%	2.9%	2.9%	2.9%						
10,000-49,999	29.3%	25.5%	33.2%	41.2%	41.0%	41.4%	2.7%	2.3%	3.0%	3.7%	3.5%	4.0%	1.1%	0.3%	1.9%	1.6%	0.4%	2.9%	5.3%	5.1%	5.5%	7.5%	7.3%	7.7%	0.8%	0.7%	0.8%	1.1%	1.0%	1.1%	0.9%	0.9%	0.9%	1.3%	1.2%	1.3%
50,000-99,999	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100,000-999,999	29.3%	25.5%	33.2%	41.2%	41.0%	41.4%	2.7%	2.3%	3.0%	3.7%	3.5%	4.0%	1.1%	0.3%	1.9%	1.6%	0.4%	2.9%	5.3%	5.1%	5.5%	7.5%	7.3%	7.7%	0.8%	0.7%	0.8%	1.1%	1.0%	1.1%	0.9%	0.9%	0.9%	1.3%	1.2%	1.3%
>=1,000,000	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total %	27.3%	22.5%	32.0%	38.5%	36.6%	40.3%	0.9%	0.9%	1.0%	1.2%	1.0%	1.4%	2.2%	1.1%	3.3%	2.0%	1.0%	2.9%	3.4%	3.4%	3.4%	3.2%	3.2%	3.2%	10.1%	10.1%	10.1%	5.2%	5.2%	5.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

System Size (Population Served)	GAC10 + AD CL2			GAC10 + AD CLM			GAC20 CL2			GAC20 CLM			GAC20 + AD CL2			GAC20 + AD CLM			Membranes CL2			Membranes CLM			TOTAL CL2			TOTAL CLM		
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	M			N			O			P			Q			R			S			T			U = A+C+E+G+I+K+M+O+Q+S			V = B+D+F+H+J+L+N+P+R+T		
<100							2.0%	2.0%	2.0%	1.3%	1.3%	1.3%	0.7%	0.4%	1.1%	0.5%	0.3%	0.8%	2.1%	2.1%	2.1%	1.4%	1.4%	1.4%	54.5%	46.6%	62.4%	45.5%	42.6%	48.4%
100-499							1.1%	1.1%	1.1%	1.0%	1.0%	1.0%	1.1%	0.8%	1.4%	1.2%	0.8%	1.6%	0.5%	0.5%	0.5%	0.5%	0.4%	0.5%	45.4%	40.0%	50.8%	54.6%	51.2%	58.0%
500-999							1.1%	1.1%	1.1%	1.0%	1.0%	1.0%	1.1%	0.8%	1.4%	1.2%	0.8%	1.6%	0.5%	0.5%	0.5%	0.5%	0.4%	0.5%	45.4%	40.0%	50.8%	54.6%	51.2%	58.0%
1,000-3,299							1.0%	1.0%	1.0%	1.2%	1.2%	1.2%	1.1%	0.8%	1.3%	1.5%	1.0%	1.9%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	39.3%	33.8%	44.9%	60.7%	56.8%	64.5%
3,300-9,999							1.0%	1.0%	1.0%	1.2%	1.2%	1.2%	1.1%	0.8%	1.3%	1.5%	1.0%	1.9%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	39.3%	33.8%	44.9%	60.7%	56.8%	64.5%
10,000-49,999	0.9%	0.8%	1.0%	1.3%	1.0%	1.5%	0.2%	0.1%	0.3%	0.3%	0.2%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	41.6%	36.1%	47.1%	58.4%	56.1%	60.7%
50,000-99,999	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
100,000-999,999	0.9%	0.8%	1.0%	1.3%	1.0%	1.5%	0.2%	0.1%	0.3%	0.3%	0.2%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	41.6%	36.1%	47.1%	58.4%	56.1%	60.7%
>=1,000,000	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total %	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	1.3%	1.3%	1.1%	1.1%	1.1%	1.0%	0.7%	1.3%	1.0%	0.7%	1.4%	0.9%	0.9%	0.9%	0.7%	0.7%	0.7%	47.1%	41.0%	53.3%	52.9%	49.6%	56.2%

Note: Detail may not add to totals due to independent rounding

[1]No advanced Treatment Technologies includes conventional, non-conventional, and softening plants.

Source: Surface water systems serving <10,000 people: Add Treatment Technologies-in-Place for the Pre-Stage 2 Baseline (Exhibit 6.14b) to the Treatment Technology Selection Delta for the Preferred Alternative. Surface water systems serving 10,000 or more people: Use ending Treatment Technology predictions from SWAT (FACA Screen Series3 v3.0 Database) for the Preferred Alternative.

Exhibit 5.12d
Post-Stage 2 DBPR Treatment Technologies-in-Place for NTNCWS Surface Water Plants (Number of Plants by Residual Disinfection Type)
Preferred Alternative

System Size (Population Served)	No Advanced Treatment Technology CL21			No Advanced Treatment Technology CLM1			Chlorine Dioxide CL2			Chlorine Dioxide CLM			UV CL2			UV CLM			Ozone CL2			Ozone CLM			MF/UF CL2			MF/UF CLM			GAC 10 CL2			GAC 10 CLM		
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	A			B			C			D			E			F			G			H			I			J			K			L		
<100	69	57	82	72	70	74							10	5	15	8	4	11							33	33	33	16	16	16						
100-499	82	69	96	125	118	131	3	3	4	4	3	5	4	2	6	4	2	6	16	16	16	14	14	14	28	28	28	15	15	15						
500-999	28	23	33	42	40	45	1	1	1	1	1	2	1	1	2	1	1	2	5	5	5	5	5	5	9	9	9	5	5	5						
1,000-3,299	22	18	26	42	40	44	2	2	2	3	2	3	1	0	1	1	1	2	4	4	4	4	4	4	6	6	6	3	3	3						
3,300-9,999	6	5	7	11	11	12	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	1	1	1	2	2	2	1	1	1						
10,000-49,999	1	1	2	2	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
50,000-99,999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100,000-999,999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
>=1,000,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Plants	209	173	246	295	281	309	7	7	8	9	8	11	17	9	25	15	8	22	26	26	26	25	25	25	77	77	77	40	40	40	0	0	0	0	0	0

System Size (Population Served)	GAC10 + AD CL2			GAC10 + AD CLM			GAC20 CL2			GAC20 CLM			GAC20 + AD CL2			GAC20 + AD CLM			Membranes CL2			Membranes CLM			TOTAL CL2			TOTAL CLM		
	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
	M			N			O			P			Q			R			S			T			U = A+C+E+G+I+K+M+O+Q+S			V = B+D+F+H+J+L+N+P+R+T		
<100							4	4	4	3	3	3	2	1	2	1	1	2	5	5	5	3	3	3	123	105	141	103	96	109
100-499							3	3	3	3	3	3	3	2	4	4	3	5	1	1	1	1	1	2	142	125	159	170	160	181
500-999							1	1	1	1	1	1	1	1	1	1	1	2	0	0	0	1	0	1	48	42	54	58	54	62
1,000-3,299							1	1	1	1	1	1	1	1	1	1	1	2	0	0	0	0	0	0	36	31	41	56	52	59
3,300-9,999							0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	8	11	15	14	16
10,000-49,999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	3	3	3
50,000-99,999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
100,000-999,999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
>=1,000,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Plants	0	0	0	0	0	0	10	10	10	8	8	8	7	5	10	8	5	11	7	7	7	5	5	6	361	314	409	406	380	431

Note: Detail may not add to totals due to independent rounding

[1]No advanced Treatment Technologies includes conventional, non-conventional, and softening plants.

Source: Surface water systems serving <10,000 people: Add Treatment Technologies-in-Place for the Pre-Stage 2 Baseline (Exhibit 6.14b) to the Treatment Technology Selection Delta for the Preferred Alternative. Surface water systems serving 10,000 or more people: Use ending Treatment Technology predictions from SWAT (FACA Screen Series3 v3.0 Database) for the Preferred Alternative.

Exhibit 5.13a Pre-Stage 2 DBPR Treatment Technologies-in-Place for CWS Ground Water Plants (Percent and Number of Plants, by Residual Disinfectant Type)
Preferred Alternative

System Size (Population Served)	No Advanced Treatment Technologies1 CL2		No Advanced Treatment Technologies1 CLM		UV CL2		UV CLM		Ozone CL2		Ozone CLM		GAC20 CL2		GAC20 CLM		Membranes CL2		Membranes CLM		TOTAL USING CL2		TOTAL USING CLM	
	A		B		C		D		E		F		G		H		I		J		K = A+C+E+G+I		L = B+D+F+H+J	
	#	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#
<100	95.9%	6,160	2.4%	156	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.9%	56	0.3%	22	0.5%	29	96.3%	6,182	3.7%	241
100-499	95.3%	14,520	2.8%	427	0.0%	0	0.0%	0	0.2%	25	0.5%	74	0.0%	0	0.6%	97	0.1%	20	0.5%	80	95.6%	14,564	4.4%	678
500-999		5,805		171		0		0		10		29		0		39		8		32		5,822		271
1,000-3,299	95.7%	7,263	2.5%	192	0.0%	0	0.0%	0	0.3%	22	0.9%	66	0.0%	0	0.1%	4	0.1%	4	0.5%	36	96.1%	7,289	3.9%	298
3,300-9,999		4,815		127		0		0		15		44		0		3		3		24		4,833		197
10,000-49,999	89.2%	4,801	7.2%	389					0.8%	46	0.8%	42	0.0%	0	0.0%	2	1.7%	90	0.3%	14	91.7%	4,936	8.3%	446
50,000-99,999		639		52						6		6		0		0		12		2		657		59
100,000-999,999	89.5%	821	7.1%	65					0.8%	8	0.7%	6	0.0%	0	0.0%	0	1.7%	15	0.2%	2	92.0%	844	8.0%	74
>=1,000,000		24		2						0		0		0		0		0		0		25		2
Total Plants	94.6%	44,849	3.3%	1,580	0.0%	0	0.0%	0	0.3%	131	0.6%	267	0.0%	0	0.4%	202	0.4%	173	0.5%	218	95.2%	45,153	4.8%	2,267

Note: Detail may not add to totals due to independent rounding

[1]No advanced Treatment Technologies includes conventional, non-conventional, and softening plants.

Source: Add Treatment Technologies-in-Place for the Pre-Stage 1 DBPR Baseline (Exhibit 3.14a) to Stage 1 Treatment Technology Selection (Exhibit C.2a).

xhibit 5.13b Pre-Stage 2 DBPR Treatment Technologies-in-Place for NTNCWS Ground Water Plants (Percent and Number of Plants, by Residual Disinfectant Typ
Preferred Alternative

System Size (Population Served)	No Advanced Treatment Technologies1 CL2		No Advanced Treatment Technologies1 CLM		UV CL2		UV CLM		Ozone CL2		Ozone CLM		GAC20 CL2		GAC20 CLM		Membranes CL2		Membranes CLM		TOTAL USING CL2		TOTAL USING CLM	
	A		B		C		D		E		F		G		H		I		J		K = A+C+E+G+I		L = B+D+F+H+J	
	#	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#
<100	95.9%	2,391	2.4%	60	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.0%	0	0.9%	22	0.3%	9	0.5%	11	96.3%	2,399	3.7%	93
100-499	95.3%	2,028	2.8%	60	0.0%	0	0.0%	0	0.2%	3	0.5%	10	0.0%	0	0.6%	14	0.1%	3	0.5%	11	95.6%	2,034	4.4%	95
500-999		561		17		0		0		1		3		0		4		1		3		563		26
1,000-3,299	95.7%	237	2.5%	6	0.0%	0	0.0%	0	0.3%	1	0.9%	2	0.0%	0	0.1%	0	0.1%	0	0.5%	1	96.1%	237	3.9%	10
3,300-9,999		21		1		0		0		0		0		0		0		0		0		21		1
10,000-49,999	89.2%	3	7.2%	0					0.8%	0	0.8%	0	0.0%	0	0.0%	0	1.7%	0	0.3%	0	91.7%	3	8.3%	0
50,000-99,999		0		0						0		0		0		0		0		0		0		0
100,000-999,999	89.5%	0	7.1%	0					0.8%	0	0.7%	0	0.0%	0	0.0%	0	1.7%	0	0.2%	0	92.0%	0	8.0%	0
>=1,000,000		0		0						0		0		0		0		0		0		0		0
Total Plants	95.6%	5,241	2.6%	144	0.0%	0	0.0%	0	0.1%	5	0.3%	16	0.0%	0	0.7%	39	0.2%	12	0.5%	27	95.9%	5,258	4.1%	225

Note: Detail may not add to totals due to independent rounding

[1]No advanced Treatment Technologies includes conventional, non-conventional, and softening plants.

Source: Add Treatment Technologies-in-Place for the Pre-Stage 1 DBPR Baseline (Exhibit 3.14b) to Stage 1 Treatment Technology Selection (Exhibit C.2b).

Exhibit 5.14a

Stage 2 DBPR Treatment Technology Selection Deltas for CWS Ground Water Plants (Percent of Plants, by Residual Disinfectant Type)

Preferred Alternative

System Size (Population Served)	CLM Only	UV CL2	UV CLM	Ozone CL2	Ozone CLM	GAC20 CL2	GAC20 CLM	Membranes CL2	Membranes CLM	Total Converting to CLM	Plants Making Treatment Technology Changes	
	A	B	C	D	E	F	G	H	I	J = A+C+E+G+I	K = SUM(A:I)	
<100	1.0%	0.0%	1.1%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	2.0%	2.4%	
100-499	1.4%	0.0%	1.6%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	3.0%	3.2%	
500-999	1.4%	0.0%	1.6%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	3.0%	3.2%	2.9%
1,000-3,299	1.1%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.7%	2.7%	
3,300-9,999	1.1%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.7%	2.7%	
10,000-49,999	1.4%			0.1%	0.2%	0.0%	0.2%	0.0%	0.2%	2.0%	2.1%	
50,000-99,999	1.4%			0.1%	0.2%	0.0%	0.2%	0.0%	0.2%	2.0%	2.1%	2.1%
100,000-999,999	1.3%			0.1%	0.2%	0.0%	0.1%	0.0%	0.2%	1.9%	2.0%	
>=1,000,000	1.4%			0.1%	0.2%	0.0%	0.1%	0.0%	0.2%	2.0%	2.1%	
Total %	1.3%	0.0%	1.3%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	2.6%	2.8%	2.8%

Note: Detail may not add to totals due to independent rounding

Exhibit 5.14b

Stage 2 DBPR Treatment Technology Selection Deltas for CWS Ground Water Plants (Number of Plants, by Residual Disinfectant Type)

Preferred Alternative

System Size (Population Served)	CLM Only	UV CL2	UV CLM	Ozone CL2	Ozone CLM	GAC20 CL2	GAC20 CLM	Membranes CL2	Membranes CLM	Total Converting to CLM	Plants Making Treatment Technology Changes	
	A	B	C	D	E	F	G	H	I	J = A+C+E+G+I	K = SUM(A:I)	
<100	61	0	70	0	0	23	0	0	0	132	155	
100-499	213	0	243	0	0	27	0	0	0	456	483	
500-999	85	0	97	0	0	11	0	0	0	182	193	1,169
1,000-3,299	82	0	118	0	0	0	4	0	0	204	204	
3,300-9,999	54	0	78	0	0	0	2	0	0	135	135	
10,000-49,999	75			3	12	0	8	2	11	107	111	
50,000-99,999	10			0	2	0	1	0	2	14	15	145
100,000-999,999	12			0	2	0	1	0	2	17	18	
>=1,000,000	0			0	0	0	0	0	0	1	1	
Total Plants	593	0	607	4	15	61	17	2	15	1,247	1,314	1,314

Note: Detail may not add to totals due to independent rounding

Exhibit 5.14c

Stage 2 DBPR Treatment Technology Selection Deltas for NTNCWS Ground Water Plants (Percent of Plants, by Residual Disinfectant Type)

Preferred Alternative

System Size (Population Served)	CLM Only	UV CL2	UV CLM	Ozone CL2	Ozone CLM	GAC20 CL2	GAC20 CLM	Membranes CL2	Membranes CLM	Total Converting to CLM	Plants Making Treatment Technology Changes	
	A	B	C	D	E	F	G	H	I	J = A+C+E+G+I	K = SUM(A:I)	
<100	1.0%	0.0%	1.1%	0.0%	0.0%	0.4%	0.0%	0.0%	0.0%	2.0%	2.4%	
100-499	1.4%	0.0%	1.6%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	3.0%	3.2%	
500-999	1.4%	0.0%	1.6%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%	3.0%	3.2%	2.8%
1,000-3,299	1.1%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.7%	2.7%	
3,300-9,999	1.1%	0.0%	1.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	2.7%	2.7%	
10,000-49,999	1.4%			0.1%	0.2%	0.0%	0.2%	0.0%	0.2%	2.0%	2.1%	
50,000-99,999	1.4%			0.1%	0.2%	0.0%	0.2%	0.0%	0.2%	2.0%	2.1%	2.1%
100,000-999,999	1.3%			0.1%	0.2%	0.0%	0.1%	0.0%	0.2%	1.9%	2.0%	
>=1,000,000	0.0%			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
Total %	1.2%	0.0%	1.4%	0.0%	0.0%	0.3%	0.0%	0.0%	0.0%	2.5%	2.8%	2.8%

Note: Detail may not add to totals due to independent rounding

Exhibit 5.14d

Stage 2 DBPR Treatment Technology Selection Deltas for NTNCWS Ground Water Plants (Number of Plants, by Residual Disinfectant Type)

Preferred Alternative

System Size (Population Served)	CLM Only	UV CL2	UV CLM	Ozone CL2	Ozone CLM	GAC20 CL2	GAC20 CLM	Membranes CL2	Membranes CLM	Total Converting to CLM	Plants Making Treatment Technology Changes	
	A	B	C	D	E	F	G	H	I	J = A+C+E+G+I	K = SUM(A:I)	
<100	24	0	27	0	0	9	0	0	0	51	60	
100-499	30	0	34	0	0	4	0	0	0	64	67	
500-999	8	0	9	0	0	1	0	0	0	18	19	153
1,000-3,299	3	0	4	0	0	0	0	0	0	7	7	
3,300-9,999	0	0	0	0	0	0	0	0	0	1	1	
10,000-49,999	0			0	0	0	0	0	0	0	0	
50,000-99,999	0			0	0	0	0	0	0	0	0	
100,000-999,999	0			0	0	0	0	0	0	0	0	0
>=1,000,000	0			0	0	0	0	0	0	0	0	
Total Plants	65	0	75	0	0	14	0	0	0	140	154	154

Note: Detail may not add to totals due to independent rounding

Exhibit 5.15a
Post-Stage 2 DBPR Treatment Technologies-in-Place for CWS Ground Water Plants (Percent of Plants, by Residual Disinfectant Type)
Preferred Alternative

System Size (Population Served)	No Advanced Treatment Technology CL21	No Advanced Treatment Technology CLM1	UV CL2	UV CLM	Ozone CL2	Ozone CLM	GAC20 CL2	GAC20 CLM	Membranes CL2	Membranes CLM	Total Using CL2	Total Using CLM
	A	B	C	D	E	F	G	H	I	J	K = A+C+E+G+I	L = B+D+F+H+J
<100	93.5%	3.4%	0.0%	1.1%	0.0%	0.0%	0.4%	0.9%	0.3%	0.5%	94.2%	5.8%
100-499	92.1%	4.2%	0.0%	1.6%	0.2%	0.5%	0.2%	0.6%	0.1%	0.5%	92.6%	7.4%
500-999	92.1%	4.2%	0.0%	1.6%	0.2%	0.5%	0.2%	0.6%	0.1%	0.5%	92.6%	7.4%
1,000-3,299	93.0%	3.6%	0.0%	1.6%	0.3%	0.9%	0.0%	0.1%	0.1%	0.5%	93.4%	6.6%
3,300-9,999	93.0%	3.6%	0.0%	1.6%	0.3%	0.9%	0.0%	0.1%	0.1%	0.5%	93.4%	6.6%
10,000-49,999	87.1%	8.6%			0.9%	1.0%	0.0%	0.2%	1.7%	0.5%	89.7%	10.3%
50,000-99,999	87.1%	8.6%			0.9%	1.0%	0.0%	0.2%	1.7%	0.5%	89.7%	10.3%
100,000-999,999	87.5%	8.4%			0.9%	0.9%	0.0%	0.2%	1.7%	0.4%	90.1%	9.9%
>=1,000,000	87.4%	8.5%			0.9%	0.9%	0.0%	0.2%	1.7%	0.4%	90.0%	10.0%
Total %	91.8%	4.6%	0.0%	1.3%	0.3%	0.6%	0.1%	0.5%	0.4%	0.5%	92.6%	7.4%

Note: Detail may not add to totals due to independent rounding

[1]No advanced Treatment Technologies includes conventional, non-conventional, and softening plants.

Source: Add Treatment Technologies-in-Place for the Pre-Stage 2 Baseline (Exhibit 6.17a) to the Treatment Technology Selection Delta for the Preferred Alternative.

Exhibit 5.15b
Post-Stage 2 DBPR Treatment Technologies-in-Place for CWS Ground Water Plants (Number of Plants, by Residual Disinfectant Type)
Preferred Alternative

System Size (Population Served)	No Advanced Treatment Technology CL21	No Advanced Treatment Technology CLM1	UV CL2	UV CLM	Ozone CL2	Ozone CLM	GAC20 CL2	GAC20 CLM	Membranes CL2	Membranes CLM	Total Using CL2	Total Using CLM
	A	B	C	D	E	F	G	H	I	J	K = A+C+E+G+I	L = B+D+F+H+J
<100	6,005	217	0	70	0	0	23	56	22	29	6,051	372
100-499	14,038	640	0	243	25	74	27	97	20	80	14,109	1,133
500-999	5,612	256	0	97	10	29	11	39	8	32	5,640	453
1,000-3,299	7,060	273	0	118	22	66	0	8	4	36	7,086	502
3,300-9,999	4,680	181	0	78	15	44	0	5	3	24	4,698	332
10,000-49,999	4,690	464			48	53	0	10	91	25	4,829	553
50,000-99,999	624	62			6	7	0	1	12	3	642	74
100,000-999,999	803	77			8	8	0	2	15	4	827	91
>=1,000,000	24	2			0	0	0	0	0	0	25	3
Total Plants	43,535	2,173	0	607	134	282	61	218	175	233	43,906	3,514

Note: Detail may not add to totals due to independent rounding Error

[1]No advanced Treatment Technologies includes conventional, non-conventional, and softening plants.

Source: Add Treatment Technologies-in-Place for the Pre-Stage 2 Baseline (Exhibit 6.17a) to the Treatment Technology Selection Delta for the Preferred Alternative.

Exhibit 5.15c
Post-Stage 2 DBPR Treatment Technologies-in-Place for NTNCWS Ground Water Plants (Percent of Plants, by Residual Disinfectant Type)
Preferred Alternative

System Size (Population Served)	No Advanced Treatment Technology CL21	No Advanced Treatment Technology CLM1	UV CL2	UV CLM	Ozone CL2	Ozone CLM	GAC20 CL2	GAC20 CLM	Membranes CL2	Membranes CLM	Total Using CL2	Total Using CLM
	A	B	C	D	E	F	G	H	I	J	K = A+C+E+G+I	L = B+D+F+H+J
<100	93.5%	3.4%	0.0%	1.1%	0.0%	0.0%	0.4%	0.9%	0.3%	0.5%	94.2%	5.8%
100-499	92.1%	4.2%	0.0%	1.6%	0.2%	0.5%	0.2%	0.6%	0.1%	0.5%	92.6%	7.4%
500-999	92.1%	4.2%	0.0%	1.6%	0.2%	0.5%	0.2%	0.6%	0.1%	0.5%	92.6%	7.4%
1,000-3,299	93.0%	3.6%	0.0%	1.6%	0.3%	0.9%	0.0%	0.1%	0.1%	0.5%	93.4%	6.6%
3,300-9,999	93.0%	3.6%	0.0%	1.6%	0.3%	0.9%	0.0%	0.1%	0.1%	0.5%	93.4%	6.6%
10,000-49,999	87.1%	8.6%			0.9%	1.0%	0.0%	0.2%	1.7%	0.5%	89.7%	10.3%
50,000-99,999	87.1%	8.6%			0.9%	1.0%	0.0%	0.2%	1.7%	0.5%	89.7%	10.3%
100,000-999,999	87.5%	8.4%			0.9%	0.9%	0.0%	0.2%	1.7%	0.4%	90.1%	9.9%
>=1,000,000	0.0%	0.0%			0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total %	92.8%	3.8%	0.0%	1.4%	0.1%	0.3%	0.3%	0.7%	0.2%	0.5%	93.3%	6.7%

Note: Detail may not add to totals due to independent rounding

[1]No advanced Treatment Technologies includes conventional, non-conventional, and softening plants.

Source: Add Treatment Technologies-in-Place for the Pre-Stage 2 Baseline (Exhibit 6.17b) to the Treatment Technology Selection Delta for the Preferred Alternative.

Exhibit 5.15d
Post-Stage 2 DBPR Treatment Technologies-in-Place for NTNCWS Ground Water Plants (Number of Plants, by Residual Disinfectant Type)
Preferred Alternative

System Size (Population Served)	No Advanced Treatment Technology CL21	No Advanced Treatment Technology CLM1	UV CL2	UV CLM	Ozone CL2	Ozone CLM	GAC20 CL2	GAC20 CLM	Membranes CL2	Membranes CLM	Total Using CL2	Total Using CLM
	A	B	C	D	E	F	G	H	I	J	K = A+C+E+G+I	L = B+D+F+H+J
<100	2,331	84	0	27	0	0	9	22	9	11	2,348	145
100-499	1,961	89	0	34	3	10	4	14	3	11	1,971	158
500-999	543	25	0	9	1	3	1	4	1	3	545	44
1,000-3,299	230	9	0	4	1	2	0	0	0	1	231	16
3,300-9,999	20	1	0	0	0	0	0	0	0	0	20	1
10,000-49,999	3	0			0	0	0	0	0	0	3	0
50,000-99,999	0	0			0	0	0	0	0	0	0	0
100,000-999,999	0	0			0	0	0	0	0	0	0	0
>=1,000,000	0	0			0	0	0	0	0	0	0	0
Total Plants	5,087	208	0	75	5	16	14	39	12	27	5,119	365

Note: Detail may not add to totals due to independent rounding Error

[1]No advanced Treatment Technologies includes conventional, non-conventional, and softening plants.

Source: Add Treatment Technologies-in-Place for the Pre-Stage 2 Baseline (Exhibit 6.17b) to the Treatment Technology Selection Delta for the Preferred Alternative.

5.5 Reduction in National Average TTHM and HAA5 Levels

This section presents the predicted reductions in average TTHM and HAA5 levels in distribution systems as a result of the Stage 2 DBPR. The reductions in average levels are used in Chapter 6 to approximate the reduction in bladder cancer cases as a result of the Stage 2 DBPR. This section presents an overview of the methodology first, followed by detailed derivations for large and medium surface water systems, small surface water systems, large and medium ground water systems, and small ground water systems. Results are summarized in Section 5.5.6.

5.5.1 Overview of Methodology

The methodology for estimating the percent reduction in average TTHM and HAA5 values resulting from the Stage 2 DBPR is as follows:

1) Predict TTHM and HAA5 levels for the pre-Stage 1 baseline (presented in Section 3.7.1)

2) Predict the percent reduction resulting from the Stage 1 DBPR and the resulting TTHM and HAA5 levels for the pre-Stage 2 baseline

3) Predict the percent reduction resulting from the Stage 2 DBPR

Reductions are predicted separately for ground and surface water systems and for large and small systems (4 predictions). A population-weighted percent reduction is then calculated for all systems.

5.5.2 Reductions for Large and Medium Surface Water Systems

The methodology for surface water systems is based on SWAT model output and the ICR Matrix Method. Results from both methods are used to predict percent reduction in average DBPs. The first section summarizes the methodology using SWAT. Section 5.5.2.2 shows how the ICR Matrix Method is used to predict percent reductions. Section 5.5.2.3 compares results for the individual methods and explains how they are combined using a Monte Carlo simulation model for the primary analysis.

5.5.2.1 SWAT Methodology

For each model run, SWAT predicted monthly TTHM and HAA5 levels for each of 273 plants evaluated (273 plants out of the possible 350 ICR plants were used in the SWAT model). See Appendix A for more information on SWAT, including a discussion of plant representativeness. Monthly data were averaged for each plant to produce plant-mean data. All plant-means were averaged together to produce a "mean of plant-means" value. The means of plant-means for Stage 1 and Stage 2 SWAT model runs were compared to the SWAT initial plant run (simulating pre-Stage 1 conditions) to compute percent reduction.

SWAT-predicted TTHM and HAA5 results were used instead of available ICR-observed data for the pre-Stage 1 DBPR baseline to allow for consistent comparison of pre-Stage 1 data to modeled pre-Stage 2 and post-Stage 2 TTHM and HAA5 results. If observed data were used for pre-Stage 1 predictions, differences between pre-Stage 1 and pre-Stage 2 or post-Stage 2 results would reflect potential inconsistencies between observed and predicted data sets, not just the expected treatment technology change from pre-Stage 1 to pre-Stage 2 or post-Stage 2.

5.5.2.2 The ICR Matrix Method

Exhibits 5.16a through 5.16d show the derivation of percent reduction in national average TTHM and HAA5 levels using the ICR Matrix Method. The ICR Matrix Method for the Preferred Regulatory Alternative with safety margins of 20 and 25 percent is presented in Exhibits 5.16a and 5.16b (the 25 percent safety margin is used to account for the potential impacts of the IDSE). Exhibits 5.16c and 5.16d show the ICR Matrix Method for Regulatory Alternatives 2 and 3. Regulatory Alternative 1 was not analyzed separately, as it contains the same MCLs for TTHM and HAA5 and therefore has the same matrix as the Preferred Regulatory Alternative.

To illustrate how the ICR matrix method works, consider the data presented in Exhibit 5.16a for the Preferred Alternative for a 20 percent safety margin. The left side of the exhibit contains three tables or matrices that are divided into different "bins." The bins are cells defined by ranges of RAA values for TTHM and HAA5 across the top, and maximum LRAA values for TTHM and HAA5 down the left-hand side. The method works by moving plants from non-compliant bins (Bins B2 and A2) into the compliant bin (Bin A1) in the second and third tables, representing their actions to comply with Stage 1 and Stage 2, respectively.

The number and percent of plants in each bin under pre-Stage 1 conditions is shown in the tables on the right-hand side of Exhibit 5.16a. Plants are assigned to a bin based on their RAA and LRAA observations as calculated from the ICR data. Note that a plant is considered in one of the non-compliant bins if it exceeds either the TTHM or HAA5 MCL. EPA assumes that plants making treatment technology changes to comply with Stage 1 will also meet Stage 2 MCLs (e.g., be moved into the Stage 1- AND Stage 2-compliant Bin A1). This is consistent with the SWAT methodology, which considers only the delta or additional plants that need to make changes to comply with the Stage 2 DBPR. EPA recognizes there is uncertainty in this assumption (see the discussion in the compliance forecast section, Section 5.3.2), but believes it is a reasonable approximation.

Unlike SWAT, the ICR Matrix Method does not use a model to predict which treatment technologies will be used by plants for compliance, or to calculate the resulting changes in average TTHM and HAA5 concentrations. EPA developed an alternative methodology to predict these effects. Based on comparisons of ICR and historical DBP databases, researchers suspect that plants changed their treatment technology in anticipation of the Stage 1 DBPR prior to the ICR data collection period (McGuire et al. 2002). It follows, then, that at least some portion of the plants reporting advanced treatment technology and/or chloramine use in the ICR had installed these treatment technologies to reduce DBPs. Therefore, the TTHM and HAA5 levels of the ICR plants using advanced treatment

technologies and/or chloramines can provide an indication of the final TTHM and HAA5 levels for plants that add these treatment technologies to comply with the Stage 2 DBPR.

The results of the analysis of TTHM and HAA5 levels for Stage 2-compliant plants that use advanced treatment technologies and/or chloramines during the ICR are summarized in Exhibit 5.17. The average of the plant-average TTHM and HAA5 concentrations for all four analyses are assumed to represent the average TTHM and HAA5 concentrations for plants that will make treatment technology changes to meet the Stage 1 and Stage 2 rules. The resulting change in the national average TTHM and HAA5 concentrations is calculated as the weighted average for the Stage 1/Stage 2 compliant plants and the non-compliant changers. EPA recognizes that there is uncertainty in using the subset of ICR plants using advanced technology and/or chloramines to model future changes in DBP occurrence, but believes it provides a plausible result.

Exhibit 5.16a ICR Matrix Method for the Stage 2 DBPR Preferred Alternative (80/60 LRAA, IDSE)- 20 Percent Safety Margin

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Max LRAA	<64/48	A1	
	>= 64/48 (S2 non-compliant)	A2	B2

Bin Assignment	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L)	
			TTHM	HAA5
A1	136	64%	31.64	20.67
A2	36	17%	51.64	33.12
B2	41	19%	69.34	53.36
All Plants	213	100%	42.28	29.07

Pre-Stage 2

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Max LRAA	<64/48	A1	
	>= 64/48 (S2 non-compliant)	A2	

Bin Assignment	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L)	
			TTHM	HAA5
A1	136	64%	31.64	20.67
A2	36	17%	51.64	33.12
A1	41	19%	31.48	19.14
All Plants	213	100%	34.99	22.48

Post-Stage 2

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Max LRAA	<64/48	A1	
	>= 64/48 (S2 non-compliant)		

Bin Assignment	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L)	
			TTHM	HAA5
A1	136	64%	31.64	20.67
A1	36	17%	31.48	19.14
A1	41	19%	31.48	19.14
All Plants	213	100%	31.58	20.11

Notes: 1) In the first table on the left, A1 through B2 are the number of ICR plants that meet the criteria for each bin under pre-Stage 1 conditions. Their calculated average TTHM and HAA5 values based on the averages of all plant-averages are shown in the first table on the right. A total of 213 ICR plants were evaluated.

2) Each cell (bin) represents a range of the TTHM and HAA5 RAA concentrations and maximum LRAA concentrations in µg/L (i.e., RAA <64/48 means the plant needs to have its TTHM RAA level below 64 µg/L and its HAA5 RAA level below 48 µg/L to be placed into the bin). The maximum TTHM or HAA5 result determines a plant's bin placement.

3) Crossed-out bins represent plants that have moved from out of compliance bins to in compliance bins.

4) The gray bins on the right-hand side represents bins that have moved into compliance with pre-Stage 2 and post-Stage 2. The TTHM and HAA5 concentrations for these plants are the averages of the values for those ICR plants that are compliant with Stage 1 and Stage 2 and that use either an advanced treatment technology, chloramines, or both (64 plants) from Exhibit 5.7.

Exhibit 5.16b ICR Matrix Method for a Stage 2 DBPR Preferred Alternative (80/60 LRAA, IDSE)- 25 Percent Safety Margin

Pre-Stage 1

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Max LRAA	<60/45	A1	
	>= 60/45 (S2 non-compliant)	A2	B2

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	125	59%	30.14	19.39
A2	47	22%	50.95	33.60
B2	41	19%	69.34	53.36
All Plants	213	100%	42.28	29.07

Pre-Stage 2

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Max LRAA	<60/45	A1+B2	
	>= 60/45 (S2 non-compliant)	A2	

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	125	59%	30.14	19.39
A2	47	22%	50.95	33.60
B2	41	19%	29.33	17.56
All Plants	213	100%	34.58	22.17

Post-Stage 2

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Max LRAA	<60/45	A1+B2+A2	
	>= 60/45 (S2 non-compliant)		

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	125	59%	30.14	19.39
A2	47	22%	29.33	17.56
B2	41	19%	29.33	17.56
All Plants	213	100%	29.80	18.63

Notes: 1) In the first table on the left, A1 through B2 are the number of ICR plants that meet the criteria for each bin under pre-Stage 1 conditions. Their calculated average TTHM and HAA5 values based on the averages of all plant-averages are shown in the first table on the right. A total of 213 ICR plants were evaluated.

2) Each cell (bin) represents a range of the TTHM and HAA5 RAA concentrations and maximum LRAA concentrations in µg/L (i.e., RAA <64/48 means the plant needs to have its TTHM RAA level below 64 µg/L and its HAA5 RAA level below 48 µg/L to be placed into the bin). The maximum TTHM or HAA5 result determines a plant's bin placement.

3) Crossed-out bins represent plants that have moved from out of compliance bins to in compliance bins.

4) The gray bins on the right-hand side represents bins that have moved into compliance with pre-Stage 2 and post-Stage 2. The TTHM and HAA5 concentrations for these plants are the averages of the values for those ICR plants that are compliant with Stage 1 and Stage 2 and that use either an advanced treatment technology, chloramines, or both (64 plants) from Exhibit 5.7.

Exhibit 5.16c ICR Matrix Method for Regulatory Alternative 2 (80/60 SH)

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Single High	<64/48	A1	
	>= 64/48 (S2 non-compliant)	A2	B2

Pre-Stage 1

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	89	42%	25.18	16.52
A2	83	39%	47.25	30.51
B2	41	19%	69.34	53.36
All Plants	213	100%	42.28	29.07

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Single High	<64/48	A1+B2	
	>= 64/48 (S2 non-compliant)	A2	

Pre-Stage 2

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	89	42%	25.18	16.52
A2	83	39%	47.25	30.51
B2	41	19%	24.99	15.12
All Plants	213	100%	33.74	21.70

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Single High	<64/48	A1+B2+A2	
	>= 64/48 (S2 non-compliant)		

Post-Stage 2

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	89	42%	25.18	16.52
A2	83	39%	24.99	15.12
B2	41	19%	24.99	15.12
All Plants	213	100%	25.07	15.71

Notes: 1) In the first table on the left, A1 through B2 are the number of ICR plants that meet the criteria for each bin under pre-Stage 1 conditions. Their calculated average TTHM and HAA5 values based on the averages of all plant-averages are shown in the first table on the right. A total of 213 ICR plants were evaluated.

2) Each cell (bin) represents a range of the TTHM and HAA5 RAA concentrations and maximum LRAA concentrations in µg/L (i.e., RAA <64/48 means the plant needs to have its TTHM RAA level below 64 µg/L and its HAA5 RAA level below 48 µg/L to be placed into the bin). The maximum TTHM or HAA5 result determines a plant's bin placement.

3) Crossed-out bins represent plants that have moved from out of compliance bins to in compliance bins.

4) The gray bins on the right-hand side represents bins that have moved into compliance with pre-Stage 2 and post-Stage 2. The TTHM and HAA5 concentrations for these plants are the averages of the values for those ICR plants that are compliant with Stage 1 and Stage 2 and that use either an advanced treatment technology, chloramines, or both (64 plants) from Exhibit 5.7.

Exhibit 5.16d ICR Matrix Method for Regulatory Alternative 3 (40/30 RAA)

Pre-Stage 1

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
RAA	<32/24	A1	
	>= 32/24 (S2 non-compliant)	A2	B2

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	58	27%	19.71	12.91
A2	114	54%	44.03	28.55
B2	41	19%	69.34	53.36
All Plants	213	100%	42.28	29.07

Pre-Stage 2

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
RAA	<32/24	A1+B2	
	>= 32/24 (S2 non-compliant)	A2	

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	58	27%	19.71	12.91
A2	114	54%	44.03	28.55
B2	41	19%	19.73	13.04
All Plants	213	100%	32.73	21.30

Post-Stage 2

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
RAA	<32/24	A1+B2+A2	
	>= 32/24 (S2 non-compliant)		

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	58	27%	19.71	12.91
A2	114	54%	19.73	13.04
B2	41	19%	19.73	13.04
All Plants	213	100%	19.72	13.00

Notes: 1) In the first table on the left, A1 through B2 are the number of ICR plants that meet the criteria for each bin under pre-Stage 1 conditions. Their calculated average TTHM and HAA5 values based on the averages of all plant-averages are shown in the first table on the right. A total of 213 ICR plants were evaluated.

2) Each cell (bin) represents a range of the TTHM and HAA5 RAA concentrations and maximum LRAA concentrations in µg/L (i.e., RAA <64/48 means the plant needs to have its TTHM RAA level below 64 µg/L and its HAA5 RAA level below 48 µg/L to be placed into the bin). The maximum TTHM or HAA5 result determines a plant's bin placement.

3) Crossed-out bins represent plants that have moved from out of compliance bins to in compliance bins.

4) The gray bins on the right-hand side represents bins that have moved into compliance with pre-Stage 2 and post-Stage 2. The TTHM and HAA5 concentrations for these plants are the averages of the values for those ICR plants that are compliant with Stage 1 and Stage 2 and that use either an advanced treatment technology, chloramines, or both (64 plants) from Exhibit 5.7.

Exhibit 5.17 TTHM and HAA5 Levels for Stage 2-Compliant Plants Using Chloramines and/or an Advanced Treatment Technology

Subset of Stage 2 Compliant Plants	Preferred Regulatory Alternative (20 Percent Safety Margin)		
	Number of Plants	Mean TTHM (µg/L)	Mean HAA5 (µg/L)
CLM only	47	34.50	20.24
ADV tech only	5	32.20	23.19
CLM & Adv. tech	12	19.33	13.14
Total	64	31.48	19.14

Subset of Stage 2 Compliant Plants	Preferred Regulatory Alternative (25 Percent Safety Margin)		
	Number of Plants	Mean TTHM (µg/L)	Mean HAA5 (µg/L)
CLM only	43	32.44	18.97
ADV tech only	4	31.07	19.06
CLM & Adv. tech	12	19.33	13.14
Total	59	29.68	17.79

Subset of Stage 2 Compliant Plants	Regulatory Alternative 2		
	Number of Plants	Mean TTHM (µg/L)	Mean HAA5 (µg/L)
CLM only	42	32.02	18.68
ADV tech only	4	31.07	19.06
CLM & Adv. tech	12	19.33	13.14
Total	58	29.33	17.56

Subset of Stage 2 Compliant Plants	Regulatory Alternative 3		
	Number of Plants	Mean TTHM (µg/L)	Mean HAA5 (µg/L)
CLM only	28	27.37	16.10
ADV tech only	4	31.07	19.06
CLM & Adv. tech	11	16.74	11.20
Total	43	24.99	15.12

Notes: All TTHM and HAA5 values represent the mean of plant-means
CLM = chloramine

Source: ICR Aux 1 database (USEPA 2000h), analysis of ICR screened data (213 surface water plants)

5.5.2.3 Combining SWAT and ICR Matrix Method Results

Exhibit 5.18 presents the results of SWAT and the ICR Matrix Method for post-Stage 2 national average TTHM and HAA5 levels. Note that predictions for a 20 and 25 percent safety margin are shown separately for the Preferred Alternative. Both predictions are used in a Monte Carlo simulation model to account for uncertainty in the impacts of the IDSE. (See Section 5.3.4 for a detailed description of the methodology used to quantify uncertainty in the potential impacts of the IDSE on large and medium surface water systems.) As shown in Exhibit 5.18, the ICR Matrix Method predicts a greater reduction in TTHM and HAA5 levels compared to SWAT for the Preferred Alternative. Such differences are expected given the inherent differences in the two methods and uncertainties associated with each one. (Possible reasons for the differences between the two methods are noted in Section 5.3.6.) Because both SWAT and the ICR Matrix Method have associated uncertainty, results from both are used to generate the estimated percent reduction in TTHM and HAA5 concentrations for large and medium surface water systems.

Similar to the compliance forecast model, EPA developed two uniform distributions based on calculated the ICR Matrix Method-to-SWAT multipliers. The distributions use 1.0 as the 5^{th} percentile value and the ICR Matrix Method-to-SWAT multiplier as the 95^{th} percentile value. There are two distributions, one for the 20 percent safety margin and one for the 25 percent safety margin. Exhibit 5.19 provides a graphical depiction of the two uniform distributions for the Preferred Alternative.

To produce final estimates of percent reduction in TTHM and HAA5 for large surface water systems, EPA developed a Monte Carlo simulation model, similar to the compliance forecast model described in Section 5.3.6, with three basic steps:

Step 1: The model randomly selects the predicted TTHM or HAA5 reduction from SWAT, as shown in column F of Exhibit 5.18 for either the 20 or 25 percent safety margin runs. Results for each of the two safety margins have an equal (50 percent) chance of being selected.

Step 2: The model randomly selects the ICR-to-SWAT multiplier from the appropriate uniform distribution from Exhibit 5.19 for the safety margin selected in Step 1.

Step 3: The model applies the multipliers from Step 2 to the TTHM or HAA5 reductions identified in Step 1 to calculate the percent reduction from Stage 1 to Stage 2 for that iteration.

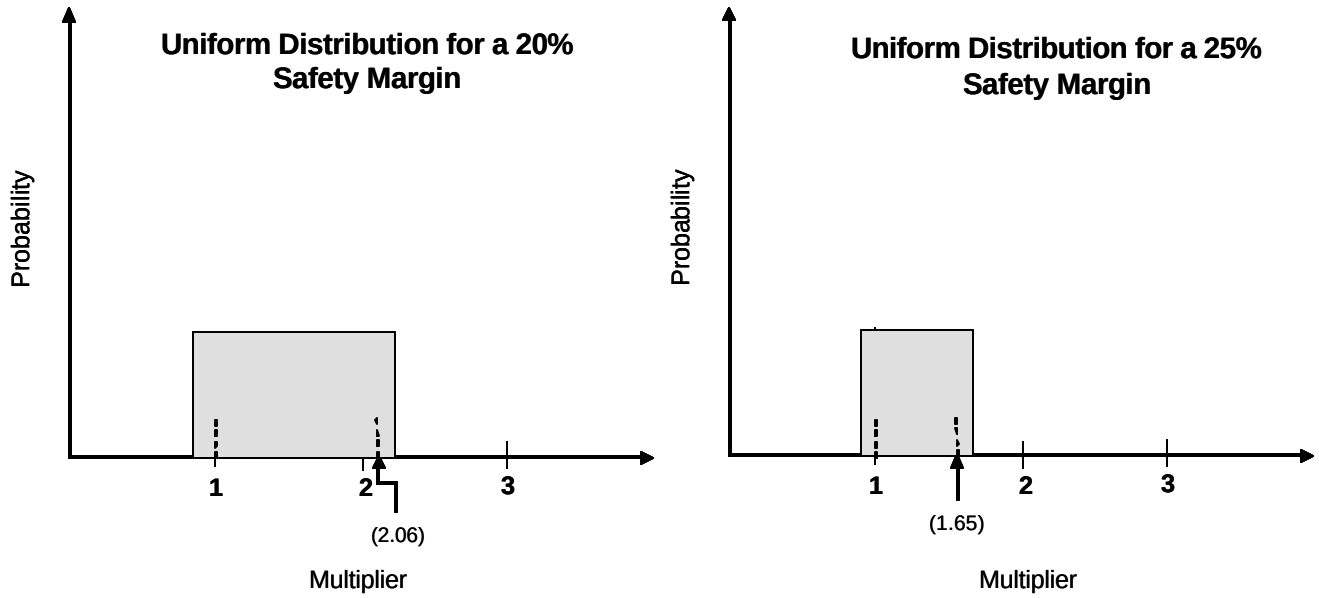
The process is repeated 10,000 times to produce a distribution of TTHM or HAA5 reductions from Stage 1 to Stage 2 for large surface water systems. This distribution is carried through the benefits model, as described in Chapter 6. Note that only TTHM or HAA5 reduction for the 20 percent safety margin is used for Regulatory Alternatives 1, 2, and 3 as the IDSE is not a component of these alternatives. Note also that results for TTHM and HAA5 are generated independently. Final estimates of predicted reduction in average TTHM and HAA5 concentrations are presented in Section 5.5.5 for all system types and sizes.

Exhibit 5.18 Inputs to Monte Carlo Simulation Model: Estimated DBP Reduction from SWAT and ICR Matrix Method

Regulatory Alternative	ICR Matrix Method			SWAT			ICR Matrix Method-to-SWAT Multiplier
	Mean of Plant Means pre-S2 (µg/L)	Mean of Plant Means post-S2 (µg/L)	% Reduction from pre-S2 to post-S2	Mean of Plant Means pre-S2 (µg/L)	Mean of Plant Means post-S2 (µg/L)	% Reduction from pre-S2 to post-S2	
	A	B	C = (B - A)/A	D	E	F = (E - D)/D	**G = C / F**
TTHM							
Preferred Reg. Alternative (80/60 LRAA, IDSE), 20% SM	35.0	31.6	9.7%	35.5	33.8	4.7%	2.06
Preferred Reg. Alternative (80/60 LRAA, IDSE), 25% SM	34.6	29.8	13.8%	35.5	32.5	8.4%	1.65
Reg. Alternative 1 (Bromate = 5), 20% SM	35.0	31.6	9.7%	35.5	33.0	6.9%	1.42
Reg. Alternative 2 (80/60 Single High), 20% SM	33.7	25.1	25.7%	35.5	23.7	33.2%	0.77
Reg. Alternative 3 (40/30 RAA), 20% SM	32.7	19.7	39.7%	35.5	21.0	40.8%	0.97
HAA5							
Preferred Reg. Alternative (80/60 LRAA, IDSE), 20% SM	22.5	20.1	10.5%	25.0	23.8	4.7%	2.23
Preferred Reg. Alternative (80/60 LRAA, IDSE), 25% SM	22.2	18.6	16.0%	25.0	22.9	8.3%	1.92
Reg. Alternative 1 (BR = 5), 20% SM	22.5	20.1	10.5%	25.0	23.6	5.6%	1.87
Reg. Alternative 2 (80/60 SH), 20% SM	21.7	15.7	27.6%	25.0	16.5	33.8%	0.82
Reg. Alternative 3 (40/30 RAA), 20% SM	21.3	13.0	39.0%	25.0	13.9	44.3%	0.88

Sources: SWAT run summaries (USEPA 2001b), ICR Matrix Method Results (USEPA 2005a)
(A) Average of plant-average values for all plants, pre-Stage 2 conditions from Exhibit 5.8a. ICR Matrix Method results for Reg. Alternative 1 are the same as for the Preferred Alternative, Unadjusted.
(B) Average of plant-average values for all plants, post-stage 2 conditions from Exhibits 5.8b through 5.8e. ICR Matrix Method results for Reg. Alternative 1 are the same as for the Preferred Alternative, Unadjusted.
(D) and (E) SWAT run summaries (USEPA 2001b).

Exhibit 5.19 Inputs to the Monte Carlo Simulation Model: Uniform Distributions Based on ICR Matrix Method-to-SWAT Multiplier



5.5.2 Reductions for Small Surface Water Systems

National Rural Water Association (NRWA) survey data were the basis for estimating baseline TTHM and HAA5 levels in small surface water systems (USEPA 2001a). Pre-Stage 2 and Post-Stage 2 TTHM and HAA5 levels for small surface water systems were assumed to be similar to large system levels. Thus, both methods used for large and medium surface water systems (SWAT and ICR Matrix Method) were used to calculate percent reduction in TTHM and HAA5 levels for small surface water systems. Note that EPA believes that the 20 percent safety margin already accounts for potential impacts of the IDSE for small surface water systems because their distribution systems as not as complex compared to large ground water systems. Therefore, an alternative percent reduction for a 25 percent safety margin was not used for small surface water systems, as it was for large and medium surface water systems.

Final estimated percent reductions in average TTHM and HAA5 concentrations are presented in Section 5.5.5 for all system types and sizes.

5.5.3 Reductions for Large and Medium Ground Water Systems

As described in Section 3.7, ICR data were used to characterize TTHM and HAA5 levels for the ground water system pre-Stage 1 baseline. EPA used the ICR Matrix Method to predict changes in

average TTHM and HAA5 levels for large ground water systems following the Stage 1 and Stage 2 rules. A detailed description of the method can be found in Section 5.5.2.2

The analysis of Stage 2-compliant, screened ground water plants using chloramines and/or an advanced treatment technology at the time of the ICR data collection is shown in Exhibit 5.20. TTHM and HAA5 levels for these plants is used to estimate the TTHM and HAA5 levels for those plants changing treatment technology to meet Stage 1 and Stage 2 rules. The number of ICR GW plants that use chloramines and/or advanced disinfectants and comply with the Stage 2 DBPR is low: 12 plants for the Preferred Alternative (considering a 20 percent safety margin on compliance). This is roughly 15 percent of the total number of screened ground water plants. EPA compared TOC levels for the Stage 2-compliant ground water plants that use chloramines and/or an advanced treatment technology to levels for the Stage 2 non-compliant plants and found them to be similar.

Exhibit 5.21a shows the ICR Matrix Method for the Stage 2 DBPR Preferred Alternative. Exhibits 5.21b and 5.21c show the method for Alternatives 2 and 3. Note that the ICR Matrix Method for ground water plants is not performed for the 25 percent safety margin. EPA believes that for ground water systems, the 20 percent safety margin analysis already accounts for the impacts of the IDSE since these systems do not typically observe high year-to-year or seasonal variability in water quality (see Section 5.3.4. for additional information). Section 5.5.5 summarizes percent reduction in TTHM and HAA5 for all system sizes and source water types.

5.5.4 Reductions for Small Ground Water Systems

Data from seven states were used to characterize TTHM and HAA5 levels for small ground water systems (USEPA 2000d). To derive the percent reduction in average TTHM and HAA5 levels for small ground water systems, EPA compared the predicted percent of plants making treatment technology changes for small ground water systems to large ground water systems. The percent reduction in DBP concentrations as predicted by the ICR Matrix Method for large ground water systems (GW_L) is multiplied by the ratio of small ground water plants changing treatment technology (GCT_s) to large ground water plants changing treatment technology (GCT_L), or

$$GW_S = GW_L * (GCT_S/GCT_L)$$

where,

GW_L and GW_S = predicted percent DBP reduction for large and small ground water systems, respectively.

GCT_L and GCT_S = the percent of plants changing treatment technology for large and small ground water plants (weighted average across large or small system size categories), respectively.

Exhibit 5.20 TTHM and HAA5 Levels for Stage 2-Compliant Ground Water Plants Using Chloramines and/or an Advanced Treatment Technology

Subset of Stage 2 Compliant Plants	Preferred Regulatory Alternative		
	No. of Plants	Mean TTHM (µg/L)	Mean HAA5 (µg/L)
CLM only	10	29.0	19.4
Adv. tech with CLM	2	19.9	16.5
Adv. tech w/o CLM	0	0.0	0.0
Total	12	27.5	18.9

Subset of Stage 2 Compliant Plants	Regulatory Alternative 2		
	No. of Plants	Mean TTHM (µg/L)	Mean HAA5 (µg/L)
CLM only	6	21.7	14.2
Adv. tech with CLM	2	19.9	16.5
Adv. tech w/o CLM	0	0.0	0.0
Total	8	21.2	14.8

Subset of Stage 2 Compliant Plants	Regulatory Alternative 3		
	No. of Plants	Mean TTHM (µg/L)	Mean HAA5 (µg/L)
CLM only	6	18.5	11.3
Adv. tech with CLM	2	19.9	16.5
Adv. tech w/o CLM	0	0.0	0.0
Total	8	18.8	12.6

Notes: All TTHM and HAA5 values represent the mean of plant-means.
Source: ICR Aux 1 database (USEPA 2000h), analysis of ICR screened data (82 ground water plants)

Exhibit 5.21a ICR Matrix Method for Ground Water Plants for the Stage 2 DBPR Preferred Alternative

Pre-Stage 1

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Max LRAA	<64/48	A1	
	>= 64/48 (S2 non-compliant)	A2	B2

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L)	
			TTHM	HAA5
A1	75	91%	11.62	5.50
A2	2	2%	35.29	31.71
B2	5	6%	63.54	43.37
All Plants	82	100%	15.36	8.45

Pre-Stage 2

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Max LRAA	<64/48	A1+B2	
	>= 64/48 (S2 non-compliant)	A2	

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L)	
			TTHM	HAA5
A1	75	91%	11.62	5.50
A2	2	2%	35.29	31.71
B2	5	6%	27.50	18.95
All Plants	82	100%	13.16	6.96

Post-Stage 2

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Max LRAA	<64/48	A1+B2+A2	
	>= 64/48 (S2 non-compliant)		

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L)	
			TTHM	HAA5
A1	75	91%	11.62	5.50
A2	2	2%	27.50	18.95
B2	5	6%	27.50	18.95
All Plants	82	100%	12.97	6.64

Notes: 1) In the first table on the left, A1 through B2 are the number of ICR plants that meet the criteria for each bin under pre-Stage 1 conditions. Their calculated average TTHM and HAA5 values based on the averages of all plant-averages are shown in the first table on the right. A total of 82 ICR plants were evaluated.

2) Each cell (bin) represents a range of the TTHM and HAA5 RAA concentrations and maximum LRAA concentrations in µg/L (i.e., RAA <64/48 means the plant needs to have its TTHM RAA level below 64 µg/L and its HAA5 RAA level below 48 µg/L to be placed into the bin). The maximum TTHM or HAA5 result determines the bin placement.

3) Crossed-out bins represent plants that have moved from out of compliance bins to in compliance bins.

4) The gray bins on the right-hand side represents bins that have moved into compliance with pre-Stage 2 and post-Stage 2. The TTHM and HAA5 concentrations for these plants are the averages of the values for those ICR plants that are compliant with Stage 1 and Stage 2 and use an advanced treatment technology and/or chloramines (12 plants).

Exhibit 5.21b ICR Matrix Method for Ground Water Plants for Regulatory Alternative 2

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Single High	<64/48	A1	
	>= 64/48 (S2 non-compliant)	A2	B2

Pre-Stage 1

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	67	82%	8.76	3.89
A2	10	12%	35.47	21.51
B2	5	6%	63.54	43.37
All Plants	82	100%	15.36	8.45

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Single High	<64/48	A1+B2	
	>= 64/48 (S2 non-compliant)	A2	

Pre-Stage 2

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	67	82%	8.76	3.89
A2	10	12%	35.47	21.51
B2	5	6%	21.23	14.80
All Plants	82	100%	12.78	6.70

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Single High	<64/48	A1+B2+A2	
	>= 64/48 (S2 non-compliant)		

Post-Stage 2

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	67	82%	8.76	3.89
A2	10	12%	21.23	14.80
B2	5	6%	21.23	14.80
All Plants	82	100%	11.04	5.88

Notes: 1) In the first table on the left, A1 through B2 are the number of ICR plants that meet the criteria for each bin under pre-Stage 1 conditions. Their calculated average TTHM and HAA5 values based on the averages of all plant-averages are shown in the first table on the right. A total of 82 ICR plants were evaluated.

2) Each cell (bin) represents a range of the TTHM and HAA5 RAA concentrations and maximum LRAA concentrations in µg/L (i.e., RAA <64/48 means the plant needs to have its TTHM RAA level below 64 µg/L and its HAA5 RAA level below 48 µg/L to be placed into the bin). The maximum TTHM or HAA5 result determines the bin placement.

3) Crossed-out bins represent plants that have moved from out of compliance bins to in compliance bins.

4) The gray bins on the right-hand side represents bins that have moved into compliance with pre-Stage 2 and post-Stage 2. The TTHM and HAA5 concentrations for these plants are the averages of the values for those ICR plants that are compliant with Stage 1 and Stage 2 and use an advanced treatment technology and/or chloramines (8 plants).

Exhibit 5.21c ICR Matrix Method for Ground Water Plants for Regulatory Alternative 3

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
RAA	<32/24	A1	
	>= 32/24 (S2 non-compliant)	A2	B2

Pre-Stage 1

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	67	82%	7.90	3.51
A2	10	12%	41.27	24.03
B2	5	6%	63.54	43.37
All Plants	82	100%	15.36	8.45

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
RAA	<32/24	A1+B2	
	>= 32/24 (S2 non-compliant)	A2	

Pre-Stage 2

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	67	82%	7.90	3.51
A2	10	12%	41.27	24.03
B2	5	6%	18.84	12.57
All Plants	82	100%	12.63	6.57

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
RAA	<32/24	A1+B2+A2	
	>= 32/24 (S2 non-compliant)		

Post-Stage 2

Bin	Number of Plants	Percent of Plants	Average of Plant Averages (ug/L) TTHM	HAA5
A1	67	82%	7.90	3.51
A2	10	12%	18.84	12.57
B2	5	6%	18.84	12.57
All Plants	82	100%	9.90	5.17

Notes: 1) In the first table on the left, A1 through B2 are the number of ICR plants that meet the criteria for each bin under pre-Stage 1 conditions. Their calculated average TTHM and HAA5 values based on the averages of all plant-averages are shown in the first table on the right. A total of 82 ICR plants were evaluated.

2) Each cell (bin) represents a range of the TTHM and HAA5 RAA concentrations and maximum LRAA concentrations in µg/L (i.e., RAA <64/48 means the plant needs to have its TTHM RAA level below 64 µg/L and its HAA5 RAA level below 48 µg/L to be placed into the bin). The maximum TTHM or HAA5 result determines the bin placement.

3) Crossed-out bins represent plants that have moved from out of compliance bins to in compliance bins.

4) The gray bins on the right-hand side represents bins that have moved into compliance with pre-Stage 2 and post-Stage 2. The TTHM and HAA5 concentrations for these plants are the averages of the values for those ICR plants that are compliant with Stage 1 and Stage 2 and use an advanced treatment technology and/or chloramines (8 plants).

5.5.5 Results for All Systems

Exhibit 5.22 presents predicted pre-Stage 1 and pre-Stage 2 TTHM and HAA5 mean distribution system concentrations for surface and ground water plants. This analysis shows that the largest percent reduction in DBP concentrations is for surface water plants from pre-Stage 1 to pre-Stage 2 conditions (reductions range from approximately 27 to 57 percent for all plants). The reduction in TTHM and HAA5 levels for ground water plants is less, ranging from 5 to 18 percent. The percent reduction for small surface water plants is greater than the percent reduction for large surface water plants because plants in small systems did not have to meet the TTHM rule MCL of 100 μg/L prior to the Stage 1 DBPR.

Exhibit 5.23 shows the predicted percent reduction in TTHM and HAA5 concentrations from pre-Stage 2 to post-Stage 2 DBPR conditions for the Preferred Alternative. Exhibit 5.24a, 5.24b, and 5.24c show similar information for regulatory alternatives 1, 2, and 3, respectively. Note that the percent reduction for Regulatory Alternative 1 is slightly less than the percent reduction for the Preferred alternative because none of the Regulatory Alternatives except the preferred include the IDSE component.

It is important to note that the calculation of the percent reduction in all plant-mean DBP levels includes plants that make minor process changes as well as those that do not make any treatment technology changes to meet the Stage 2 DBPR. The predicted percent reduction for the subset of plants that add advanced treatment technologies or chloramines, therefore, is much higher. Among those plants reducing DBP levels from Stage 1 to Stage 2, it is predicted that the average reductions in DBP levels will be approximately 30 percent, and may range from less than 5 up to 60 percent.

Exhibit 5.22 Reduction in Average TTHM and HAA5 Concentrations from Pre-Stage 1 to Pre-Stage 2

Source Water Type	System Size (Population Served)	Population	TTHM		
			Pre-Stage 1 (µg/L)	Pre-Stage 2 (µg/L)	Percent Reduction
		A	B	C	D = (B-C)/B
SW	Large (> 10,000)	160,935,736	48.7	35.5	27.2%
	Small (= 10,000)	8,422,403	82.8	35.5	57.2%
GW	Large (> 10,000)	65,152,168	15.4	13.2	14.3%
	Small (= 10,000)	28,514,211	16.5	15.6	5.6%
All Systems*		**263,024,518**	**38.05**	**27.79**	**27.0%**

Source Water Type	System Size (Population Served)	Population	HAA5		
			Pre-Stage 1 (µg/L)	Pre-Stage 2 (µg/L)	Percent Reduction
		A	E	F	G = (E-F)/E
SW	Large (> 10,000)	160,935,736	35.5	25.0	29.5%
	Small (= 10,000)	8,422,403	45.3	25.0	44.8%
GW	Large (> 10,000)	65,152,168	8.4	7.0	17.6%
	Small (= 10,000)	28,514,211	9.1	8.5	6.1%
All Systems*		**263,024,518**	**26.24**	**18.75**	**28.6%**

Notes:

All TTHM and HAA5 concentrations represent the mean of all plant-mean concentrations

* TTHM and HAA5 concentrations for all systems are the population-weighted values

(A) SDWIS 2003 3rd quarter freeze, community water system population (exhibit 3.3, CWSs only)

(B) and (E) Large SW: Exhibit 3.15, SWAT plant-mean data. Small SW: Exhibit 3.21, NRWA plant-mean data. Large GW: Exhibit 3.20, ICR plant-mean data. Small GW: Exhibit 3.21, State plant-mean data.

(C) and (F) For SW, Pre-Stage 2 runs from SWAT (USEPA 2001e). For large GW, pre-Stage 2 based on the ICR matrix method. For small GW, pre-Stage 2 based on based on percent reduction in large GW and comparison of percent changing technology (see methodology in Section 5.5)

Exhibit 5.23 Reduction in Average TTHM and HAA5 Concentrations from Pre-Stage 2 to Post-Stage 2, Preferred Alternative

Source Water Type	System Size (Population Served)	Population	TTHM						
			Pre-Stage 2 Level (µg/L)	Post-Stage 2 Level (µg/L)			Percent Reduction		
				mean	5th	95th	Mean	5th	95th
		A	B	C = B * (1-D)			D		
SW	Large (> 10,000)	160,935,736	35.5	32.2	33.6	30.7	9.3%	5.2%	13.5%
	Small (= 10,000)	8,422,403	35.5	32.9	33.8	32.0	7.2%	4.7%	9.7%
GW	Large (> 10,000)	65,152,168	13.2	13.0			1.4%		
	Small (= 10,000)	28,514,211	15.6	15.5			0.7%		
All Systems*		**263,024,518**	**27.79**	**25.63**	**26.55**	**24.72**	**7.8%**	**4.5%**	**11.1%**

Source Water Type	System Size (Population Served)	Population	HAA5						
			Pre-Stage 2 Level (µg/L)	Post-Stage 2 Level (µg/L)			Percent Reduction		
				mean	5th	95th	Mean	5th	95th
		A	E	F = E * (1-G)			G		
SW	Large (> 10,000)	160,935,736	25.0	22.5	23.7	21.1	10.0%	5.3%	15.5%
	Small (= 10,000)	8,422,403	25.0	23.1	23.8	22.4	7.6%	4.7%	10.5%
GW	Large (> 10,000)	65,152,168	7.0	6.6			4.5%		
	Small (= 10,000)	28,514,211	8.5	8.3			2.2%		
All Systems*		**263,024,518**	**18.75**	**17.06**	**17.81**	**16.22**	**9.0%**	**5.0%**	**13.5%**

Notes:

All TTHM and HAA5 concentrations represent the mean of all plant-mean concentrations

The benefits analysis performs the monte carlo simulation model using percent reductions in DBPs (not post-stage 2 DBP values). Thus, columns C and F are calculated, and D and G are outputs from the model.

* TTHM and HAA5 concentrations for all systems are the population-weighted values

(A) SDWIS 2003 3rd quarter freeze, community water system population (exhibit 3.3, CWSs only)

(B) and (E) Exhibit 5.22

(D) and (G) Outputs from the benefits monte carlo simulation model. Confidence bounds for large and medium SW systems account for uncertainties in compliance forecast methodologies and potential impacts of the IDSE. Confidence bounds for small SW systems account for uncertainties in compliance forecast methodologies.

Exhibit 5.24a Reduction in Average TTHM and HAA5 Concentrations from Pre-Stage 2 to Post-Stage 2, Regulatory Alternative 1

Source Water Type	System Size (Population Served)	Population	TTHM Pre-Stage 2 Level (µg/L)	TTHM Post-Stage 2 Level (µg/L) mean	TTHM Post-Stage 2 Level (µg/L) 5th	TTHM Post-Stage 2 Level (µg/L) 95th	TTHM Percent Reduction Mean	TTHM Percent Reduction 5th	TTHM Percent Reduction 95th
		A	B	C = B * (1-D)			D		
SW	Large (> 10,000)	160,935,736	35.5	32.5	33.0	32.0	8.3%	6.9%	9.7%
	Small (= 10,000)	8,422,403	35.5	32.5	33.0	32.0	8.3%	6.9%	9.7%
GW	Large (> 10,000)	65,152,168	13.2	13.0			1.4%		
	Small (= 10,000)	28,514,211	15.6	15.5			0.7%		
All Systems*		**263,024,518**	**27.79**	**25.83**	**26.16**	**25.49**	**7.1%**	**5.9%**	**8.3%**

Source Water Type	System Size (Population Served)	Population	HAA5 Pre-Stage 2 Level (µg/L)	HAA5 Post-Stage 2 Level (µg/L) mean	HAA5 Post-Stage 2 Level (µg/L) 5th	HAA5 Post-Stage 2 Level (µg/L) 95th	HAA5 Percent Reduction Mean	HAA5 Percent Reduction 5th	HAA5 Percent Reduction 95th
		A	E	F = E * (1-G)			G		
SW	Large (> 10,000)	160,935,736	25.0	23.0	23.6	22.4	8.1%	5.6%	10.5%
	Small (= 10,000)	8,422,403	25.0	23.0	23.6	22.4	8.1%	5.6%	10.5%
GW	Large (> 10,000)	65,152,168	7.0	6.6			4.5%		
	Small (= 10,000)	28,514,211	8.5	8.3			2.1%		
All Systems*		**263,024,518**	**18.75**	**17.34**	**17.72**	**16.96**	**7.5%**	**5.5%**	**9.5%**

Notes:

All TTHM and HAA5 concentrations represent the mean of all plant-mean concentrations

The benefits analysis performs the monte carlo simulation model using percent reductions in DBPs (not post-stage 2 DBP values). Thus, columns C and F are calculated, and D and G are outputs from the model.

* TTHM and HAA5 concentrations for all systems are the population-weighted values

(A) SDWIS 2003 3rd quarter freeze, community water system population (exhibit 3.3, CWSs only)

(B) and (E) Exhibit 5.22

(D) and (G) Outputs from the benefits monte carlo simulation model. Confidence bounds for SW systems account for uncertainties in compliance forecast methodologies

Exhibit 5.24b Reduction in Average TTHM and HAA5 Concentrations from Pre-Stage 2 to Post-Stage 2, Regulatory Alternative 2

Source Water Type	System Size (Population Served)	Population	TTHM Pre-Stage 2 Level (µg/L)	TTHM Post-Stage 2 Level (µg/L) mean	TTHM Post-Stage 2 Level (µg/L) 5th	TTHM Post-Stage 2 Level (µg/L) 95th	TTHM Percent Reduction Mean	TTHM Percent Reduction 5th	TTHM Percent Reduction 95th
		A	B	C = B * (1-D)			D		
SW	Large (> 10,000)	160,935,736	35.5	25.0	26.4	23.7	29.4%	25.7%	33.2%
	Small (= 10,000)	8,422,403	35.5	25.0	26.4	23.7	29.4%	25.7%	33.2%
GW	Large (> 10,000)	65,152,168	13.2	11.0			16.1%		
	Small (= 10,000)	28,514,211	15.6	15.1			2.9%		
All Systems*		**263,024,518**	**27.79**	**20.48**	**21.39**	**19.56**	**26.3%**	**23.0%**	**29.6%**

Source Water Type	System Size (Population Served)	Population	HAA5 Pre-Stage 2 Level (µg/L)	HAA5 Post-Stage 2 Level (µg/L) mean	HAA5 Post-Stage 2 Level (µg/L) 5th	HAA5 Post-Stage 2 Level (µg/L) 95th	HAA5 Percent Reduction Mean	HAA5 Percent Reduction 5th	HAA5 Percent Reduction 95th
		A	E	F = E * (1-G)			G		
SW	Large (> 10,000)	160,935,736	25.0	17.3	18.1	16.5	30.7%	27.6%	33.8%
	Small (= 10,000)	8,422,403	25.0	17.3	18.1	16.5	30.7%	27.6%	33.8%
GW	Large (> 10,000)	65,152,168	7.0	5.9			15.4%		
	Small (= 10,000)	28,514,211	8.5	8.3			2.8%		
All Systems*		**263,024,518**	**18.75**	**13.49**	**14.05**	**12.93**	**28.0%**	**25.0%**	**31.0%**

Notes:

All TTHM and HAA5 concentrations represent the mean of all plant-mean concentrations

The benefits analysis performs the monte carlo simulation model using percent reductions in DBPs (not post-stage 2 DBP values). Thus, columns C and F are calculated, and D and G are outputs from the model.

* TTHM and HAA5 concentrations for all systems are the population-weighted values

(A) SDWIS 2003 3rd quarter freeze, community water system population (exhibit 3.3, CWSs only)

(B) and (E) Exhibit 5.22

(D) and (G) Outputs from the benefits monte carlo simulation model. Confidence bounds for SW systems account for uncertainties in compliance forecast methodologies

Exhibit 5.24c Reduction in Average TTHM and HAA5 Concentrations from Pre-Stage 2 to Post-Stage 2, Regulatory Alternative 3

Source Water Type	System Size (Population Served)	Population	TTHM Pre-Stage 2 Level (µg/L)	TTHM Post-Stage 2 Level (µg/L) mean	TTHM Post-Stage 2 Level (µg/L) 5th	TTHM Post-Stage 2 Level (µg/L) 95th	TTHM Percent Reduction Mean	TTHM Percent Reduction 5th	TTHM Percent Reduction 95th
		A	B	C = B * (1-D)			D		
SW	Large (> 10,000)	160,935,736	35.5	21.2	21.4	21.0	40.2%	39.7%	40.8%
	Small (= 10,000)	8,422,403	35.5	21.2	21.4	21.0	40.2%	39.7%	40.8%
GW	Large (> 10,000)	65,152,168	13.2	9.9			24.8%		
	Small (= 10,000)	28,514,211	15.6	15.2			2.3%		
All Systems*		**263,024,518**	**27.79**	**17.75**	**18.06**	**17.44**	**36.1%**	**35.0%**	**37.3%**

Source Water Type	System Size (Population Served)	Population	HAA5 Pre-Stage 2 Level (µg/L)	HAA5 Post-Stage 2 Level (µg/L) mean	HAA5 Post-Stage 2 Level (µg/L) 5th	HAA5 Post-Stage 2 Level (µg/L) 95th	HAA5 Percent Reduction Mean	HAA5 Percent Reduction 5th	HAA5 Percent Reduction 95th
		A	E	F = E * (1-G)			G		
SW	Large (> 10,000)	160,935,736	25.0	14.6	15.3	13.9	41.6%	39.0%	44.3%
	Small (= 10,000)	8,422,403	25.0	14.6	15.3	13.9	41.6%	39.0%	44.3%
GW	Large (> 10,000)	65,152,168	7.0	5.2			25.7%		
	Small (= 10,000)	28,514,211	8.5	8.3			2.4%		
All Systems*		**263,024,518**	**18.75**	**11.57**	**12.10**	**11.03**	**38.3%**	**35.4%**	**41.2%**

Notes:

All TTHM and HAA5 concentrations represent the mean of all plant-mean concentrations

The benefits analysis performs the monte carlo simulation model using percent reductions in DBPs (not post-stage 2 DBP values). Thus, columns C and F are calculated, and D and G are outputs from the model.

* TTHM and HAA5 concentrations for all systems are the population-weighted values

(A) SDWIS 2003 3rd quarter freeze, community water system population (exhibit 3.3, CWSs only)

(B) and (E) Exhibit 5.22

(D) and (G) Outputs from the benefits monte carlo simulation model. Confidence bounds for SW systems account for uncertainties in compliance forecast methodologies

5.6 Reduction in Frequency of Peak TTHM and HAA5 Concentrations

Treatment technology changes to meet the Stage 1 and Stage 2 DBPRs can reduce the frequency of peak TTHM and HAA5 values and reduce all levels of TTHM and HAA5 concentrations. Both effects have potential health benefits, which are discussed in detail in Chapter 6. This section summarizes the methodology for estimating reduced frequency of peak TTHM and HAA5 concentrations as a result of the Stage 1 and Stage 2 Preferred Alternative.

5.6.1 Methodology and Assumptions

For the purposes of this section, a "peak" TTHM or HAA5 is defined as any individual measurement greater than a specified threshold concentration. The level does not have to be sustained over any period of time to be considered a peak measurement, and it can be a measurement taken at any time in the year. As discussed in Chapter 6, the health data do not conclusively identify a peak TTHM or HAA5 level of concern. Therefore, the analyses in this section use the following alternative threshold concentrations (or "study levels") for the purposes of defining peaks: 60, 75, 80, and 100 μg/L for TTHM and 45, 60, and 75 μg/L for HAA5. The analyses in this section predict the percent of locations with at least one TTHM and HAA5 observation greater than each study level for pre-Stage 1, simulated pre-Stage 2 and simulated post-Stage 2 conditions. This information is used in the exposure assessment in Chapter 6.

EPA evaluated TTHM and HAA5 data from both ground and surface water plants for the four ICR distribution system sampling locations (DSE, AVG1, AVG2, and DS Maximum) to predict how the frequency of peak TTHM and HAA5 concentrations changes as a result of the Stage 1 and Stage 2 rules. For surface water plants, ICR-observed data is used instead of SWAT-predicted data because, as explained in Appendix A, SWAT-predicted TTHM and HAA5 concentrations are valid only when considering national averages, not at the plant level.

The method used to predict reduction in locations with peaks is the ICR Matrix Method. Section 5.5.2.2 provides a detailed description of how the matrix method predicts reductions in average DBP concentrations. The method works in the same way to predict reduction in locations with peaks. Plants are assigned to a bin (bins are defined in the tables in the left-hand side of the exhibit) based on their RAA and LRAA observations, as calculated from the ICR data. The method works by moving plants from non-compliant bins (Bins B2 and A2) into the compliant bin (Bin A1) in the second and third tables, representing their actions to comply with Stage 1 and Stage 2, respectively.

Exhibit 5.25a ICR Matrix Method for Peaks for the Stage 2 DBPR, 20 Percent Safety Margin, Large Surface and Ground Water Plants

Pre-Stage 1

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Max LRAA	<64/48	A1	
	>= 64/48 (S2 non-compliant)	A2	B2

Bin	Number of Locations	Locations with TTHM >60 ug/L	Locations with TTHM >75 ug/L	Locations with TTHM >80 ug/L	Locations with TTHM >100 ug/L	Locations with HAA5 >45 ug/L	Locations with HAA5 >60 ug/L	Locations with HAA5 >75 ug/L
A1	880	122	31	19	4	80	13	3
A2	155	96	65	54	17	82	32	9
B2	195	173	151	142	83	136	112	72
All Plants	1,230	391	247	215	104	298	157	84

Pre-Stage 2

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Max LRAA	<64/48	A1+B2	
	>= 64/48 (S2 non-compliant)	A2	

Bin	Number of Locations	Locations with TTHM >60 ug/L	Locations with TTHM >75 ug/L	Locations with TTHM >80 ug/L	Locations with TTHM >100 ug/L	Locations with HAA5 >45 ug/L	Locations with HAA5 >60 ug/L	Locations with HAA5 >75 ug/L
A1	880	122	31	19	4	80	13	3
A2	155	96	65	54	17	82	32	9
B2	195	40	5	1	0	21	3	0
All Plants	1,230	258	101	74	21	183	48	12

Post-Stage 2

		RAA	
		<64/48	>=64/48 (S1 non-compliant)
Max LRAA	<64/48	A1+B2+A2	
	>= 64/48 (S2 non-compliant)		

Bin	Number of Locations	Locations with TTHM >60 ug/L	Locations with TTHM >75 ug/L	Locations with TTHM >80 ug/L	Locations with TTHM >100 ug/L	Locations with HAA5 >45 ug/L	Locations with HAA5 >60 ug/L	Locations with HAA5 >75 ug/L
A1	880	122	31	19	4	80	13	3
A2	155	32	4	1	0	17	2	0
B2	195	40	5	1	0	21	3	0
All Plants	1,230	193	40	21	4	117	18	3

Notes: 1) In the Pre-Stage 1 tables, A1 through B2 are the number of locations for ICR plants that meet the criteria for each bin under pre-Stage 1 conditions. A total of 1,230 locations for 311 screened ICR surface and ground water plants were evaluated.

2) Each cell (bin) represents a range of the TTHM and HAA5 RAA concentrations and Maximum LRAA concentrations in µg/L (i.e., RAA <64/48 means the plant needs to have its TTHM RAA level below 64 µg/L and its HAA5 RAA level below 48 µg/L to be placed into the bin). The maximum TTHM or HAA5 result determines the bin placement. Note that bins are based on a 20 percent safety margin on the Stage 1 and Stage 2 MCLs

3) Crossed-out bins represent plants that have moved from out of compliance bins to in compliance bins.

4) The gray bins on the right-hand side represents bins that have moved into compliance with pre-Stage 2 and post-Stage 2. The percent locations with TTHM and HAA5 concentrations above each study level is the percent of locations above the study level for those ICR plants that are compliant with Stage 1 and Stage 2 and use an advanced treatment technology and/or chloramines (as shown in Exhibit 5.26).

Exhibit 5.25b ICR Matrix Method for Peaks for the Stage 2 DBPR, 25 Percent Safety Margin, Large Surface and Ground Water Plants

Pre-Stage 1

		RAA	
		<64/48	>=64/48 (S1 non compliant)
Max LRAA	<60/45	A1	
	>= 60/45 (S2 non-compliant)	A2	B2

Bin	Number of Locations	Locations with TTHM >60 ug/L	Locations with TTHM >75 ug/L	Locations with TTHM >80 ug/L	Locations with TTHM >100 ug/L	Locations with HAA5 >45 ug/L	Locations with HAA5 >60 ug/L	Locations with HAA5 >75 ug/L
A1	832	90	18	11	2	52	4	1
A2	203	128	78	62	19	110	41	11
B2	195	173	151	142	83	136	112	72
All Plants	1,230	391	247	215	104	298	157	84

Pre-Stage 2

		RAA	
		<64/48	>=64/48 (S1 non compliant)
Max LRAA	<60/45	A1+B2	
	>= 60/45 (S2 non-compliant)	A2	

Bin	Number of Locations	Locations with TTHM >60 ug/L	Locations with TTHM >75 ug/L	Locations with TTHM >80 ug/L	Locations with TTHM >100 ug/L	Locations with HAA5 >45 ug/L	Locations with HAA5 >60 ug/L	Locations with HAA5 >75 ug/L
A1	832	90	18	11	2	52	4	1
A2	203	128	78	62	19	110	41	11
B2	195	40	5	1	0	21	3	0
All Plants	1,230	258	101	74	21	183	48	12

Post-Stage 2

		RAA	
		<64/48	>=64/48 (S1 non compliant)
Max LRAA	<60/45	A1+B2+A2	
	>= 60/45 (S2 non-compliant)		

Bin	Number of Locations	Locations with TTHM >60 ug/L	Locations with TTHM >75 ug/L	Locations with TTHM >80 ug/L	Locations with TTHM >100 ug/L	Locations with HAA5 >45 ug/L	Locations with HAA5 >60 ug/L	Locations with HAA5 >75 ug/L
A1	832	90	18	11	2	52	4	1
A2	203	41	5	1	0	22	3	0
B2	195	40	5	1	0	21	3	0
All Plants	1,230	171	28	14	2	94	9	1

Notes: 1) In the Pre-Stage 1 tables, A1 through B2 are the number of locations for ICR plants that meet the criteria for each bin under pre-Stage 1 conditions. A total of 1,230 locations for 311 screened ICR surface and ground water plants were evaluated.

2) Each cell (bin) represents a range of the TTHM and HAA5 RAA concentrations and Maximum LRAA concentrations in µg/L (i.e., RAA <64/48 means the plant needs to have its TTHM RAA level below 64 µg/L and its HAA5 RAA level below 48 µg/L to be placed into the bin). The maximum TTHM or HAA5 result determines the bin placement. Note that bins are based on a 20 percent safety margin on the Stage 1 and Stage 2 MCLs

3) Crossed-out bins represent plants that have moved from out of compliance bins to in compliance bins.

4) The gray bins on the right-hand side represents bins that have moved into compliance with pre-Stage 2 and post-Stage 2. The percent locations with TTHM and HAA5 concentrations above each study level is the percent of locations above the study level for those ICR plants that are compliant with Stage 1 and Stage 2 and use an advanced treatment technology and/or chloramines (as shown in Exhibit 5.26).

Characterization of peak TTHM and HAA5 levels for plants in each bin is shown in the tables on the right-hand side of Exhibit 5.25a for the 20 percent safety margin and 5.25b for the 25 percent safety margin. The first column shows the total number of locations in the bin. Subsequent columns show the percent of the locations that have at least one TTHM sampling result above study levels of 60, 75, 80, and 100 µg/L followed by the percent of locations with at least one HAA5 result above 45, 60, and 75 µg/L. Shaded rows represent those sampling locations associated with non-compliant plants that are expected to make treatment technology changes to meet Stage 1, then Stage 2 compliance.

Similar to the method explained in Section 5.5.1.2, EPA used information on the occurrence of peaks for ICR plants using advanced treatment technologies and/or chloramines at the time of the ICR to estimate the occurrence of peaks for plants predicted to change treatment technology to comply with the Stage 2 DBPR. The results of the analysis of TTHM and HAA5 peaks for this subset of plants is summarized in Exhibit 5.26. The frequency of peak TTHM and HAA5 concentrations in Exhibit 5.26 are assumed to represent the frequency of peak TTHM and HAA5 concentrations for plants that will make treatment technology changes to meet the Stage 1 and Stage 2 rules (identified as shaded rows for the pre-Stage 2 and post-Stage 2 tables in Exhibits 5.25a and 5.25b).

Exhibit 5.26 Frequency of Occurrence of Peaks for ICR Surface and Ground Water Plants Using Chloramines and/or Advanced Treatment Technologies

Technology Category	Number of Locations	Percent of Locations with TTHM Peaks Above				Percent of Locations with HAA5 Peaks Above		
		60 µg/L	75 µg/L	80 µg/L	100 µg/L	45 µg/L	60 µg/L	75 µg/L
	A	C	D	E	F	I	J	K
Stage 2 Compliance Based on a 20 Percent Safety Margin								
CLM only	235	24.7%	3.0%	0.9%	0.0%	11.9%	1.7%	0.0%
Adv. tech with CLM	55	7.3%	1.8%	0.0%	0.0%	1.8%	0.0%	0.0%
Adv. tech w/o CLM	20	5.0%	0.0%	0.0%	0.0%	20.0%	0.0%	0.0%
All plants	**310**	**20.3%**	**2.6%**	**0.6%**	**0.0%**	**10.6%**	**1.3%**	**0.0%**
Stage 2 Compliance Based on a 25 Percent Safety Margin								
CLM only	219	19.2%	1.8%	0.9%	0.0%	9.1%	0.9%	0.0%
Adv. tech with CLM	55	7.3%	1.8%	0.0%	0.0%	1.8%	0.0%	0.0%
Adv. tech w/o CLM	16	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
All plants	**290**	**15.9%**	**1.7%**	**0.7%**	**0.0%**	**7.2%**	**0.7%**	**0.0%**

Notes: Advanced technologies include chlorine dioxide,ozone, GAC, and membranes. Advanced technologies DO NOT consider enhanced coagulation or enhanced softening.

The 25 percent safety margin results include ground water systems.

Source: ICR database (USEPA 2000h), analysis of 311 screened ICR surface and ground water plants

5.6.2 Results

Exhibit 5.27 summarizes the results for each TTHM study level. Using the ICR Matrix Approach, the predicted percent of locations with at least one peak observation declines from 20.1 percent for pre-Stage 1 to 8.2 percent for pre-Stage 2 to 3.3 percent for post-Stage 2 DBPR conditions at a TTHM study level of 75 µg/L. EPA believes that this analysis of reduction in occurrence of peaks is conservatively low because it does not consider the potential impacts of the IDSE on large surface water plants (i.e., more plants may need to make treatment changes as a result of the IDSE, causing additional reduction in occurrence of peaks). Only the 20 percent safety margin results as shown in Exhibit 5.27 were used for the illustrative calculation in Appendix G. The 25 percent safety margin analysis of peaks also covers ground water systems, which is inconsistent with the compliance forecast and average DBP reduction analyses. Using the 25 percent safety margin results for the peaks analysis, therefore, would likely overestimate the results.

Exhibit 5.27 Predicted Percent of Distribution System Sampling Locations with Peaks for Pre-Stage 1, Pre-Stage 2, and Post-Stage 2 Conditions

TTHM Study Level Evaluated	Pre-Stage 1 Conditions			Pre-Stage 2 Conditions			Post-Stage 2 Conditions		
	No. of Locations Evaluated	No. of Locations with Peaks	Percent of Locations with Peaks	No. of Locations Evaluated	No. of Locations with Peaks	Percent of Locations with Peaks	No. of Locations Evaluated	No. of Locations with Peaks	Percent of Locations with Peaks
	A	B	C = B/A	D	E	F = E/D	G	H	I = H/G
60 µg/L	1,230	391	31.8%	1,230	258	20.9%	1,230	193	15.7%
75 µg/L	1,230	247	20.1%	1,230	101	8.2%	1,230	40	3.3%
80 µg/L	1,230	215	17.5%	1,230	74	6.0%	1,230	21	1.7%
100 µg/L	1,230	104	8.5%	1,230	21	1.7%	1,230	4	0.3%

Sources:
(A), (D), and (G) are the number of distribution system locations evaluated for 311 screened ICR surface and ground water plants.
(B), (E), and (H) are number of locations with at least one TTHM observation over the TTHM study level as derived in Exhibits 5.25

5.7 Uncertainties in these Compliance Forecast and Subsequent DBP Reduction

There are numerous sources of uncertainty in the compliance forecast, as discussed previously in this chapter and in detail in Appendices A and B. Exhibit 5.28 summarizes the key uncertainties in the compliance forecast, with the exception of uncertainties in baseline data inputs (e.g., the ICR data), which are discussed in detail in Section 3.8.

EPA believes that two of these uncertainties could have a potentially large impact on Stage 2 DBPR cost and benefit analysis:

- Uncertainty in the impacts of the Initial Distribution System Evaluation (IDSE) on the Compliance Forecast for large and medium surface water sytems.

- Uncertainty in compliance forecast tools.

EPA has adjusted the compliance forecast methodology to quantify and incorporate both of these uncertainties into the compliance forecast results and the cost and benefits models. Section 5.3 discusses the methods used to quantify these uncertainties. A more detailed description of the mechanisms of the benefit and cost models are in Chapters 6 and 7, respectively.

The remaining uncertainties listed in Exhibit 5.28 fall into two categories—uncertainty in the DBP data and uncertainty in the models. These two categories are discussed in Sections 5.7.1 and 5.7.2, respectively.

It is important to note that any biases in the compliance forecasts affect cost and benefits similarly. If more plants make treatment technology changes than predicted, costs for the treatment technology changes would be higher and there would also be a higher overall reduction in DBP levels. Conversely, if fewer plants make treatment technology changes than predicted, treatment costs and benefits from DBP reduction would be less.

Exhibit 5.28 Summary of Uncertainties in the Compliance Forecast

Source Water Type	Uncertainty	Section With Additional Discussion of Uncertainty	Effect on Benefit Predictions			Effect on Cost Predictions		
			Under-estimate	Over-estimate	Unknown Impact	Under-estimate	Over-estimate	Unknown Impact
Surface	Uncertainty in tools used to derive compliance forecast and DBP reductions for large surface water systems	A.6	Quantified in the primary analysis (addresses potential underestimate or overestimate)			Quantified in the primary analysis (addresses potential underestimate or overestimate)		
Ground	Uncertainty in Ground Water Delphi results	B.2.2			X			X
All	Uncertainty in extrapolating compliance forecasts from large to small systems	A.9.1 & B.3.1			X			X
All	Uncertainty in using the Delta approach (effectively assuming that plants changing for Stage 1 meet Stage 2 MCLs)	5.2	X			X		
All	Operational safety margin of 20 percent for Stage 1 and Stage 2	5.2			X			X
Surface	Impacts of the IDSE on the compliance forecast for large and medium surface water systems	5.3	Quantified in the primary analysis (addresses potential underestimate)			Quantified in the primary analysis (addresses potential underestimate)		

5.7.1 Uncertainty in DBP data

One factor that influences the compliance forecast results is the representativeness of the ICR data. For example, ICR observed data are used as the basis for the pre-Stage 1 baseline, although EPA recognizes that some plants had already made changes to comply with Stage 1 by the time the ICR was conducted. Additionally, there are limitations associated with the subsets of the ICR data that were used for the analysis with both SWAT and the ICR Matrix Method. Limitations of the ICR data are discussed in Section 3.8. Data limitations related to SWAT are discussed in greater detail in Appendix A, and limitations related to the ICR Matrix Method are discussed in this section.

5.7.1.1 Representativeness of the ICR data

There are uncertainties regarding the ICR TTHM and HAA5 data in general, as explained in detail in Section 3.8. EPA examined the climate conditions during the ICR sampling period to determine the representativeness of DBP levels over time. On a nationwide basis, 1998 was hotter and wetter than normal. Increased rainfall may have biased the results by increasing levels of contaminants from runoff, such as TOC. Other constituents may have been lower than normal, such as bromide, which tends to rise during droughts. Higher temperatures in 1998 could have caused the DBP levels in the ICR data to be unusually high as compared to an average year.

In addition, the representativeness of the DBP sample results are uncertain due to the nature of distribution system monitoring. Research has shown that TTHM and HAA5 levels can vary as much as 20 percent over the course of a day at locations in the distribution system (Pereira et al. 2004). One grab sample collected at a discrete point in time for the ICR does not represent this potential variability. In addition to hourly variations, the ICR data were not required to be collected at evenly spaced intervals. Thus, there is uncertainty in assuming that a single data point represents the typical level over the entire quarter.

5.7.1.2 Uncertainty in the subset of ICR data used for the ICR Matrix Method

The data set used for the ICR Matrix Method contains 213 of the 353 surface water plants in the ICR database, or roughly 60 percent. To evaluate the representativeness of the ICR Matrix Method subset, EPA evaluated source water TOC and distribution system DBP data. Plants in the screened data set have a mean influent TOC level of 3.21, and the plants excluded from this data set have mean influent TOC level of 3.19, indicating relatively little bias from source water quality.

TTHM and HAA5 data for plants that passed the data quality screen were compared to data for the plants that were excluded from the analyses. For the excluded plants, only those that had matching TTHM and HAA5 samples were considered, leaving 75 of the 140 SW plants that were excluded. The TTHM levels were higher in the excluded plants, with a plant mean of 50.5, as opposed to 42.3 for the screened plants. The excluded plants may have higher overall DBP levels, and their inclusion would raise the percentage of plants out of compliance with Stage 1 and Stage 2. However, these plants were

excluded due to missing data, so it is possible that the complete data set would have DBP levels more similar to the screened plants.

5.7.2 Uncertainty in the Delta Approach

This section briefly describes some of the larger uncertainties in the compliance forecast. Uncertainties associated with SWAT are discussed in greater detail in Appendix A.

Both SWAT and the ICR Matrix Method are limited in allowing systems to make multiple treatment technology changes. In both models, when systems make treatment technology changes to come into compliance with Stage 1, they will simultaneously come into compliance with Stage 2 MCLs. It is possible that some plants may need to make a second treatment technology change after achieving compliance with Stage 1 to achieve compliance with Stage 2, although EPA believes this is unlikely for most systems. The Agency believes this uncertainty is small and the delta approach is reasonable for reasons presented in Section 5.3.2.

There is also uncertainty associated with the 20 percent safety margin. Individual systems may use higher or lower safety margins based on system-specific conditions. The M-DBP TWG recommended that a 20 percent operational safety margin be used for DBP MCLs (TTHM, HAA5, bromate, and chlorite) when evaluating all regulatory alternatives. This safety margin is consistent with practices in prior DBP regulatory development efforts. It is intended to represent the level at which systems typically take some action to ensure consistent compliance with a new drinking water standard and the level at which systems target new treatment to meet the standard. In addition to representing industry practices, the safety margin also is intended to account for year-to-year fluctuations in DBP data. (ICR data are limited to 1 year and must not represent the highest DBP concentrations that occur in a system.)

6. Benefits Analysis

6.1 Introduction

The mission of the Environmental Protection Agency (EPA) is to protect human health and to safeguard the natural environment (USEPA 2000m). The Safe Drinking Water Act (SDWA) provides that the

> Administrator shall…publish a maximum contaminant level goal and promulgate a national primary drinking water regulation for a contaminant…if the Administrator determines that - (i) the contaminant may have an adverse effect on the health of persons; (ii) the contaminant is known to occur or there is a substantial likelihood that the contaminant will occur in public water systems with a frequency and at levels of public health concern; and (iii) in the sole judgment of the Administrator, regulation of such contaminant presents a meaningful opportunity for health risk reduction for persons served by public water systems. (42 USC §300g-1(b)(1)(A))

When carrying out its statutory mandate, EPA must often make regulatory decisions using incomplete or uncertain information. EPA believes it is appropriate and prudent to act to protect public health when there are indications that exposure to a contaminant could present significant risks to the public, rather than take no action until risks are unequivocally proven. Evidence from both human epidemiology and animal toxicology studies indicate that the consumption of drinking water containing disinfection byproducts (DBPs) may result in adverse health effects. The two main categories of such effects that have been associated with DBPs are reproductive and developmental effects and cancer (particularly bladder cancer). EPA has concluded that DBPs occur at levels that are a public health concern in some public water systems (PWSs) that apply a chemical disinfectant, and that the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR) presents a meaningful opportunity for a reduction in the risk of adverse health effects.

Under Executive Order 12866, EPA must conduct an Economic Analysis (EA) for rules costing over $100 million annually. The benefit analyses presented in this chapter follow the requirements of the executive order and related Office of Management and Budget (OMB) and EPA guidance, and provide a reasonable basis for estimating potential health benefits using the best available science.

EPA has quantified the benefits associated with expected reductions in the incidence of bladder cancer. Scientific knowledge about the association of reproductive and developmental health effects with DBP exposure is not known well enough to fully quantify these risks or the benefits of reduced DBP exposure. Nevertheless, although the results from different studies are mixed, a weight of evidence evaluation of the health effects data suggests a potential association between DBP exposure and various adverse reproductive and developmental outcomes. EPA believes that the reproductive and developmental effects benefits resulting from the Stage 2 DBPR has the potential to be substantial and that it is important to provide some quantitative indication of the potential risk. To do this, EPA completed an illustrative calculation of potential benefits for one specific reproductive effects end-point (fetal loss).

Section 6.1.1 provides an overview of the methodology and key assumptions used to estimate the benefits that may be attributed to the Stage 2 DBPR (including the illustrative calculations for a developmental and reproductive health endpoint). Section 6.1.2 summarizes results.

Section 6.2 presents the problem identification and the assessment of potential hazard. Carcinogenic and non-carcinogenic (e.g., reproductive and developmental) risks are presented with

toxicological and epidemiological evidence. Section 6.3 follows with an assessment of exposure. The rule's benefits, including cancer cases avoided and the associated value of those benefits, are addressed in Sections 6.4 and 6.5. Section 6.6 summarizes uncertainties of national benefits estimates. Section 6.7 contains a sensitivity analysis for benefits from avoiding colon and rectal cancers. Potential benefits from reductions in one reproductive and developmental endpoint—fetal loss—are evaluated through an illustrative calculation in Section 6.8.

The following provide additional details in support of this chapter:

- Chapter 5 estimates reduction in TTHM and HAA5 occurrence as a result of DBP risks in support of the exposure assessment in Section 6.3.

- Appendix D shows the schedule for all rule activities (this information is used as input for the quantified benefits calculation).

- Appendix E provides general background information on population attributable risk (PAR) and a detailed description of the derivation of PAR values used to quantify benefits associated with reduction in cancer cases. The development and modeling of the cessation lag equations are described. Lastly, Appendix E shows detailed calculations for estimating the number of bladder cancer cases avoided as a result of the Stage 2 DBPR.

- Appendix F describes the valuation of Stage 2 DBPR benefits and presents results for all regulatory alternatives and sensitivity analyses.

- Appendix G provides detailed calculations for the illustrative calculation of reproductive and developmental health impacts.

6.1.1 Overview of Methodology for Quantifying Stage 2 DBPR Benefits

Three categories of benefits are addressed in this EA: those associated with reductions in the incidence of bladder cancer, those associated with reductions in the incidence of colon and rectal cancers, and those associated with reductions in the incidence of adverse reproductive and developmental health effects. The primary benefits analysis in this EA is based on reductions in bladder cancer cases. Potential benefits associated with reduced incidence of colon and rectal cancers are quantified in a sensitivity analysis, while potential benefits associated with decreasing adverse developmental and reproductive health effects (specifically, fetal losses) are presented as an illustrative calculation.

EPA used similar approaches to estimate the number of bladder cancer cases avoided (the primary benefits analysis), the number of colon and rectal cancer avoided (the sensitivity analysis), and the number of avoided incidence of fetal loss (the illustrative calculation). The major steps in deriving and characterizing cases avoided are:

- Estimate the current and future annual cases of illness from all causes

- Estimate how many cases can be attributed to current DBP occurrence and exposure

- Estimate the reduction in future cases corresponding to anticipated reductions in DBP occurrence and exposure due to the Stage 2 DBPR

All benefit calculations were performed using the Stage 2 DBPR Benefits Model (USEPA 2005h).

For bladder cancer, EPA computed the monetized benefits of the Stage 2 DBPR by multiplying the estimated number of bladder cases avoided by the estimated monetary value associated with avoiding both fatal and non-fatal cases of bladder cancer. The value of a statistical life (VSL) was used for fatal bladder cancers, while two alternate estimates of willingness-to-pay to avoid non-fatal bladder cancer are used (one based on avoiding a case of curable lymphoma and the other based on avoiding a case of chronic bronchitis). EPA also computed the benefits for the reduction in colon and rectal cancer by using the same VSL and willingness to pay (WTP) estimates. EPA recognizes that there could be a significant value associated with the number of avoided fetal losses estimated in the illustrative calculation. However, the Agency is unable at this time either to develop a specific estimate of this value or to use a benefit transfer method to estimate the value from studies that address other endpoints (see Section 6.8 for a full discussion of this issue).

Bladder Cancer

To calculate potential benefits from reduced incidence of bladder cancer cases, EPA began by estimating the number of new bladder cancer cases occurring per year from all causes. The National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER, 2004) program provides data on cancer rates (new cases per 100,000 population per year) as a function of age. EPA used this information in conjunction with population-by-age data from the 2000 U.S. Census to estimate the number of new cases of bladder cancer. Results show that the number of new bladder cancer cases per year starts to increase at about age 35 and peaks at 1,500 to 2,000 cases from about age 60 to 80. Although the annual rate of bladder cancer does not decline much after age 80, the incidence of new bladder cancers does, which represents the overall decline in the number of individuals alive after that age. The resulting total number of new bladder cancer cases per year, 56,505, is slightly lower than that currently estimated by the American Cancer Society (ACS).[1] This likely represents EPA's use of the census population data from 2000.

To estimate the baseline number of cases attributable to DBP exposure, EPA used three different approaches:

- Using the range of Population Attributable Risk (PAR) values derived from consideration of 5 individual epidemiology studies used for the Stage 1 EA and the Stage 2 proposal EA (yields a pre-Stage 1 range of best estimates for PAR of 2% to 17%).

- Using the Odds Ratio (OR) of 1.2 from the Villanueva et al. (2003) meta-analysis that reflects both sexes, ever exposed population from the studies considered (yields a pre-Stage 1 best estimate for PAR of ~16%)

- Using the Villanueva et al. (2004) pooled data analysis to develop a dose-response relationship for OR as a function of Average TTHM. The dose-response relationship was modeled as linear with an intercept of OR = 1.0 at TTHM exposure level = 0 (yields a pre-Stage 1 best estimate for PAR of ~17%)

All three approaches are considered equally valid and provide feasible estimates of risk. For the sake of simplicity, EPA carried only one these approaches, that based on Villanueva et al. (2003), through the entire benefits model.

[1]The American Cancer Society estimated in 2004 that 60,240 new cases of bladder cancer would occur in the U.S. population that year (ACS website, 2004).

To quantify the reduction in cases, EPA assumes that there is a linear relationship between average DBP concentration and relative risk of bladder cancer. Thus, percent reductions in national average DBPs are used to determine the percent reductions in bladder cancer cases attributable to DBPs. Predicted reductions in national average TTHM and HAA5 levels resulting from predicted treatment technology changes to comply with Stage 2 were used as indicators of overall chlorination DBP reductions. The baseline cases attributable to DBPs multiplied by the percent reductions in TTHM or HAA5 concentrations result in the estimated annual bladder cancer cases "ultimately avoidable" for the Stage 1 and Stage 2 rules.

Over the long run, the cases ultimately avoidable (derived as described above) will be attained. They will not be achieved instantaneously, however. Research shows that a lag period (referred to as "cessation lag") exists between the point in time when reduction in exposure to a carcinogen occurs and the point in time when the full risk reduction benefit of that exposure reduction is realized by affected individuals. Because there is no epidemiological or other empirical data available that specifically address the rate of achieving bladder cancer benefits resulting from DBP reductions, EPA uses data from three epidemiological studies that address the rate of risk reduction following exposure reduction to other carcinogens (namely cigarette smoke and arsenic) to generate three possible cessation lag functions for bladder cancer and DBPs.

The cessation lag functions are used to project the number of bladder cancer cases avoided each year after implementation as a result of the Stage 2 DBPR over a 100-year period. A 100-year period was selected as the timeframe after which effectively all of the exposed population is composed of individuals exposed only to post-Stage 2 levels for their entire lifetime. At that time (and from that point forward) the annual bladder cancer cases ultimately avoidable is achieved for the exposed population. The projected number of cases avoided each year is also adjusted to reflect when systems are expected to install new treatment to reduce DBPs based on the rule implementation schedule. Although a 100-year cessation lag period is modeled, annual avoided cases of bladder cancer are calculated primarily for the first 25 years after rule promulgation. A 25-year time period was used to coincide with the estimated life span of capital equipment and a time lag of five to ten years for technology installation after rule promulgation.

The final step in the benefit calculation is to monetize the average annual cases avoided. This is done by applying economic values for avoided illnesses and deaths. EPA has estimated that 74 percent of bladder cancer cases are non-fatal (USEPA, 1999a). The value of avoiding non-fatal bladder cancer cases is based on people's WTP for incremental reductions in the risk they face of contracting cancer. The metric of WTP to avoid an increased risk includes the desire to avoid treatment costs, pain and discomfort, productivity losses, and any other adverse consequences related to a non-fatal case of bladder cancer. Because specific estimates of WTP for avoiding non-fatal bladder cancer are not available, EPA estimated values from two other non-fatal illnesses: curable lymphoma and chronic bronchitis. Both are considered valid estimates of WTP for non-fatal cancer.

For fatal bladder cancer cases, VSL is used to capture the value of benefits. The VSL represents an estimate of the monetary value of reducing risks of premature death from cancer. Therefore, it is not an estimate of the value of saving a particular individual's life. Rather, it represents the sum of the values placed on small individual risk reductions across an exposed population. Other economic factors are taken into consideration when calculating benefits over time, such as income growth and social discount rates.

There are several areas of uncertainty with respect to quantified benefits for bladder cancer. Many are described qualitatively in the analysis, while other are incorporated explicitly as follows:

- There is uncertainty in the percent reduction in TTHM and HAA5 concentrations resulting from predicted treatment technology changes (i.e., the compliance forecasts). Uncertainty in SWAT and potential impacts of the IDSE are quantified in the primary analysis.

- Three approaches were used to estimate the baseline number of bladder cancer cases attributable to DBP exposure. For the sake of simplicity, one approach using data from Villanueva et al. (2003) was carried through the full benefits model.

- The estimated PAR values from the Villanueva et al. (2003) meta-analysis include confidence bounds resulting from statistical uncertainty in the odds ratio underlying the PAR calculation. The confidence bounds from Villanueva et al. (2003) capture a significant portion of the confidence intervals of the other two approaches.

- Three independent cessation lag models derived from three different epidemiological studies are used in the model. Also, two functional forms are used for each of these data sets and uncertainty in the parameters of those functions is included in the analysis.

- EPA uses two alternatives for valuing non-fatal bladder cancer.

Colon and Rectal Cancers

Human epidemiology studies on chlorinated surface water have reported associations with colon and rectal cancers. Colon and rectal cancers combined are the third most common type of new cancer cases and deaths in both men and women in the U.S., excluding skin cancers. Therefore, any benefit from reducing the incidence of colon and rectal cancers could be significant. EPA is including a quantitative sensitivity analysis for benefits accrued from the Stage 2 DBPR from avoiding colon and rectal cancers.

EPA estimated the reduction in colon and rectal cancer in a similar manner to bladder cancer cases. Background incidence data were available from the SEER cancer registry and two quality studies were chosen to estimate a PAR value. Using the percent reductions in DBPs and the smoking and lung cancer cessation lag model, the number of colon and rectal cancer cases avoided annually was estimated and monetized with the same VSL and WTP estimates as for bladder cancer.

Developmental And Reproductive Health Effects

As noted previously, EPA predicts that a significant portion of the total benefit of this rule could come from reductions in developmental and reproductive health effects, although the relationship of these effects to DBP exposure is not known well enough to fully quantify risks or benefits. EPA was able to do a preliminary calculation of the benefits of reducing the risk of fetal loss, the non-cancer effect for which the most epidemiological data exist in relation to DBP exposure. Because approximately one million of the six million pregnancies each year in the United States end in a miscarriage or stillbirth (Ventura et al. 2000), avoiding even a small risk attributable to DBP exposure by reducing DBP levels may result in a significant number of avoided fetal losses.

EPA estimated the reduction in fetal losses in a similar manner to bladder cancer cases. A range of possible PAR values for relating annual fetal losses to DBP exposure was obtained from available epidemiological studies. Reductions in the number of peak DBP events due to the Stage 1 DBPR and the Stage 2 DBPR were estimated. Reductions in exposure to peak DBPs were assumed to be proportional to reductions in peak DBP events. Like the analysis of bladder cancer, there is uncertainty in fetal loss PAR values, reflected in the range of values used in the analysis. There are other important uncertainties in this

illustrative calculation, including the assumed proportional relationship between reduction in fetal losses and reduction in exposure to peak levels due to the Stage 2 DBPR.

6.1.2 Summary of National Benefits of the Stage 2 DBPR

Exhibit 6.1 summarizes the estimated number of bladder cancer cases avoided as a result of the Stage 2 DBPR and the monetized value of those cases. The benefits in Exhibit 6.1 are for the Preferred Regulatory Alternative (which includes a requirement for the IDSE) for the Stage 2 DBPR. Benefit estimates for the other regulatory alternatives were derived using the same methods as for the Preferred Regulatory Alternative and are presented in Section 6.5.4.

While causality has not been established, the weight of evidence supports non-zero PAR estimates, which imply potential bladder cancer benefits from DBP exposure reduction. The confidence bounds of the results in Exhibit 6.1 incorporate uncertainty in PAR, uncertainty in the compliance forecast and resulting reduction in DBP concentrations, and cessation lag. The confidence bounds of the monetized benefits also incorporate uncertainty in the valuation parameters. An estimated 26 percent of bladder cancer cases avoided are fatal, and 74 percent are non-fatal. The monetized benefits therefore represent the estimate of avoiding both fatal and non-fatal cancers in those proportions.

In addition to bladder cancer cases avoided, EPA provides an illustrative calculation of the potential number of fetal losses that might be avoided per year, ranging from 250 to 4,100. The value of other health benefits, including the potential reduction in other types of cancer such as colon or rectal, could be significant, and is calculated in a sensitivity analysis. Also, the value of non-health benefits, such as improved taste and odor of water, are expected to be positive. These are discussed further in Section 6.4.

Exhibit 6.1 Summary of Quantified Benefits for the Stage 2 DBPR

Cessation Lag Model used to estimate Annual Bladder Cancer Cases Avoided	Annual Average Bladder Cancer Cases Avoided for the first 25 years [1]			Discount Rate, WTP for Non-Fatal Bladder Cancer Cases	Annualized Benefits of Bladder Cancer Cases Avoided ($Millions)		
	Mean	5th	95th		Mean	5th	95th
Smoking/Lung Cancer Model	277	101	540	3 %, Lymphoma	$ 1,523	$ 232	$ 3,518
				7 % Lymphoma	$ 1,240	$ 189	$ 2,862
				3 % Bronchitis	$ 759	$ 164	$ 1,684
				7 % Bronchitis	$ 617	$ 134	$ 1,368
Smoking/Bladder Cancer Model	187	60	398	3 %, Lymphoma	$ 1,027	$ 156	$ 2,373
				7 % Lymphoma	$ 840	$ 128	$ 1,940
				3 % Bronchitis	$ 512	$ 111	$ 1,135
				7 % Bronchitis	$ 418	$ 91	$ 927
Arsenic/Bladder Cancer Model	332	136	610	3 %, Lymphoma	$ 1,842	$ 280	$ 4,254
				7 % Lymphoma	$ 1,537	$ 234	$ 3,547
				3 % Bronchitis	$ 918	$ 199	$ 2,035
				7 % Bronchitis	$ 765	$ 166	$ 1,694

Note: [1] The 90 percent confidence interval incorporates uncertainty in PAR, reduction in average TTHM and HAA5 concentrations, cessation lag, and monetization input (for value of cases avoided only).

Sources: Summarized from detailed figures presented in Appendix E (Exhibits E.38d, E.38h and E.38l) and F (Exhibits F.2v and F.2w, F.3v and F.3w).

6.2 Problem Identification and Assessment of Potential Hazard

This section provides detailed information from the toxicological and epidemiological literature for the key adverse health effects that have been associated with exposure to DBPs. In addition to the studies and reviews presented here, EPA has addressed reproductive and developmental effects, carcinogenicity, and other adverse health effects at length in several Health Criteria Documents. Specifically, EPA has developed Drinking Water Criteria Documents for the following DBPs: brominated trihalomethanes (USEPA 2005b), brominated haloacetic acids (USEPA 2005c), trichloroacetic acid (2005 d), and monochloroacetic acid (USEPA 2005e). EPA has also completed toxicological reviews of dichloroacetic acid (IRIS 2003), bromate (IRIS 2001a), chloroform (IRIS 2001b), chlorine dioxide and chlorite (IRIS 2000), and an addendum for dichloroacetic acid (USEPA 2005j). A similar document exists for 3-Chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX) (USEPA 2000f).

EPA's weight of evidence evaluation of the best available science on carcinogenicity and reproductive and developmental effects, in conjunction with the widespread exposure to DBPs, supports the incremental regulatory changes in today's rule that target lowering DBPs and providing equitable public health protection.

6.2.1 Cancer

Several DBPs have been identified by EPA as probable or possible human carcinogens. EPA believes that the cancer epidemiology and toxicology literature provide important information that contributes to the weight of evidence for potential health risks from exposure to chlorinated drinking water. At this time, the cancer epidemiology studies support a potential association between exposure to chlorinated drinking water and cancer, but evidence is insufficient to establish a causal relationship. The epidemiological evidence for an association between DBP exposure and colon and rectal cancers is not as consistent as it is for bladder cancer, although similarity of effects reported in animal toxicity and human epidemiology studies strengthens the evidence for an association with colon and rectal cancers. EPA believes that the overall cancer epidemiology and toxicology data support the decision to pursue additional DBP control measures as reflected in the Stage 2 DBPR. The following sections provide an overview of the epidemiological and toxicological evidence for the carcinogenicity of key DBPs.

6.2.1.1 Epidemiological Evidence of DBP Carcinogenicity

A number of epidemiological studies have been conducted to investigate the relationship between exposure to chlorinated drinking water and various cancers. These studies contribute to the overall evidence on potential human health hazards from exposure to chlorinated drinking water.

Epidemiology studies provide useful health effects information because they reflect human exposure to a drinking water DBP mixture through multiple routes of intake such as ingestion, inhalation and dermal absorption. The greatest difficulty with conducting cancer epidemiology studies is the length of time between exposure and effect. Higher quality studies have adequately controlled for confounding and have limited the potential for exposure misclassification, for example, using DBP levels in drinking water as the exposure metric as opposed to type of source water. Study design considerations for interpreting cancer epidemiology data include sufficient follow-up time to detect disease occurrence, adequate sample size, valid ascertainment of cause of the cancer, and reduction of potential selection bias in case-control and cohort studies (by having comparable cases and controls and by limiting loss to follow-up). Epidemiology studies provide extremely useful information on human exposure to chlorinated water, which is preferable over single chemical, high dose animal data.

Bladder Cancer - Causes and Risk Factors

The National Cancer Institute (NCI) lists the following primary risk factors for bladder cancer: age, tobacco, occupation, certain infections, certain drug treatments, race, being male, family history and personal history (NCI 2002). The American Cancer Society (ACS) estimates that there will be about 60,240 new cases of bladder cancer diagnosed in the United States (about 44,460 men and 15,600 women) in 2004 (ACS 2004). The cancer is more common in men than in women, although women who smoke have twice the risk of men who smoke (Mayo Clinic 2004). Whites are about two times more likely to develop bladder cancer than African Americans or Hispanics (ACS 2004).

The literature on bladder cancer and its causes and risk factors describes several well-known etiologic agents. Two useful review articles on bladder cancer in humans are Cohen et al. (2000) and Fukushima and Wanibuchi (2000). The following is derived largely from these reviews.

Bladder cancer involves a heterogenous group of tumors, but is often categorized into one of two main types: squamous cell carcinomas (which are mainly seen as secondary to schistosomiasis infections) and transitional (urothelial) cell carcinomas.

Schistosomiasis is caused by the parasite *Schistosoma haematobium*, which is most prevalent in Egypt and other Nile River countries, but is found in other parts of Africa, the Middle East and India. Generally, bladder cancers in areas that have endemic schistosomiasis involve squamous cell carcinomas rather than transitional cell carcinomas, and also tend to occur in somewhat younger individuals (40s or 50s) than those typically experiencing transitional cell carcinomas. Cohen et al. (2000) indicated that the incidence and mortality rates for bladder tumors of this etiology are not well characterized. Bladder cancer related to *Schistosoma* infections does not appear to be directly relevant to that associated with DBPs or other chemical agents, and is therefore not considered further here.

Bladder cancers not associated with *Schistosoma* infections occur throughout the developed world, and these are almost all of the transitional cell carcinoma type, and include low-grade, recurrent papillary tumors and high-grade invasive malignancies. In countries without schistosomiasis, over 95 percent of bladder cancers involve transitional cell tumors. There is a relatively long history of association of these bladder cancers with specific environmental and occupational factors. For example, an association of bladder cancer with workers in the aniline dyes industry dates back to a 1895 German study by Rehn, with similar observations between exposure to certain aromatic amines and related compounds in the dye industry throughout the twentieth century. A number of specific aromatic amine compounds considered to be bladder carcinogens have been identified through epidemiological studies, occupational studies, and animal toxicity studies. Well-recognized among these are:

- 2-Naphthylamine
- 4-Aminobiphenyl
- Benzidine (and some benzidine-related "azo" dyes)
- 4,4-Methylenebis(2-chloraoaniline) (MBOCA)
- o-Toluidine
- 4-Chloro-o-toluidine
- Methylenedianiline (MDA)

Other specific chemical compounds that have been associated with bladder cancer include the analgesic phenacetin and some chemotherapeutic agents, such as cyclophosphamide and chlornaphazine (N,N-bis(2-chloroethyl)-2-naphthylamine).

Although there has been some indication of a relationship between certain artificial sweeteners (saccharin and cyclamates) with bladder cancer, these are now generally considered very weak associations at best (Mayo Clinic 2004). Also, there do not appear to be any dietary factors associated with bladder cancer beyond the associations made between cancer in general and diets high in fats, red meats and fried foods. In a systematic literature review, Zeegers et al. (2004) concluded that coffee and tea consumption are probably not associated with bladder cancer, and the association of alcohol consumption and bladder cancer risk in men has some convincing evidence, but the risk is not statistically significant.

The most significant environmental factor that is associated with bladder cancer is tobacco smoke (ACS 2004). The causative agent(s) in tobacco smoke is not known, but it should be noted that cigarette smoke contains aromatic amine compounds, including some of those that have been specifically linked with bladder cancer in other studies as noted above. Ingestion of arsenic, notably as a drinking water contaminant, has been associated with bladder cancer. Consumption of chlorinated drinking water has also been associated with bladder cancer.

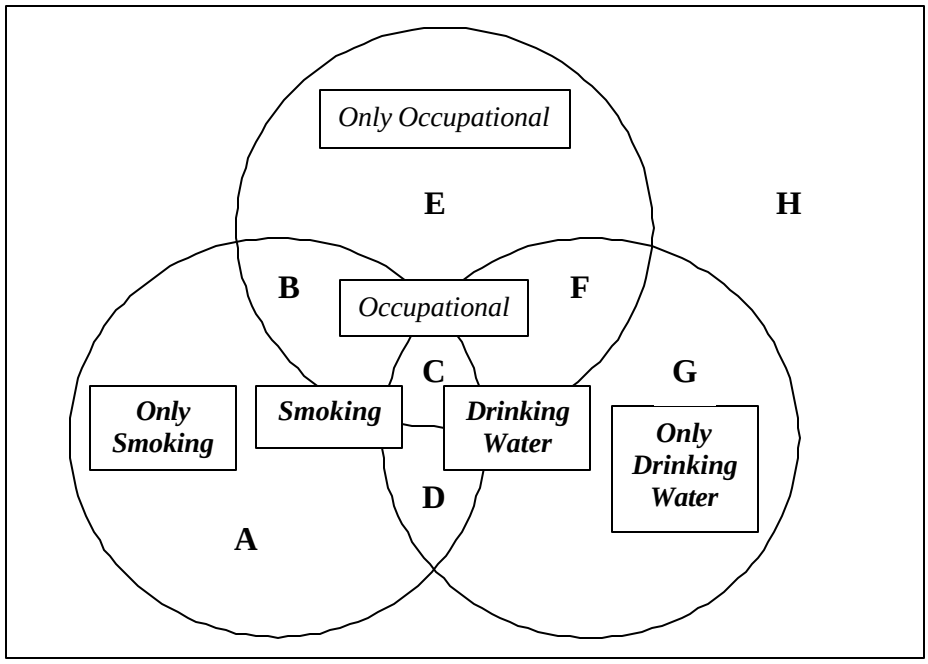
It has been reported that smoking is the attributable factor for about 50 percent of bladder cancers in men and 30 percent in women (NCI 2004). The NCI also indicates that up to 25 percent of bladder cancers may be attributable to occupational factors, again notably those involving exposure to certain aromatic amine compounds (Mayo Clinic 2004). Other studies have estimated that occupational exposure may be the attributable factor in 20 percent of cases (Silverman et al. 1989a, Silverman et al. 1989b, and Silverman et al. 1990). Less than half a percent of bladder cancers can be attributed to a rare bladder birth defect, and hereditary factors may account for 1 percent (ACS 2004).

In the benefits analysis supporting the January 2001 arsenic rule, EPA did not derive an estimate of the bladder cancer attributable factor for arsenic in drinking water, and no other estimate was found in the literature. However, based on estimates of annual bladder cancer cases avoided by the various arsenic regulations considered, including the most stringent of them at 3 μg/L (approximately 30 to 80 cases per year), it would appear that the total cases attributable to arsenic in drinking water is a small fraction of the approximately 60,000 new cases reported each year.

For both the Stage 1 Final Rule (November 1998) and the proposed Stage 2 Rule (August 2003), EPA provided estimates that chlorinated drinking water consumed prior to these rules maybe responsible for between 2 and 17 percent of bladder cancers.

It is not appropriate simply to add the estimates of percent contribution to total bladder cancer estimated separately for each of the individual causes described above, as there may be overlap among them. The Venn diagram shown in Exhibit 6.2 is intended to provide a schematic depiction of possible overlaps among the major attributable causes of bladder cancer noted above: smoking, occupational exposures, and drinking water.

Exhibit 6.2 Venn Diagram of Bladder Cancer in the U.S. Population



The total bladder cancers each year is represented by the space in the rectangle, and is the sum of A+B+C+D+E+F+G+H = 100 percent. Smoking, noted previously as being associated with approximately 50 percent of bladder cancers, is represented by the circle with areas A+B+C+D. Occupational sources, estimated as the principal factor for 25 percent of bladder cancer cases, is the circle composed of areas B+C+E+F. Drinking water is represented by the circle with areas C+D+F+G.

The overlap areas among these circles (that is, areas B, C, D and F) represent circumstances where contributions from multiple sources may not be fully accounted for in the epidemiological data. To the extent this is the case, the sum of the two major individual sources noted above – smoking at 50 percent, occupational at 25 percent – would be less than the 75 percent implied by adding those two values.

Bladder Cancer - Studies Supporting EPA's PAR Analysis

More evidence is available to support a possible association between bladder cancer and chlorinated water or DBP exposure than for other cancers. The Stage 1 DBPR Regulatory Impact Assessment (USEPA 1998a) presents EPA's review of the large body of epidemiology literature for bladder cancer and its association with DBPs in drinking water. From this review, EPA concluded that although causality has not been established, the data support a potential association, which is a concern. Particular gaps in EPA's understanding include the reason for inconsistent results across subpopulations in the different studies, especially for males versus females and smokers versus nonsmokers.

For both the Stage 1 DBPR EA and the Stage 2 proposal EA, EPA used five epidemiological studies conducted in the 1980s and 1990s to calculate a range of PAR values for bladder cancer associated with exposure to chlorinated drinking water. The five epidemiological studies used by EPA are as follows (note that Cantor et al. 1985 and Cantor et al. 1987 use the same epidemiological data):

- Cantor et al. (1985; 1987)
- McGeehin et al. (1993)
- King and Marrett (1996)
- Freedman et al. (1997)
- Cantor et al. (1998)

Exhibit 6.3 provides relevant summary information for each of these studies and the PAR values calculated from them by EPA. Appendix E provides additional information on the derivation and use of PAR values in general, as well as additional details on the PAR values derived from these studies by EPA.

All of these studies include adjustments in their analyses to account for possible confounding by other factors that may contribute to bladder cancer, notably sex, age, and smoking. Cantor et al. and McGeehin et al. also included adjustments for occupational exposure.

As shown in Exhibit 6.3, the estimated PAR percentages from the studies range from 2 percent to 17 percent. Those values are "best estimates" derived from the study data as described in Appendix E. EPA has also estimated 95 percent confidence intervals for those PAR values using a Monte Carlo simulation procedure, which is also described in Appendix E. In most cases, the lower confidence bound has been truncated at 0 percent based on biological plausibility considerations. That is, notwithstanding statistical indications of PAR values < 0 percent implied by odds ratios < 1.0, there is no toxicological or epidemiological data to support a conclusion that increased DBP exposure would reduce bladder cancer.

Exhibit 6.3 Summary of Epidemiology Studies for Bladder Cancer Associated with Chlorinated Drinking Water and EPA Calculated PAR Values

Study	Description	Summary of Results	Comments	PAR (95% CI)[1]
Cantor et al. (1985)	Case-control study of association between bladder cancer and consumption of chlorinated surface water	- Odds ratio for all whites with over 59 years of exposure is 1.1 (95% Confidence Interval: 0.8-1.5) - Odds ratio for nonsmokers is 2.3 (95% Confidence Interval: 1.3-4.2) - Odds ratio for current smokers is 0.6 (95% Confidence Interval: 0.3-1.2)	Majority of water systems contained less than 20 μg/L THMs.	2% (0% - 15%)
Cantor et al. (1987)[2]	Case-control study of association between bladder cancer and consumption of chlorinated surface water	- Odds ratio for both sexes with over 59 years of exposure to tap water is 1.4 (95% Confidence Interval: 0.9-2.3) - Odds ratio for nonsmokers with over 59 years of exposure to tap water is 3.1 (95% Confidence Interval: 1.3-7.3)	Results were statistically significant for non-smokers only	15% (0% - 31%)
McGeehin et al. (1993)	Case-control study of association between bladder cancer and consumption of chlorinated surface water	- Odds ratio for bladder cancer with over 30 years of exposure is 1.8 (95% Confidence Interval: 1.1-2.9) - Odds ratio for cases consuming over 5 glasses of tap water per day is 2.0 (95% Confidence Interval: 1.1-2.8)	Level of total THMs, residual chlorine, or nitrates not associated with bladder cancer risk controlling for years of exposure.	17% (0% - 33%)
King and Marrett (1996)	Case-control study of association between bladder cancer and consumption of chlorinated surface water	- Odds ratio for bladder cancer for 35 years of exposure compared to 10 years is 1.42 (95% Confidence Interval: 1.10-1.81) - Bladder cancer risk increased with years of exposure - Risk increases by 11 percent with each 1,000 µg/L THM-year[3]	Statistically significant only for lengthy exposures. Results provide no support for an interaction between volume of water consumed and years of exposure to THMs level > 49 µg/L.	17% (1% - 28%)
Freedman et al. (1997)	Nested case-control study of association between bladder cancer and consumption of chlorinated drinking water	- Odds ratio for bladder cancer using 1975 measure of exposure is 1.2 (95% Confidence Interval: 0.9-1.6) - Slight gradient of increasing risk with increasing duration noted only among smokers	Further stratification by gender showed elevated odds ratios to be restricted to male smokers.	3% (0% - 22%)
Cantor et al. (1998)	Case-control study of association between bladder cancer and consumption of chlorinated surface water	- Little overall association between bladder cancer risk and exposure to chlorination byproducts - Bladder cancer risk increased with exposure duration	Opposite trends were found in males and females. Total lifetime and average lifetime TTHM levels show all risk increases are apparently restricted to male smokers.	3% (0% - 8%)

[1] Confidence intervals truncated at zero to reflect biological plausibility. The actual lower confidence level is often negative.

[2] The Cantor et al. 1987 study is based upon the same data set as the Cantor et al. 1985 study. OR and PAR values for Cantor 1987 reflect modifications to the inclusion criteria and adjustments for confounders relative to the analysis performed in the 1985 study.

[3] THM-years are the product of the continuous estimate of a given THM level (1,000 µg/L) and years at that level, analogous to pack-years of cigarette smoking.

Just prior to completion of the Stage 2 DBPR proposal, Villanueva et al. (2003) published a meta-analysis of epidemiological studies addressing bladder cancer related to exposure to chlorinated drinking water. The Villanueva et al. (2003) meta-analysis included most of the studies that EPA had used for Stage 1 and the Stage 2 proposal (see Exhibit 6.3). The specific studies considered by these authors are as follows:

- Cantor et al. (1998)
- Koivusalo et al. (1998)
- King and Marrett (1996)
- McGeehin et al. (1993)
- Vena et al. (1993)
- Cantor et al. (1987)
- Wilkins and Comstock (1981)
- Doyle et al. (1997)

The first six of these are case-control studies, the latter two are cohort studies.

Villanueva et al. (2003) developed several sets of ORs reflecting different exposure conditions (mid-term, long-term, and ever-exposed), separately for men, women as well as for both sexes combined. In addition to estimating overall OR values for those several populations and exposure conditions, Villanueva et al. (2003) presented data showing an increase in OR with increased duration of exposure. The authors present a dose-response analysis quantifying that relationship.

For the purposes of supporting the final Stage 2 analysis, EPA has chosen to use the estimated OR from Villanueva et al. (2003) for the "ever-exposed, both sexes" category. Exhibit 6.4 provides a summary of the 6 studies that were used by Villanueva et al. (2003) for this exposure group; Exhibit 6.5 summarized the weights, the OR values for those individual studies and the combined OR obtained by the authors.

Exhibit 6.4 Summary of Epidemiology Studies from Villanueva et al. (2003) for Bladder Cancer Associated with Chlorinated Drinking Water used in Developments of the PAR Analysis

Study	Description	Summary of Results	Comments
Cantor et al. (1998)	Case-control study of association between bladder cancer and consumption of chlorinated surface water	- Little overall association between bladder cancer risk and exposure to chlorination byproducts - Bladder cancer risk increased with exposure duration	Opposite trends were found in males and females. Total lifetime and average lifetime TTHM levels show all risk increases are apparently restricted to male smokers.

Study	Description	Summary of Results	Comments
Koivusalo et al. (1998)	Case-control study of association between estimated historical exposure to drinking water mutagenicity and kidney and bladder cancers	- Non-significant excess risk of bladder cancer associated with mutagenic drinking water for men and women - Statistically significant OR (2.59, 95% CI 1.13-5.94) for a 3,000 net revertants/L increase in average exposure for nonsmoking men with ≤30 years estimable exposure history	- Authors claim their study (at publication) was first to report an exposure-response relationship between the quantitative level of drinking water chlorination by-products and kidney cancer. - Authors acknowledge that higher OR for those with ≤30 years in highest exposure category (in this study, 3,000 net revertants/L) could indicate that exposure period used was too short to appropriately study the relationship w/bladder cancer, and risk may be underestimated in this study.
King and Marrett (1996)	Case-control study of association between bladder cancer and consumption of chlorinated surface water	- Odds ratio for bladder cancer for 35 years of exposure compared to 10 years is 1.42 (95% Confidence Interval: 1.10-1.81) - Bladder cancer risk increased with years of exposure - Risk increases by 11 percent with each 1,000 µg/L THM-year	Statistically significant only for lengthy exposures. Results provide no support for an interaction between volume of water consumed and years of exposure to THMs levels > 49 µg/L.
McGeehin et al. (1993)	Case-control study of association between bladder cancer and consumption of chlorinated surface water	- Odds ratio for bladder cancer with over 30 years of exposure is 1.8 (95% Confidence Interval: 1.1-2.9) - Odds ratio for cases consuming over 5 glasses of tap water per day is 2.0 (95% Confidence Interval: 1.1-2.8)	Level of total THMs, residual chlorine, or nitrates are not associated with bladder cancer risk, controlling for years of exposure.
Cantor et al. (1987)[1]	Case-control study of association between bladder cancer and consumption of chlorinated surface water	- Odds ratio for both sexes with over 59 years of exposure to tap water is 1.4 (95% Confidence Interval: 0.9-2.3) - Odds ratio for nonsmokers with over 59 years of exposure to tap water is 3.1 (95% Confidence Interval: 1.3-7.3)	Long-term bladder cancer risks are more prominent in nonsmokers.
Wilkins and Comstock (1981)[2]	Cohort study of association between bladder cancer and chlorinated surface water	- Relative Risk of 1.8 for men (95% Confidence Interval: 0.8-4.75) - Relative Risk of 1.6 for women (95% Confidence Interval: 0.54-6.32)	Results not statistically significant.

[1]The Cantor et al. 1987 study is based upon the same data set as the Cantor et al. 1985 study. OR and PAR values for Cantor 1987 represent modifications to the inclusion criteria and adjustments for confounders relative to the analysis performed in the 1985 study.

[2] Freedman et al. (1997) is a subset of the Wilkins and Comstock 1981 study and was used in Stage 1 and the Stage 2 proposal for calculation of bladder cancer PAR range values.

Exhibit 6.5 Estimated OR for Ever-Exposed, Both Sexes Category from Villanueva et al. (2003) Meta-Analysis

Study	Weight	OR	95% CI
Cantor et al. (1998)	34.9	1.1	0.9 - 1.3
Koivusalo et al. (1998)	6.6	1.4	0.9 - 2.1
King and Marrett (1996)	19.2	1.4	1.1 - 1.8
McGeeehin et al. (1993)	8.5	1.3	0.9 - 1.9
Cantor et al. (1987)	28.7	1.2	1.0 - 1.5
Wilkins & Comstock (1981)	2.2	1.7	0.8 - 3.6
Combined		**1.2**	**1.1 - 1.4**

Based on the combined OR value of 1.2 and the corresponding 95 percent CI values of 1.1 and 1.4, respectively, EPA calculated a PAR from the Villanueva et al. (2003) study of 15.8 percent (95 percent CI = 8.5 percent - 27.2 percent). See Appendix E for details of the PAR calculation.

Subsequent to the Stage 2 DBPR proposal, Villanueva et al. (2004) published a pooled-analysis of studies addressing the potential association between DBPs and bladder cancer. This pooled analysis included the six studies summarized in Exhibit 6.6.

Exhibit 6.6 Summary of Epidemiology Studies from Villanueva et al. (2004) for Bladder Cancer Associated with Chlorinated Drinking Water used in Developments of the PAR Analysis

Study	Description	Summary of Results	Comments
Lynch et al. (1989)	Case control study of association between years of exposure to chlorinated drinking water and bladder cancer.	- Adjusted OR for both sexes = 1.52 (95% CI 1.10-2.10) for average exposure more than 1µg/L THM compared with ≤ 1µg/L THM	Statistically significant for both sexes combined, and also increased for men and women separately.
Cordier et al. (1993)	Hospital-based case control study of occupational risks of bladder cancer. TTHM data previously unpublished.	- Adjusted OR for both sexes = 1.02 (95% CI 0.66-1.57) for average exposure more than 1µg/L THM compared with ≤ 1µg/L THM	TTHM data was previously unpublished.
Cantor et al. (1998)	Case-control study of association between bladder cancer and consumption of chlorinated surface water	- Little overall association between bladder cancer risk and exposure to chlorination byproducts - Bladder cancer risk increased with exposure duration	Opposite trends were found in males and females. Total lifetime and average lifetime TTHM levels show all risk increases are apparently restricted to male smokers.

Study	Description	Summary of Results	Comments
Koivusalo et al. (1998)	Case-control study of association between estimated historical exposure to drinking water mutagenicity and kidney and bladder cancers	- Non-significant excess risk of bladder cancer associated with mutagenic drinking water for men and women - Statistically significant OR (2.59, 95% CI 1.13-5.94) for a 3,000 net revertants/L increase in average exposure for nonsmoking men with ≤30 years estimable exposure history	- Authors claim their study (at publication) was first to report an exposure-response relationship between the quantitative level of drinking water chlorination by-products and kidney cancer. - Authors acknowledge that higher OR for those with ≤30 years in highest exposure category (in this study, 3,000 net revertants/L) could indicate that exposure period used was too short to appropriately study the relationship w/bladder cancer, and risk may be underestimated in this study.
King and Marrett (1996)	Case-control study of association between bladder cancer and consumption of chlorinated surface water	- Odds ratio for bladder cancer for 35 years of exposure compared to 10 years is 1.42 (95% Confidence Interval: 1.10-1.81) - Bladder cancer risk increased with years of exposure - Risk increases by 11 percent with each 1,000 µg/L THM-year	Statistically significant only for lengthy exposures. Results provide no support for an interaction between volume of water consumed and years of exposure to THMs levels > 49 µg/L.
Porru (2003)	Hospital-based case control study of association between years of exposure to chlorinated drinking water and bladder cancer. TTHM data previously unpublished.	- Adjusted OR for men = 4.74 (95% CI 0.76-29.6) for average exposure more than 1µg/L THM compared with ≤ 1µg/L THM	TTHM data was previously unpublished.

This pooled analysis (Villanueva et al. 2004) focused on TTHM exposure specifically and presented OR estimates (adjusted for age, smoking, occupation, coffee consumption and education) for men and women separately, as well as for both sexes combined for any exposure to TTHMs and as a function of average TTHM exposure and cumulative TTHM exposure. The authors also evaluated the relationship between OR for bladder cancer and duration of exposure to chlorinated water.

For support of the Stage 2 DBPR, EPA is using information based on the relationship between OR and average TTHM exposure from the Villanueva et al. (2004) study for both sexes combined. These estimates as presented in Villanueva et al. (2004) are shown in Exhibit 6.7.

Exhibit 6.7 Summary of Estimated OR Values Associated with Average TTHM Exposures for Both Sexes from Villanueva et al. (2004)

Average TTHM (ug/L)	OR	95% CI
0	1.0	NA
> 0	1.2	1.0 - 1.4
0 - 1	1.0	NA
> 1	1.2	1.1 - 1.3
0 - 1	1.0	NA
> 1 - 5	1.1	0.9 - 1.3
> 5 - 25	1.2	1.0 - 1.4
> 25 - 50	1.2	1.0 - 1.4
> 50	1.3	1.1 - 1.5

EPA also obtained additional detailed data on the relationship between average TTHM levels and OR from the authors of the Villanueva et al. (2004) study (Kogevinas and Villanueva 2005). These additional data are presented in Exhibit 6.8. Using a linear relationship fit to the data in Exhibit 6.8 provided by Kogevinas and Villanueva (2005), and an estimate of a national average Pre-Stage 1 TTHM concentration of 38.05 ug/L, EPA has estimated a pre-Stage 1 PAR value of 17.1 percent (95 percent CI = 2.5 percent - 33.1 percent). See Appendix E for details of the PAR calculation.

Exhibit 6.9 provides a summary of the estimated annual bladder cancer cases attributable to DBPs reflecting pre-Stage 1 occurrence and exposure levels for the three approaches to estimating risk described above:

- Range of PAR values from five individual studies
- Villanueva et al. (2003), and
- Villanueva et al. (2004).

All three approaches are considered equally valid and provide feasible estimates of risk. These estimates, summarized in Exhibit 6.9, assume an annual total of 56,506 new cases of bladder cancer from all causes. These values are obtained by multiplying the 56,506 total cases by the appropriate Pre-Stage 1 PAR values presented.

Exhibit 6.8 Detailed Data on OR as a Function of Average TTHM Exposure Level Provided by Kogevinas and Villanueva (2005)

Average TTHM (ug/L)	Odds Ratio	Lower 95% CI	Upper 95% CI
0	1.0	--	--
10	1.1	1.0	1.3
20	1.2	1.0	1.4
30	1.2	1.0	1.4
40	1.2	1.0	1.4
50	1.2	1.0	1.4
60	1.3	1.1	1.5
70	1.3	1.1	1.6
80	1.4	1.1	1.7
90	1.5	1.1	1.9
100	1.6	1.1	2.2
110	1.7	1.1	2.6
120	1.8	1.0	3.1
130	1.9	1.0	3.7

Exhibit 6.9 Estimates of Pre-Stage 1 Annual Bladder Cancer Cases Attributable to DBPs

Study	Lower 95% CI	Best Estimate of Annual Cases Attributable to DBPs	Upper 95% CI
Five Studies Used in Stage 1 and Stage 2 Proposal[1]	0	1,130 - 9,606	18,647
Villanueva et al. (2003)	4,830	8,899	15,376
Villanueva et al. (2004)	1,412	9,670	18,716

[1]For the estimates for the five studies used in Stage 1 and the Stage 2 proposal, the range shown for the "Best Estimate" reflects the 2 percent and 17 percent PAR values; the lower 95 percent CI reflects 0 percent PAR and the upper 95 percent CI reflects 33 percent PAR (the highest of the upper 95 percent CI estimates for the individual studies).

The details of the calculations of the Pre-Stage 1 attributable cases shown in Exhibit 6.9 are provided in Appendix E.

Other New Cancer Studies

In the Stage 1 DBPR, EPA concluded that the epidemiological evidence suggested a potential increased risk for bladder cancer due to DBP exposure. Some key studies EPA considered for Stage 1 include Cantor et al. (1998), Doyle et al. (1997), Freedman et al. (1997), King and Marrett (1996), McGeehin et al. (1993), Cantor et al. (1987), and Cantor et al. (1985). Several studies published since the Stage 1 DBPR continue to support an association between increased risk of bladder cancer and exposure to chlorinated surface water (Chevrier et al. 2004, Koivusalo et al. 1998, Yang et al. 1998). One study found no effects for a biomarker of genotoxicity in urinary bladder cells and TTHM exposure (Ranmuthugala et al. 2003). Epidemiological reviews and meta-analyses generally support the possibility of an association between chlorinated water or THMs and bladder cancer (Villanueva et al. 2004, Villanueva et al. 2003, Villanueva et al. 2001, Mills et al. 1998). The World Health Organization (WHO 2000) found data inconclusive or insufficient to determine causality between chlorinated water and any health endpoint, although they concluded that the evidence is better for bladder cancer than for other cancers.

In the Stage 1 DBPR, EPA concluded that early studies suggested a small possible increase in rectal and colon cancers from exposure to chlorinated surface waters. The database of studies on colon and rectal cancers continues to support a possible association, but evidence remains mixed. For colon cancer, one newer study supports the evidence of an association (King et al. 2000a) while others showed inconsistent findings (Hildesheim et al. 1998, Yang et al. 1998). Rectal cancer studies are also mixed. Hildesheim et al. (1998) and Yang et al. (1998) support an association with rectal cancer while King et al. (2000a) did not. A review of colon and rectal cancer concluded evidence was inconclusive but that there was a stronger association for rectal cancer and chlorination DBPs than for colon cancer (Mills et al. 1998). The WHO (2000) review reported that studies showed weak to moderate associations with colon and rectal cancers and chlorinated surface water or THMs but that evidence is inadequate to evaluate these associations.

Recent studies on kidney, brain, and lung cancers and DBP exposure support a possible association (kidney: Yang et al. 1998, Koivusalo et al. 1998; brain: Cantor et al. 1999; lung: Yang et al. 1998). However, so few studies have examined these endpoints that definitive conclusions cannot be made. Studies on leukemia found little or no association with DBPs (Infante-Rivard et al. 2002, Infante-Rivard et al. 2001). A recent study did not find an association between pancreatic cancer and DBPs (Do et al. 2005). A study researching multiple cancer endpoints found an association between THM exposure and all cancers when grouped together (Vinceti et al. 2004). In the development of the Stage 2 DBPR, EPA has evaluated several key bladder cancer studies. Summary information on these studies can be found in Exhibit 6.10.

Exhibit 6.10 Summary of Bladder Cancer Epidemiology Studies and Review/Meta-analysis Studies Reviewed for Stage 2 DBPR

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Find
Do *et al.* 2005	Case-control study in Canada, 1994-1997.	Estimated chlorinated DBPs, chloroform, BDCM concentrations.	Pancreatic cancer.	No association was found between pancreatic cancer and exposure to chlorinated DBPs, chloroform, or BDCM.
Chevrier *et al.* 2004	Case-control study in France, 1985-1987.	Compared THM levels, duration of exposure, and 3 types of water treatment (ozonation, chlorination, ozonation/chlorination) .	Bladder cancer.	A statistically significant decreased risk of bladder cancer was found as duration of exposure to ozonated water increased. This was evident with and without adjustment for other exposure measures. A small increased risk and trend was detected for increased bladder cancer risk and duration of exposure to chlorinated surface water and with the estimated THM content of the water, achieving statistical significance only when adjusted for duration of ozonated water exposures. Effect modification by gender was noted in the adjusted analyses.
Vinceti *et al.* 2004	Retrospective cohort study in Italy, 1987-1999.	Standardized mortality ratios from all causes vs. cancer for consumers drinking water with high THMs.	15 cancers including colon, rectum, and bladder.	Mortality ratio from all cancers showed a statistically significant small increase for males consuming drinking water with high THMs. For females, an increased mortality ratio for all cancers was seen but was not statistically significant. Stomach cancer in men was the only individual cancer in which a statistically significant excess in mortality was detected for consumption of drinking water with high THMs.
Ranmuthugala *et al.* 2003	Cohort study in 3 Australian communities, 1997.	Estimated dose of TTHM, chloroform, and bromoform from routinely-collected THM measurements and fluid intake diary.	Frequency of micronuclei in urinary bladder epithelial cells.	Relative risk estimates for DNA damage to bladder cells for THM dose metrics were near 1.0. The study provides no evidence that THMs are associated with DNA damage to bladder epithelial cells, and dose-response patterns were not detected.
Infante-Rivard *et al.* 2002	Population-based case-control study in Quebec, 1980-1993.	Estimated prenatal and postnatal exposure to THMs and polymorphisms in two genes.	Acute lymphoblastic leukemia.	Data are suggestive, but imprecise, linking DNA variants with risk of acute lymphoblastic leukemia associated with drinking water DBPs. The number of genotyped subjects for *GSTT1* and CYP2E1 genes was too small to be conclusive.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Find
Infante-Rivard *et al.* 2001	Population-based case-control study in Quebec, 1980-1993.	Compared water chlorination (never, sometimes, always) and exposure to TTHMs, metals, and nitrates.	Acute lymphoblastic leukemia.	No increased risk for lymphoblastic leukemia was observed for prenatal exposure at average levels of TTHMs, metals or nitrates. However, a non-statistically significant, small increased risk was seen for postnatal cumulative exposure to TTHMs and chloroform (both at above the 95th exposure percentile of the distribution for cases and controls), for zinc, cadmium, and arsenic, but not other metals or nitrates.
King *et al.* 2000a	Population-based case-control study in southern Ontario, 1992-1994.	Compared source of drinking water and chlorination status. Estimated TTHM levels, duration of exposure, and tap water consumption.	Colon and rectal cancer.	Colon cancer risk was statistically associated with cumulative long term exposure to THMs, chlorinated surface water, and tap water consumption metrics among males only. Exposure-response relationships were evident for exposure measures combining duration and THM levels. Associations between the exposure measures and rectal cancer were not observed for either gender.
Cantor *et al.* 1999	Population-based case-control study in Iowa, 1984-1987.	Compared level and duration of THM exposure (cumulative and average), source of water, chlorination, and water consumption.	Brain cancer.	Among males, a statistically significant increased risk of brain cancer was detected for duration of chlorinated versus non-chlorinated source water, especially among high-level consumers of tap water. An increased risk of brain cancer for high water intake level was found in men. No associations were found for women for any of the exposure metrics examined.
Cantor *et al.* 1998	Population-based case-control study in Iowa, 1986-1989.	Compared level and duration of THM exposure (cumulative and average), source of water, chlorination, and water consumption.	Bladder cancer.	A statistically significant positive association between risk of bladder cancer and exposure to chlorinated groundwater or surface water reported for men and for smokers, but no association found for male/female non-smokers, or for women overall. Limited evidence was found for an association between tapwater consumption and bladder cancer risk. Suggestive evidence existed for exposure-response effects of chlorinated water and lifetime THM measures on bladder cancer risk.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Find
Hildesheim *et al.* 1998	Population-based case-control study in Iowa, 1986-1989.	Compared level and duration of THM exposure (cumulative and average), source of water, chlorination, and water consumption.	Colon and rectal cancer.	Increased risks of rectal cancer was associated with duration of exposure to chlorinated surface water and any chlorinated water, with evidence of an exposure-response relationship. Risk of rectal cancer is statistically significant increased with >60 years lifetime exposure to THMs in drinking water, and risk increased for individuals with low dietary fiber intake. Risks were similar for men and women and no effects were observed for tapwater measures. No associations were detected for water exposure measures and risk of colon cancer.
Koivusalo *et al.* 1998	Population-based case-control study in Finland, 1991-1992.	Estimated residential duration of exposure and level of drinking water mutagenicity.	Bladder and kidney cancer.	Drinking water mutagenicity was associated with a small, statistically significant, exposure-related excess risk for kidney and bladder cancers among men; weaker associations were detected for mutagenic water and bladder or kidney cancer among women. The effect of mutagenicity on bladder cancer was modified by smoking status, with an increased risk among non-smokers.
Yang *et al.* 1998	Cross-sectional study in Taiwan, 1982-1991.	Examined residence in chlorinated (mainly surface water sources) relative to non-chlorinated (mainly private well) water.	Cancer of rectum, lung, bladder, kidney, colon, and 11 others.	Residence in chlorinating municipalities (vs. non-chlorinating) was statistically significantly associated with the following types of cancer in both males and females: rectal, lung, bladder, and kidney cancer. Liver cancer and all cancers were also statistically significantly elevated in chlorinated towns for males only. Mortality rates for cancers of the esophagus, stomach, colon, pancreas, prostate, brain, breast, cervix uteri and uterus, and ovary were comparable for chlorinated and non-chlorinated residence.
Doyle *et al.* 1997	Prospective cohort study in Iowa, 1987-1993.	Examined chloroform levels and source of drinking water.	Colon, rectum, bladder, and 8 other cancers in women.	Statistically significant increased risk of colon cancer, breast cancer and all cancers combined was observed for women exposed to chloroform in drinking water, with evidence of exposure-response effects. No associations were detected between chloroform and bladder, rectum, kidney, upper digestive organs, lung, ovary, endometrium, or breast cancers, or for melanomas or non-Hodgkin's lymphoma. Surface water exposure (compared to ground water users) was also a significant predictor of colon and breast cancer risk.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Find
Freedman *et al.* 1997	Population-based case-control study in Maryland, 1975-1992.	Estimated duration of exposure to chlorinated water. Compared exposure to chlorinated municipal water (yes/no).	Bladder cancer.	There was a weak association between bladder cancer risk and duration of exposure to municipal water for male cigarette smokers, as well as an exposure-response relationship. No association was seen for those with no history of smoking, suggesting that smoking may modify a possible effect of chlorinated surface water on the risk of bladder cancer.
King and Marrett 1996	Case-control study in Ontario, Canada, 1992-1994.	Compared source of drinking water and chlorination status. Estimated TTHM levels, duration of exposure, and tap water consumption.	Bladder cancer.	Statistically significant associations were detected for bladder cancer and chlorinated surface water, duration or concentration of THM levels and tap water consumption metrics. Population attributable risks were estimated at 14 to 16 percent. An exposure-response relationship was observed for estimated duration of high THM exposures and risk of bladder cancer.
Cordier *et al.* 1993	Hospital-based case-control study in France, 1984-1987.	Estimated duration of exposure to TTHMs.	Bladder cancer.	No associations were not detected for bladder cancer and exposure to TTHMs.
McGeehin *et al.* 1993	Population-based case-control study in Colorado, 1990-1991.	Compared source of drinking water, water treatment, and tap water versus bottled water. Estimated duration of exposure to TTHMs and levels of TTHMs, nitrates, and residual chlorine.	Bladder cancer.	Statistically significant associations were detected for bladder cancer and duration of exposure to chlorinated surface water. The risk was similar for males and females and among nonsmokers and smokers. The attributable risk was estimated at 14.9 percent. High tap water intake was associated with risk of bladder cancer in a exposure-response fashion. No associations were detected between bladder cancer and levels of TTHMs, nitrates, and residual chlorine.
Vena *et al.* 1993	Case-control study in western NY, 1979-1985.	Compared consumption of fluids, including chlorinated tap water.	Bladder cancer.	Bladder cancer and consumption of total fluids and tap water alone showed a significant finding for both age categories (under 65 years and over 65 years). A dose-response relationship was observed for consumption of tap water and total fluid intake. Risks associated with tap water consumption were higher for nonsmokers.
Lynch *et al.* 1989	Case-control study in Iowa, 1894-1979.	Compared source of drinking water. Estimated chlorinated water consumption	Bladder cancer.	Bladder cancer was statistically associated with duration of exposure to chlorinated drinking water sources for both sexes.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Find
		and duration of exposure.		
Cantor *et al.* 1987 (and Cantor *et al.* 1985)	Population-based case-control study in 10 areas of the U.S., 1977-1978.	Compared source of drinking water. Estimated total beverage and tap water consumption and duration of exposure.	Bladder cancer.	Bladder cancer was statistically associated with duration of exposure to chlorinated surface water for women and nonsmokers of both sexes. The largest risks were seen when both exposure duration and level of tap water ingestion were combined. No association was seen for total beverage consumption.
Wilkins and Comstock 1981	Cohort study in Washington County, MD, 1963-1975	Compared chlorinated surface water.	Bladder cancer.	Incidence rates for bladder cancer among men were nearly twofold higher in the chlorinated surface water group than in the referent group (results not statistically significant).
Reviews/Meta-analyses				
Villanueva *et al.* 2004	Review and meta-analysis of 6 case-control studies.	Individual-based exposure estimates to THMs and water consumption over a 40-year period.	Bladder cancer.	The meta-analysis suggests that risk of bladder cancer in men increases with long-term exposure to TTHMs. An exposure-response pattern was observed among men exposed to TTHMs, with statistically significant risk seen at exposures higher than 50 µg/L. No association between TTHMs and bladder cancer was seen for women.
Villanueva *et al.* 2003 (and Goebell *et al.* 2004)	Review and meta-analysis of 6 case-control studies and 2 cohort studies.	Compared source of water and estimated duration of exposure to chlorinated drinking water.	Bladder cancer.	The meta-analysis findings showed a moderate excess risk of bladder cancer attributable to long-term consumption of chlorinated drinking water for both genders, particularly in men. Statistically significance seen with men and combined both sexes. The risk was higher when exposure exceeded 40 years.
Villanueva *et al.* 2001	Qualitative review of 31 cancer studies.	Compared exposure to TTHM levels, mutagenic drinking water, water consumption, source water, types of disinfection (chlorination and chloramination), and residence times.	Cancer of bladder, colon, rectum, and 5 other cancers.	Review found that although results for cancer studies varied and were not always statistically significant, evidence for bladder cancer is strongest, and all 10 of the bladder cancer studies showed increased cancer risks with ingestion of chlorinated water. The authors felt associations with chlorinated water and cancer of the colon, rectum, pancreas, esophagus, brain, and other cancers were inconsistent.
WHO 2000	Qualitative	Various exposures to	Various	Studies reviewed reported weak to moderate increased

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Find
	reviews of various studies in Finland, U.S., and Canada.	THMs.	cancers.	relative risks of bladder, colon, rectal, pancreatic, breast, brain or lung cancer associated with long-term exposure to chlorinated drinking water. The authors felt evidence is inconclusive for an association between colon cancer and long-term exposure to THMs, that evidence is insufficient to evaluate a causal relationship between THMs and rectal, bladder, and other cancers. They found no association between THMs and increased risk of cardiovascular disease.
Mills *et al.* 1998	Qualitative review of 22 studies.	Examined TTHM levels and water consumption. Compared source of water and 2 types of water treatment (chlorination and chloramination).	Cancer of colon, rectum, and bladder.	Review suggests possible increases in risks of bladder cancer with exposure to chlorinated drinking water. The authors felt evidence for increased risk of colon and rectal cancers is inconclusive, though evidence is stronger for rectal cancer.

6.2.1.2 Toxicological Evidence of DBP Carcinogenicity

Toxicological studies provide important information on the potential carcinogenicity of DBPs in humans. EPA's Integrated Risk Information System (IRIS), which is accessible at http://www.epa.gov/iris, provides detailed descriptions of cancer risk assessments that EPA has performed for seven DBPs. Included on IRIS are weight-of-evidence characterizations of the carcinogenic potential of those seven DBPs and lifetime unit cancer risk factors for five of the seven, based primarily on animal toxicological data. As with all risk evaluations based on animal toxicological studies, several extrapolations were required to establish lifetime unit cancer risks for humans (e.g., from high to low doses, from nonhuman species to humans, and for DBPs, from gavage to ingestion of water). Exhibit 6.11 provides a summary of the cancer risk assessments for those seven DBPs as presented on the IRIS database.

Analyses done for the Stage 2 DBPR follow the 1999 EPA Proposed Guidelines for Carcinogenic Risk Assessment (USEPA 1999b). In March 2005, EPA updated and finalized the Cancer Guidelines and a Supplementary Children's Guidance, which include new considerations on mode of action for cancer risk determination and additional potential risks due to early childhood exposure (USEPA 2005f, USEPA 2005g). Conducting the cancer evaluation using the 2005 Cancer Guidelines would not result in any change from the existing analysis. With the exception of chloroform, no mode of action has been established for other specific regulated DBPs. Although some of the DBPs have given mixed mutagenicity and genotoxicity results, having a positive mutagenicity study does not necessarily mean that a chemical has a mutagenic mode of action. The extra factor of safety for children's health protection does not apply, because the new Supplementary Children's Guidance requires application of the children's factor only when a mutagenic mode of action has been identified.

The lifetime unit risk factors shown in Exhibit 6.11 for bromoform, bromodichloromethane, and dibromochloromethane were included in the cancer risk assessment and benefit analyses performed by EPA in support of the Stage 1 DBPR promulgated in 1998. Since the Stage 1 DBPR, EPA has updated the quantitative risk assessments for these three DBPs in order to represent the methodology proposed in the 1996/1999 draft cancer guidelines (USEPA 1996c and 1999b), resulting in revisions to the unit risk factors. Also, a new study of dichloroacetic acid tumorigenicity in mice by DeAngelo et al. (1999) examined doses lower than those used in previously published studies and has been judged by EPA to be suitable for quantification of risk, also using the newer methodology.

Except for DCAA, these updated cancer risk assessments do not yet appear on the IRIS database. A toxicological review for DCAA exists on IRIS. EPA is completing a new brominated THM Criteria Document for bromoform, bromodichloromethane, and dibromochloromethane that supports the Stage 2 Rule, and this document provides details on the animal toxicological data used to derive the new cancer unit risk factors for these DBPs.

The updated cancer risk factors for these four DBPs are presented in Exhibit 6.12. They have been used to estimate the pre-Stage 2 baseline cancer cases, the pre-Stage 1 concentrations of these compounds, the changes in those concentrations following Stage 1, and the estimated number of people exposed. As described in the Criteria Documents, cancer risk values were developed by fitting the key animal toxicological data to linearized multistage models using a Maximum Likelihood Estimation (MLE) methods. The MLE method provides parameter estimates for the model that fit the underlying data. Two risk factors are then derived from the dose-response curve that is fit to the data.

The first risk factor is based on the estimated dose that the model predicts will result in a carcinogenic response in 10 percent of the subjects (referred to as the Effective Dose for 10 percent

response, or ED_{10}). (Note: This unit risk factor is also sometimes referred to as the MLE estimate since it represents the dose taken directly from the curve fit by the MLE method.)

The second risk factor, which represents a more conservative estimate of the risk (and which corresponds more directly to the lifetime unit risks shown in Exhibit 6.11 from the IRIS database), is based on the lower 95 percent confidence bound on the dose that the model predicts will result in a carcinogenic response in 10 percent of those exposed to the chemical, relative to control (referred to as the Lower Bound on the Effective Dose for 10 percent response, or LED_{10}).

Exhibit 6.11 Summary of EPA's Cancer Risk Assessments as currently presented on IRIS for Specific DBPs

Chemical	EPA's Human Carcinogen Assessment	Lifetime Unit Cancer Risk Factor	Date and Source
Bromoform	Probable[1]	2.3×10^{-7} $(\mu g/L)^{-1}$	1993 (IRIS)
Bromodichloromethane	Probable[1]	1.8×10^{-6} $(\mu g/L)^{-1}$	1993 (IRIS)
Chloroform	Probable[1] Likely human carcinogen under high-exposure conditions that lead to cytotoxicity and regenerative hyperplasia in susceptible tissues. Not likely without cytotoxicity and cell regeneration.[2]	Not Available	2001 (IRIS)
Dibromochloromethane	Possible[1]	2.4×10^{-6} $(\mu g/L)^{-1}$	1992 (IRIS)
Dichloroacetic Acid	Likely[2]	1.4×10^{-6} $(\mu g/L)^{-1}$	2003 (IRIS)
Trichloroacetic Acid	Possible[1]	Not Available	1996 (IRIS)
Bromate	Probable[1] Likely to be carcinogenic via oral route of exposure[2]	2×10^{-5} $(\mu g/L)^{-1}$	2001 (IRIS)

[1] EPA's Human Carcinogen Assessment reported, as classified under EPA 1986 Cancer Risk Assessment Guidelines (USEPA 1986).
[2] EPA's Human Carcinogen Assessment reported, as classified under EPA 1996 and 1999 Proposed Cancer Risk Assessment Guidelines (USEPA 1996c and 1999b).

In both cases, EPA derives unit risk values assuming low-dose linearity and no threshold to estimate risk. As shown in Exhibit 6.12, the baseline number of annual Pre-Stage 2 cancer cases calculated from the risk factors for these four DBPs are 39 cases for the ED_{10} risk factors and 91 cases for the LED_{10} risk factors. Assuming that DBP risk reductions for Stage 2 for the entire population average 7.76 percent, corresponding to the reduction in average TTHM levels (see Exhibit 6.19), Stage 2 cancer cases avoided based on the toxicological data range from 1.7 to 4.0 cases per year.

Several limitations must be considered in conjunction with the interpretation and use of these cancer risk estimates. There are only seven DBPs (those shown in Exhibit 6.11) for which EPA has

determined that adequate toxicology studies are available to support an assessment of their potential for carcinogenicity in humans. As discussed elsewhere in this document, a large number of DBPs are present in drinking water that has been disinfected, including many substances that have not yet been specifically identified. It must also be recognized that these highly controlled toxicology studies involve exposure to each respective DBP separately, while actual exposure to humans is to a mixture that includes many other DBPs in a wide array of relative proportions. Lastly, these toxicology studies limit exposure to the oral route only, whereas humans are generally exposed to DBPs in drinking water not only by the oral route but by dermal exposure and inhalation as well.

Exhibit 6.12 Quantification of Cancer Risk for BDCM, Bromoform, DBCM, and DCAA, Pre-Stage 2 Baseline[1]

Source Water Type	Pre-Stage 2 Conc (ug/L), Mean of Plant Means, DS Average	Population	Derivation of cases using ED_{10}				Derivation of cases using LED_{10}			
			Lifetime unit risk (cases/ person)/ (mg/kg-day)	Lifetime unit risk conc. (cases/ person)/ (ug/L)	Annual unit risk conc. (cases/ person)/ (ug/L)	Baseline Cases	Lifetime unit risk (cases/ person)/ (mg/kg-day)	Lifetime unit risk conc. (cases/ person)/ (ug/L)	Annual unit risk conc. (cases/ person)/ (ug/L)	Baseline Cases
	A	B	C	D=C*(1/1000)* (2L/day)*(1/70 kD)	E=D/70 years	F=A*B*E	G	H=G*(1/1000)* (2L/day)*(1/70 kD)	I=H/70 years	J=A*B*I
BDCM										
SW	8.20	169,358,139	2.2E-02	6.29E-07	8.98E-09	12.5	3.4E-02	9.71E-07	1.39E-08	19.3
GW	2.92	93,666,379	2.2E-02	6.29E-07	8.98E-09	2.5	3.4E-02	9.71E-07	1.39E-08	3.8
Total		263,024,518				**14.9**				**23.1**
Bromoform										
SW	2.69	169,358,139	3.4E-03	9.71E-08	1.39E-09	0.6	4.5E-03	1.29E-07	1.84E-09	0.8
GW	1.94	93,666,379	3.4E-03	9.71E-08	1.39E-09	0.3	4.5E-03	1.29E-07	1.84E-09	0.3
Total		263,024,518				**0.9**				**1.2**
DBCM										
SW	5.50	169,358,139	1.7E-02	4.86E-07	6.94E-09	6.5	4.0E-02	1.14E-06	1.63E-08	15.2
GW	2.81	93,666,379	1.7E-02	4.86E-07	6.94E-09	1.8	4.0E-02	1.14E-06	1.63E-08	4.3
Total		263,024,518				**8.3**				**19.5**
DCAA										
SW	11.98	169,358,139	1.5E-02	4.29E-07	6.12E-09	12.4	4.8E-02	1.36E-06	1.94E-08	39.4
GW	4.28	93,666,379	1.5E-02	4.29E-07	6.12E-09	2.5	4.8E-02	1.36E-06	1.94E-08	7.8
Total		263,024,518				**14.9**				**47.2**
Grand Total						**39.0**				**91.0**

Note: Unit risk factors are different from Exhibit 6.5 - see text for discussion

Sources: A) SW: SWAT DBP Summary Statistics, Run 300 (Pre-Stage 2); GW: Stage 2 Benefits Model
B) Stage 2 Population Baseline: Exhibit 3.3
C) The unit risk factor is based on the ED_{10} (effective dose for 10 percent response) based on the Maximum Likelihood Estimation (MLE) method (provided by Nancy Chiu of EPA's Health and Ecological Criteria Division in email (5/22/03)).
D) This calculation assumes a 70 kg person with the average drinking water consumption rate of 2L/day.
G) The unit risk factor is based on the LED_{10} (lower 95 percent confidence bound on effective dose for 10 percent response) based on the MLE method (provided by Nancy Chiu in email (5/22/03)).

More research on DBPs is underway at EPA and other research institutions. Summaries of on-going studies may be found on EPA's DRINK website (http://www.epa.gov/safewater/drink/intro.html). Two-year bioassays by the National Toxicology Program (NTP) released in abstract form have recently been completed on BDCM and chlorate. The draft abstract on BDCM reported no evidence of carcinogenicity when BDCM was administered via drinking water (NTP 2005a). The results of this draft report do not affect the Stage 2 benefits analysis, because the quantified benefits are based on data from epidemiological studies as presented in Section 6.4 and Appendix E. Another recent study, a modified two-year bioassay on BDCM in the drinking water, reported little evidence of carcinogenicity (George et al. 2002). In a previous NTP study, tumors were observed, including an increased incidence of kidney, liver, and colon tumors, when BDCM was administered at higher doses by gavage in corn oil (NTP 1987). EPA will examine new information on BDCM as it becomes available. In the chlorate draft abstract, NTP found some evidence that it may be a carcinogen (NTP 2004). Chlorate is a byproduct of hypochlorite and chlorine dioxide systems. A long-term, two-year bioassay NTP study on DBA is also complete but has not yet undergone peer review (NTP 2005b).

Another significant advancement beyond the Stage 1 DBPR was the evaluation of the chloroform tumorigenicity data on the basis of its nonlinear mode of action following the draft 1999 proposed Guidelines for Carcinogen Risk Assessment (USEPA 1999b). The new chloroform assessment became available on IRIS in October 2001.

An International Life Sciences Institute (ILSI) Expert Panel recommended that DBP risk cannot be assessed by single-chemical testing approaches alone (ILSI and RSI 1998). The report suggested the use of modern approaches (e.g., studies relating chemical structure to toxicity, application of molecular biology techniques, studies of mechanism of action), the use of a 3-tiered testing approach (i.e., in-vitro tests; short-term screening tests or 90-day animal studies; long-term chronic bioassays). It also recommended a focus on three scenarios: (1) defined (simple) mixtures of less than 10 DBPs; (2) whole mixtures produced by simulating disinfection scenarios; and (3) real drinking water samples or their extracts.

Other byproducts with carcinogenic potential

Along with the reduction in DBPs from chlorination such as TTHM and HAA5 as a result of the Stage 2 DBPR, there may be increases in other DBPs as systems switch from chlorine to alternative disinfectants. For all disinfectants, many DBPs are not regulated and many others have not yet been identified. EPA will continue to review new studies on DBPs and their occurrence levels to determine if they pose possible health risks. EPA continues to support regulation of TTHM and HAA5 as indicators for chlorination DBP occurrence and believes that operational and treatment technology changes made because of the Stage 2 DBPR will result in an overall decrease in risk.

Emerging DBPs

Iodo-DBPs and nitrogenous DBPs including halonitromethanes are DBPs that have recently been reported (Richardson et al. 2002, Richardson 2003). One recent occurrence study sampled quarterly at twelve plants using different disinfectants across the U.S. for several iodo-THMs and halonitromethane species (Weinberg et al. 2002). The concentrations of iodo-THMs and halonitromethane in the majority of samples in this study were less than the analytical minimum reporting levels; plant-average concentrations of iodo-THM and halonitromethane species were typically less than 0.002 mg/L, which is an order of magnitude lower than the corresponding average concentrations of TTHM and HAA5 at those same plants. Chloropicrin, a halonitromethane species, was also measured in the ICR with a median concentration of 0.0002 mg/L across all surface water samples. No occurrence data exist for the

iodoacids due to the lack of a quantitative method and standards. Further work on chemical formation of iodo-DBPs and halonitromethanes is needed.

Iodoacetic acid was found to be cytotoxic and genotoxic in Salmonella and mammalian cells (Plewa et al. 2004a) as were some of the halonitromethanes (Kundu et al. 2004; Plewa et al. 2004b). Although potent in these in vitro screening studies, further research is needed to determine if these DBPs are active in living systems. No conclusions on human health risk can be drawn from such preliminary studies.

N-nitrosamines

Another group of nitrogenous DBPs are the N-nitrosamines. A number of N-nitrosamines exist, and N-nitrosodimethylamine (NDMA), a probable human carcinogen (IRIS 1993), has been identified as a potential health risk in drinking water. NDMA is a contaminant from industrial sources and a potential disinfection byproduct from reactions of chlorine or chloramine with nitrogen containing organic matter and from some polymers used as coagulant aids. Studies have produced new information on the mechanism of formation of NDMA, but there is not enough information at this time to draw conclusions regarding a potential increase in NDMA occurrence as systems change treatment. Although there are studies that examined the occurrence of NDMA in some water systems, there are no systematic evaluations of the occurrence of NDMA and other nitrosamines in US waters. Recent studies have provided new occurrence information that shows NDMA forms in both chlorinated and chloraminated systems. Barrett et al. (2003) reported median concentrations of less than 2ng/L for the seven chlorine systems studied and less than 3 ng/L for 13 chloramine systems. Another study demonstrated that factors other than disinfectant type may play an important role in the formation of NDMA (Schreiber and Mitch 2005). More research is underway to determine the extent of NDMA occurrence in drinking water systems. EPA is also considering proposing monitoring for NDMA under Unregulated Contaminant Monitoring Rule 2.

Risk assessments have estimated that the 10^{-6} lifetime cancer risk level is 7 ng/L based on induction of tumors at multiple sites. NDMA is also present in food, tobacco smoke, and industrial emissions, and additional research is underway to determine the relative exposure of NDMA in drinking water to these other sources.

Other DBPs

Some systems, depending on bromide and organic precursor levels in the source water and treatment technology selection, may experience a shift to higher ratios, or concentrations, of brominated DBPs while the overall TTHM or HAA5 concentration may decrease. In some instances where alternative disinfectants are used, levels of chlorite and bromate may increase as a result of systems switching to chlorine dioxide or ozone, respectively. However, EPA anticipates that changes in chlorite and bromate concentration as a result of the Stage 2 DBPR will be minimal (see Section 6.4). For most systems, overall levels of DBPs, as well as brominated DBP species, should decrease as a result of this rule. EPA continues to believe that precursor removal is a highly effective strategy to reduce levels of DBPs.

Other toxicological effects

The Agency has modified the reference dose (RfD) values of the chlorinated acetic acids since the Stage 1 DBPR. Under the Stage 1 DBPR there was no established RfD for monochloroacetic acid (MCAA). Data from a drinking water exposure study of MCAA in rats by DeAngelo et al. (1997) were used to establish an RfD of 0.01 mg/kg-day based on observed increases in spleen weights. Data from

DeAngelo et al. (1997) were also used to calculate a new RfD of 0.03 mg/kg-day for trichloroacetic acid based on observed effects on body weight and liver effects.

WHO review of toxicology literature (2000)

The IPCS report on Disinfectants and Disinfection Byproducts (WHO 2000) emphasizes that the bulk of the toxicology data focus primarily on carcinogenesis. The Task Group found BDCM to be of particular interest because it produces tumors in both rats and mice at several sites. Although the HAAs appear to be without significant genotoxic activity, the brominated HAAs appear to induce oxidative damage to deoxyribose nucleic acid (DNA), leading to tumor formation.

6.2.1.3 Issues with Human and Animal Cancer Data Concordance

According to the *Guidelines for Carcinogen Risk Assessment* (USEPA 2005f), tumor site concordance between human and test animal is not necessary to determine carcinogenic potential; mechanistic considerations should only be applied when there is sufficient data to support a mode of action. The guidelines state that "Target organ concordance is not a prerequisite for evaluating the implications of animal study results for humans." Although concordance of effects between the test species and humans is highly desirable and lends credence and support in the analysis of mode of action, it is not necessary to cite animal and human tumor site concordance in order to justify a quantitative cancer risk assessment. In addition, there is insufficient data to support potential mode(s) of action for DBPs, with the exception of chloroform. Therefore, consideration of site concordance across species for cancer is not appropriate at this time.[2]

It is important to consider some key similarities and differences across species when conducting such a cross-species concordance evaluation for bladder cancer. The mechanisms controlling cell growth and differentiation are similar across species, but there are marked differences in the way these mechanisms are managed in various tissues within a given species. In addition, it is important to consider the differences in exposure routes for the animal studies (ingestion and gavage) and the epidemiological studies, which may include inhalation and dermal exposure.

Disinfection byproducts may be associated with bladder cancer in humans, but may appear as kidney or liver cancers in laboratory animal toxicology studies in rodents; laboratory animal toxicology studies of individual DBPs have reported cancer of the liver and kidney. Though this appears to indicate a lack of concordance in target organs, concordance on the general tissue type may be present in different organs. Kidney cancer in the renal pelvis, which has been reported for a few DBPs, may be linked with bladder cancer, as the renal pelvis is lined with the same transitional cell epithelium as found in the bladder (Cohen et al. 1988). Further, the pathogenesis of transitional cell carcinomas in the urinary bladder appears to be similar throughout the renal pelvis, ureter, and urinary bladder (Cohen et al. 1988). For example, the DBP MX has been reported to cause individual transitional cell hypertrophy with karyomegaly in the urinary bladder of rats (Komulainen et al. 1997). A review of occupational cancer of the urinary tract reported that approximately 15 percent of kidney neoplasms are in the renal pelvis and appear to be caused by the same carcinogens as bladder neoplasms (Schulte et al. 1987). Finally, over 90 percent of human bladder cancers involve the transitional cell epithelium or urothelium (Silverman et al. 1996), suggesting that a component of the kidney and bladder can be considered part of the same target tissue, known as the urinary tract.

[2]Site concordance has been found for colon cancer and for reproductive and toxicological endpoints.

DBPs may not be unique with respect to an apparent lack of tissue-specific concordance across species. A majority of the non-DBP agents that clearly act through genotoxic mechanisms, including benzidine and benzidine-derived azo dyes (Cohen and Johansson 1992), are known to cause urinary bladder carcinoma in humans and to cause cancer in rodents at various sites that do not always include the urinary bladder (Rice et al. 1999). Other examples of this include inorganic arsenicals, which are human bladder carcinogens but are negative in animals studies (NRC 1990, USEPA 1994a). Conversely, nitrosamines (i.e., N-methyl-N-nitrosourea) are bladder carcinogens in laboratory animals, but not in humans (Cohen and Johansson 1992). And similar to disinfection byproducts, caffeine is a risk factor for bladder cancer in humans, but there is no evidence of increased risk reported in laboratory animals (Cohen and Johansson 1992). Although 40 percent of the NTP chemicals that cause bladder tumors are not mutagenic, EPA concludes that a majority of the agents that clearly act through genotoxic mechanisms are known to cause urinary bladder carcinoma in humans and rodents at various sites that do not always include the urinary bladder.

Another potential influence on the difference in observations in animals and humans is the difference in exposure route in animal studies versus human studies. The animal studies all use ingestion or gavage as the route of administration, whereas human drinking water exposure includes inhalation and dermal exposure. For example, tumor responses from chloroform exposure in the liver and kidney of rats varied by route of exposure, sex and strain (ILSI 1997).

EPA has completed a comprehensive review of the cancer data on disinfection byproducts; and while there is evidence from human cancer epidemiology studies that lifetime consumption of the DBP mixture within chlorinated surface water poses a bladder cancer risk, the specific causative constituents have not been identified. Since there is no definitive support provided by studies to date for or against the generalization of adverse effects across different organs or between or within species, EPA concludes that target organ concordance for cancer is not a prerequisite for evaluating the implications of animal study results for humans at this time. EPA will reevaluate this issue as new data become available to support a mode-of-action.

6.2.1.4 Conclusions

EPA concludes that the epidemiological and toxicological studies support a weight-of-evidence conclusion that there may be an association between DBPs and cancer. The evidence is insufficient to establish a causal relationship. The following are the key factors used to support EPA's weight-of-evidence conclusion:

- There is some evidence from animal studies for the carcinogenicity of individual DBPs included in this rule. Exhibit 6.11 summarizes the Agency findings on the carcinogenicity of seven DBPs. They have all been characterized on IRIS as either "possible" or "probable" carcinogens under EPA's 1986 guidelines, and in some cases also as "likely" carcinogens under EPA's 1996/1999 guidelines. One of these (chloroform) has been evaluated based on its mode of action, with the finding that it is likely to be carcinogenic only under high-exposure conditions that lead to cytotoxicity and regenerative hyperplasia.

- Epidemiological data from individual investigations and from a meta-analysis (Villanueva et al. 2003) links exposure to chlorinated water with an increased risk for bladder cancer in some population subgroups.

- An analysis of pooled of data by Villanueva et al. (2004) links exposure to TTHMs with an increased risk of bladder cancer.

- The epidemiological data cannot link specific DBPs with cancer risk because of difficulties in characterizing the exposure. Exposure in some epidemiology studies was monitored purely in terms of chlorinated water, which contains a mixture of DBPs, some of which have not yet been identified, as well as a variety of other drinking water contaminants. In other studies the DBP exposure was monitored in terms of trihalomethane concentrations (a variable mixture of four individual DBPs). Thus, the Agency must rely on both the bioassays for individual chemicals as well as the epidemiology data in making a weight-of-evidence determination.

- Associations of chlorinated water to cancer of the colon, rectum, and kidney were found in some cases but the data are less robust than the data for bladder cancer.

EPA has a research program that continues to examine the relationship between exposure to DBPs and carcinogenicity. Additional data needs include information on modes of action, the reasons for inconsistencies in findings between men and women, inconsistencies across studies in the role of smoking, and carcinogenicity testing for selected brominated and chlorinated DBPs administered in drinking water. New studies are under way or planned that would help provide this type of data.

6.2.2 Reproductive and Developmental Health Effects

Both human epidemiology studies and animal toxicology studies have examined associations between chlorinated drinking water or DBPs and reproductive and developmental health effects. Based on the weight-of-evidence evaluation of the reproductive and developmental epidemiology data EPA concludes that there is a potential association between DBPs and adverse reproductive and developmental effects. Despite inconsistent findings across studies, recent studies using stronger methods and study design continue to suggest associations between DBP exposure and various adverse reproductive and developmental effects. In addition, data from a number of toxicology studies, although the majority of them were conducted using high doses, indicate a health hazard and demonstrate biological plausibility for the effects observed in epidemiology studies. No dose-response relationship or causal link has been established. EPA's evaluation of the best available studies, particularly epidemiology studies, provides an indication of a potential health hazard that warrants incremental regulatory action beyond the Stage 1 DBPR.

The Centers for Disease Control (CDC) reports that, for the 10 year period between 1986 and 1996, spontaneous fetal losses were estimated to be between 0.8 million and 1.0 million per year. For births in the United States in the year 2002 (as reported by the CDC, 2005), 1.4 percent of births are considered very low birth weight (defined by CDC as below 1,500 g) and 7.8 percent are considered low birth weight (defined by the CDC as below 2,500 g). Birth defects are reported to occur in approximately 1 in 33 live births per year in the United States (CDC 2005). Although research has identified some risk factors for these adverse birth outcomes, including nutritional factors (e.g., lack of folic acid supplementation) and fetal exposure to tobacco smoke and alcohol, the causes of most such outcomes are unknown.

A variety of research is underway to examine the potential role that maternal exposure to specific contaminants might play in these adverse outcomes. The following sections provide a review of the

literature addressing the potential relationship between DBPs and adverse reproductive and developmental outcomes.

6.2.2.1 Epidemiological Evidence of Adverse Reproductive and Developmental Health Effects

As discussed previously, epidemiology studies have the strength of relating human exposure to DBP mixtures through multiple intake routes. Although the critical exposure window for reproductive and developmental effects is much smaller than that for cancer (generally weeks versus years), exposure assessment is also a main limitation of reproductive and developmental epidemiology studies. Exposure assessment uncertainties arise from limited data on DBP concentrations and maternal water usage and source over the course of the pregnancy. However, classification errors typically push the true risk towards the null value (Vineis 2004). According to Bove et al. (2002), "Difficulties in assessing exposure may result in exposure misclassification biases that would most likely produce substantial underestimates of risk as well as distorted or attenuated exposure–response trends." Studies of rare outcomes (e.g., individual birth defects) often have limited statistical power because of the small number of cases being examined. This limits the ability to detect statistically significant associations for small to moderate relative risk estimates. Small sample sizes also result in imprecision around risk estimates reflected by wide confidence intervals. In addition to the limitations of individual studies, evaluating reproductive and developmental epidemiology studies collectively is difficult because of the methodological differences between studies and the wide variety of endpoints examined. These factors may contribute to inconsistencies in the scientific body of literature as noted below.

More recent studies tend to be of higher quality because of improved exposure assessments and other methodological advancements. For example, studies that use THM levels to estimate exposure tend to be higher quality than studies that define exposure by source or treatment. These factors were taken into account by EPA when comparing and making conclusions on the reproductive and developmental epidemiology literature. What follows is a summary of available epidemiology literature on reproductive and developmental endpoints such as spontaneous abortion, stillbirth, neural tube and other birth defects, low birth weight, and intrauterine growth retardation. Information is grouped, where appropriate, into three categories on fetal growth, viability, and malformations, and reviews are described separately afterward.

Epidemiology reports and reviews

Fetal growth

Many studies looked for an association between fetal growth (mainly small for gestational age, low birth weight, and pre-term delivery) and chlorinated water or DBPs. The results from the collection of studies as a whole are inconsistent. A number of studies support the possibility that exposure to chlorinated water or DBPs are associated with adverse fetal growth effects (Infante-Rivard 2004, Wright et al. 2004, Wright et al. 2003, Källén and Robert 2000, Gallagher *et al.* 1998, Kanitz et al. 1996, Bove et al. 1995, Kramer et al. 1992). Other studies showed mixed results (Porter et al. 2005, Savitz et al. 2005, Yang 2004) or did not provide evidence of an association (Toledano et al. 2005, Jaakkola et al. 2001, Dodds et al. 1999, Savitz et al. 1995) between DBP exposure and fetal growth. EPA notes that recent, higher quality studies provide some evidence of an increased risk of small for gestational age and low birth weight.

Fetal viability

While the database of epidemiology studies for fetal loss endpoints (spontaneous abortion or stillbirth) remains inconsistent as a whole, there is suggestive evidence of an association between fetal loss and chlorinated water or DBP exposure. Numerous studies support the possibility that exposure to chlorinated water or DBPs is associated with decreased fetal viability (Toledano 2005, Dodds et al. 2004, King et al. 2000b, Dodds et al. 1999, Waller et al. 1998, Aschengrau et al. 1993, Aschengrau et al. 1989). Many of the more recent, higher quality studies report associations. Some studies did not support an association (Bove et al. 1995) or reported inconclusive results (Savitz et al. 2005, Swan et al. 1998, Savitz 1995) between fetal viability and exposure to THMs or tapwater. A recent study by King et al. (2005) found little evidence of an association between stillbirths and haloacetic acids after controlling for trihalomethane exposures, though non-statistically significant increases in stillbirths were seen across various exposure levels.

Fetal malformations

A number of epidemiology studies have examined the relationship between fetal malformations (such as neural tube, oral cleft, cardiac, or urinary defects, and chromosomal abnormalities) and chlorinated water or DBPs. It is difficult to assess fetal malformations in aggregate due to inconsistent findings and disparate endpoints being examined in the available studies. Some studies support the possibility that exposure to chlorinated water or DBPs is associated with various fetal malformations (Cedergren et al. 2002, Hwang et al. 2002, Dodds and King 2001, Klotz and Pyrch 1999, Bove et al. 1995, Aschengrau et al. 1993). Other studies found little evidence (Shaw et al. 2003, Källén and Robert 2000, Dodds et al. 1999, Shaw et al. 1991) or inconclusive results (Magnus et al. 1999) between chlorinated water or DBP exposure and fetal malformations. Birth defects most consistently identified as being associated with DBPs include neural tube defects and urinary tract malformations.

Other endpoints have also been examined in recent epidemiology studies. One study suggests an association between DBPs and decreased menstrual cycle length (Windham et al. 2003), which, if corroborated, could be linked to the biological basis of other reproductive endpoints observed. No association between THM exposure and semen quality was found (Fenster et al. 2003). More work is needed in both areas to support these results.

Epidemiological reviews have progressively offered more support for a possible association between various reproductive and developmental effects and chlorinated water or DBPs. An early review supported an association between measures of fetal viability and tap water (Swan et al. 1992). Three other reviews found data inadequate to support an association between reproductive and developmental health effects and THM exposure (Reif et al. 1996, Craun 1998, WHO 2000). Mills et al. (1998) examined data on and found support for an association between fetal viability and malformations and THMs. Another review presented to the Stage 2 MDBP FACA found some evidence for an association with fetal viability and some fetal malformations and exposure to DBPs but reported that the evidence was inconsistent for these endpoints as well as for fetal growth (Reif et al. 2000). Reif et al. (2000) concluded that the weight of evidence from epidemiology studies suggests that "DBPs are likely to be reproductive toxicants in humans under appropriate exposure conditions," but from a risk assessment perspective, data are primarily at the hazard identification stage. Nieuwenhuijsen et al. (2000) found some evidence for an association between fetal growth and THM exposure and concluded evidence for associations with other fetal endpoints is weak but gaining weight. A qualitative review by Villanueva et al. (2001) found evidence generally supports a possible association between reproductive effects and drinking chlorinated water. Graves et al. (2001) supports a possible association for fetal growth but not fetal viability or malformations. More recently, Bove et al. (2002) examined and supported an association between small for gestational age, neural tube defects and spontaneous abortion endpoints and

DBPs. Following a meta-analysis on five malformation studies, Hwang and Jaakkola (2003) concluded that there was evidence which supported associations between DBPs and risk of birth defects, especially neural tube defects and urinary tract defects. More detail on some of these critical reviews is presented later in this section. Exhibit 6.13 provides summary information for key epidemiological reports and reviews to the Stage 2 DBPR.

Exhibit 6.13 Summary of Reproductive/Developmental Epidemiology Studies

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Findings
Porter *et al.* 2005	Cross-sectional study in Maryland, 1998-2002.	Estimated trimester-specific and pregnancy-average exposures to THMs and HAAs, including individual DBPs.	Intrauterine growth retardation.	No consistent association or dose-response relationship was found between exposure to either TTHM or HAA5 and intrauterine growth retardation. Results suggest an increased risk of intrauterine growth retardation associated with TTHM and HAA5 exposure in the third trimester, although only HAA5 results were statistically significant.
Savitz *et al.* 2005	Population-based prospective cohort study in three communities around the U.S., 2000-2004.	Estimated TTHM, HAA9, and TOX exposures during pregnancy. Individual brominated THMs and HAA species were examined. Indices examined included concentration, ingested amount, exposure from showering and bathing, and an integration of all exposures combined.	Early and late pregnancy loss, preterm birth, small for gestational age, and term birth weight.	No association with pregnancy loss was seen when high TTHM exposures were compared to low exposures. When examining individual THMs, a statistically significant association was found between bromodichloromethane (BDCM) and pregnancy loss. Although non-statistically significant, an increased risk similar in magnitude was seen between dibromochloromethane (DBCM) and pregnancy loss. Some increased risks were seen for losses at greater than 12 weeks' gestation for TTHM, BDCM, and TOX (total organic halide), but most results generally did not provide support for an association. Preterm birth showed a small inverse relationship with DBP exposure (i.e. higher exposures were less likely to have a preterm birth), but this association was weak. TTHM exposure of 80 ug/L was significantly associated with twice the risk for small for gestational age during the third trimester.
Toledano *et al.* 2005	Large cross-sectional study in England, 1992-1998.	Linked mother's residence at time of delivery to modeled estimates of TTHM levels in water zones.	Stillbirth, low birth weight.	A significant association between TTHM and risk of stillbirth, low birth weight, and very low birth weight was observed in one of the three regions. When all three regions were combined, small, but non-significant, excess risks were found between all three outcomes and TTHM and chloroform. No associations were observed between reproductive risks and BDCM or total brominated THMs.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Findings
Dodds *et al.* 2004 (and King *et al.* 2005)	Population-based case-control study in Nova Scotia and Eastern Ontario, 1999-2001.	Estimated THM and HAA exposure at residence during pregnancy. Linked water consumption and showering/bathing to THM exposure.	Stillbirth.	A statistically significant association was observed between stillbirths and exposure to total THM, BDCM, and chloroform. Associations were also detected for metrics which incorporated water consumption, showering and bathing habits. Elevated relative risks were observed for intermediate exposures for total HAA and DCAA measures; TCAA and brominated HAA exposures showed no association. No statistically significant associations or dose-response relationships between any HAAs and stillbirth were detected after controlling for THM exposure.
Infante-Rivard 2004	Case-control study of newborns in Montreal, 1998-2000.	Estimated THM levels and water consumption during pregnancy. Exposure from showering and presence of two genetic polymorphisms.	Intrauterine growth retardation.	No associations were found between exposure to THMs and intrauterine growth retardation. However, a significant effect was observed between THM exposure and intrauterine growth retardation for newborns with the *CYP2E1* gene variant. Findings suggest that exposure to THMs at the highest levels can affect fetal growth but only in genetically susceptible newborns.
Wright *et al.* 2004	Large cross-sectional study: Massachusetts, 1995-1998.	Estimated maternal third-trimester exposures to TTHMs, chloroform, BDCM, total HAAs, DCA, TCA, MX and mutagenicity in drinking water.	Birth weight, small for gestational age, preterm delivery, gestational age.	Statistically significant reductions in mean birth weight were observed for BDCM, chloroform, and mutagenic activity. An exposure-response relationship was found between THM exposure and reductions in mean birth weight and risk of small for gestational age. There was no association between preterm delivery and elevated levels of HAAs, MX, or mutagenicity. A reduced risk of preterm delivery was observed with high THM exposures. Gestational age was associated with exposure to THMs and mutagenicity.
Yang 2004 (and Yang *et al.* 2000)	Large cross-sectional studies in Taiwan, 1994-1996.	Compared maternal consumption of chlorinated drinking water (yes/no).	Low birth weight, preterm delivery.	Residence in area supplied with chlorinated drinking water showed a statistically significant association with preterm delivery. No association was seen between chlorinated drinking water and low birth weight.
Fenster *et al.* 2003	Small prospective study in California, 1990-1991.	Examined TTHM levels within the 90 days preceding semen collection.	Sperm motility, sperm morphology.	No association between TTHM level and sperm mobility or morphology. BDCM was inversely associated with linearity of sperm motion. There was some suggestion that water consumption and other ingestion metrics may be associated with different indicators of semen quality.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Findings
Shaw *et al.* 2003	2 case-control maternal interview studies: CA, 1987-1991.	Estimated THM levels for mothers' residences from before conception through early pregnancy.	Neural tube defects, oral clefts, selected heart defects.	No associations or exposure-response relation were observed between malformations and TTHMs in either study.
Windham *et al.* 2003	Prospective study: CA, 1990-1991.	Estimated exposure to THMs through showering and ingestion over average of 5.6 menstrual cycles per woman.	Menstrual cycle, follicular phase length (in days).	Findings suggest that THM exposure may affect ovarian function. All brominated THM compounds were associated with significantly shorter menstrual cycles with the strongest finding for chlorodibromomethane. There was little association between TTHM exposure and luteal phase length, menses length, or cycle variability.
Wright *et al.* 2003	Cross-sectional study: Massachusetts, 1990.	Estimated TTHM exposure in women during pregnancy (average for pregnancy and during each trimester).	Birth weight, small for gestational age, preterm delivery, gestational age.	Statistically significant associations between 2nd trimester and pregnancy average TTHM exposure and small for gestational age and fetal birth weight were detected. Small, statistically significant increases in gestational duration/age were observed at increased TTHM levels, but there was little evidence of an association between TTHM and preterm delivery or low birth weight.
Cedergren *et al.* 2002	Retrospective case-control study: Sweden, 1982-1997.	Examined maternal periconceptional DBP levels and used GIS to assign water supplies.	Cardiac defects.	Exposure to chlorine dioxide in drinking water showed statistical significance for cardiac defects. THM concentrations of 10 µg/L and higher were significantly associated with cardiac defects. No excess risk for cardiac defect and nitrate were seen.
Hwang *et al.* 2002	Large cross-sectional study in Norway, 1993-1998.	Compared exposure to chlorination (yes/no) and water color levels for mother's residence during pregnancy.	Birth defects (neural tube defects, cardiac, respiratory system, oral cleft, urinary tract).	Risk of any birth defect, cardiac, respiratory system, and urinary tract defects were significantly associated with water chlorination. Exposure to chlorinated drinking water was statistically significantly associated with risk of ventricular septal defects, and an exposure-response pattern was seen. No other specific defects were associated with the exposures that were examined.
Dodds and King 2001	Population-based retrospective cohort in Nova Scotia, 1988-1995.	Estimated THM, chloroform, and bromodichloromethane (BDCM) exposure.	Neural tube defects, cardiovascular defects, cleft defects, chromosomal abnormalities.	Exposure to BDCM was associated with increased risk of neural tube defects, cardiovascular anomalies. Chloroform was not associated with neural tube defects, but was associated with chromosomal abnormalities. No association between THM and cleft defects were detected.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Findings
Jaakkola *et al.* 2001	Large cross-sectional study in Norway, 1993-1995.	Compared chlorination (yes/no) and water color (high/low) for mother during pregnancy.	Low birth weight, small for gestational age, preterm delivery.	No evidence found for association between prenatal exposure to chlorinated drinking water and low birth weight or small for gestational age. A reduced risk of preterm delivery was noted for exposure to chlorinated water with high color content.
Källén and Robert 2000	Large cross-sectional cohort study in Sweden, 1985-1994.	Linked prenatal exposure to drinking water disinfected with various methods (no chlorine, chlorine dioxide only, sodium hypochlorite only).	Gestational duration, birth weight, intrauterine growth, mortality, congenital malformations, and other birth outcomes.	A statistically significant difference was found for short gestational duration and low birth weight among infants whose mother resided in areas using sodium hypochlorite, but not for chlorine dioxide. Sodium hypochlorite was also associated with other indices of fetal development but not with congenital defects. No other effects were observed for intrauterine growth, childhood cancer, infant mortality, low Apgar score, neonatal jaundice, or neonatal hypothyroidism in relation to either disinfection method.
Dodds *et al.* 1999 (and King *et al.* 2000b)	Population-based retrospective cohort study in Nova Scotia, 1988-1995.	Estimated TTHM level for women during pregnancy.	Low birth weight, preterm birth, small for gestational age, stillbirth, chromosomal abnormalities, neural tube defects, cleft defects, major cardiac defects.	A statistically significant increased risk for stillbirths and high total THMs and specific THMs during pregnancy was detected, with higher risks observed among asphyxia-related stillbirths. Bromodichloromethane had the strongest association and exhibited an exposure-response pattern. There was limited evidence of an association between THM level and other reproductive outcomes. No congenital anomalies were associated with THM exposure, except for a non-statistically significant association with chromosomal abnormalities.
Klotz and Pyrch 1999 (and Klotz and Pyrch 1998)	Population-based case-control study in New Jersey, 1993-1994.	Estimated exposure of pregnant mothers to TTHMs and HAAs, and compared source of water.	Neural tube defects.	A significant association was seen between exposure to THMs and neural tube defects. No associations were observed for neural tube defects and haloacetic acids or haloacetonitriles.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Findings
Magnus *et al.* 1999	Large cross-sectional study in Norway, 1993-1995.	Compared chlorination (yes/no) and water color (high/low) at mothers' residences at time of birth.	Birth defects (neural tube defects, major cardiac, respiratory, urinary, oral cleft).	Statistically significant associations were seen between urinary tract defects and chlorination and high water color (high content of organic compounds). No associations were detected for other outcomes or all birth defects combined. A non-statistically significant, overall excess risk of birth defects was seen within municipalities with chlorination and high water color compared to municipalities with no chlorination and low color.
Gallagher *et al.* 1998	Retrospective cohort study of newborns in Colorado, 1990-1993.	Estimated THM levels in drinking water during third trimester of pregnancy.	Low birth weight, term low birthweight, and preterm delivery.	Weak, non-statistically significant association with low birth weight and TTHM exposure during the third trimester. Large statistically significant increase for term low birthweight at highest THM exposure levels. No association between preterm delivery and THM exposure.
Swan *et al.* 1998	Prospective study in alifornia, 1990-1991.	Compared consumption of cold tap water to bottled water during early pregnancy.	Spontaneous abortion.	Pregnant women who drank cold tap water compared to those who consumed no cold tap water showed a significant finding for spontaneous abortion at one of three sites.
Waller *et al.* 1998 (and Waller *et al.* 2001)	Prospective cohort in California, 1989-1991.	Estimated TTHM levels during first trimester of pregnancy via ingestion and showering.	Spontaneous abortion.	Statistically significant increased risk between high intake of TTHMs and spontaneous abortion compared to low intake. BDCM statistically associated with increased spontaneous abortion; other THMs not. Reanalysis of exposure yielded less exposure misclassification and relative risks similar in magnitude to earlier study. An exposure-response relationship was seen between spontaneous abortion and ingestion exposure to TTHMs.
Kanitz *et al.* 1996	Cross-sectional study in Italy, 1988-1989.	Compared 3 types of water treatment (chlorine dioxide, sodium hypochlorite, and chlorine dioxide/sodium hypochlorite).	Low birth weight, body length, cranial circumference, preterm delivery, and other effects.	Smaller body length and small cranial circumference showed statistical significant association with maternal exposure to chlorinated drinking water. Neonatal jaundice linked statistically to prenatal exposure to drinking water treated with chlorine dioxide. Length of pregnancy, type of delivery, and birthweight showed no association.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Findings
Bove *et al.* 1995 (and Bove *et al.* 1992a & 1992b)	Large cohort cross-sectional study in New Jersey, 1985-1988.	Examined maternal exposure to TTHM and various other contaminants.	Low birth weight, fetal deaths, small for gestational age, birth defects (neural tube defects, oral cleft, central nervous system, major cardiac).	Weak, statistically significant increased risk found for higher TTHM levels with small for gestational age, neural tube defects, central nervous system defects, oral cleft defects, and major cardiac defects. Some association with higher TTHM exposure and low birth weight. No effect seen for preterm birth, very low birth weight, or fetal deaths.
Savitz *et al.* 1995	Population-based case-control study: North Carolina, 1988-1991.	Examined TTHM concentration at residences and water consumption (during first and third trimesters).	Spontaneous abortion, preterm delivery, low birth weight.	There was a statistically significant increased miscarriage risk with high THM concentration, but THM intake (based on concentration times consumption level) was not related to pregnancy outcome. No associations were seen for preterm delivery or low birth weight. Water source was not related to pregnancy outcome either, with the exception of a non-significant, increased risk of spontaneous abortion for bottled water users. There was a non-statistically significant pattern of educed risk with increased consumption of water for all three outcomes.
Aschengrau *et al.* 1993	Case-control study in Massachusetts, 1977-1980.	Source of water and 2 types of water treatment (chlorination, chloramination).	Neonatal death, stillbirth, congenital anomalies.	There was a non-significant, increased association between frequency of stillbirths and maternal exposure to chlorinated versus chloraminated surface water. An increased risk of urinary track and respiratory track defects and chlorinated water was detected. Neonatal death and other major malformations showed no association. No increased risk seen for any adverse pregnancy outcomes for surface water versus ground and mixed water use.
Kramer *et al.* 1992	Population-based case-control study in Iowa, 1989-1990.	Examined chloroform, DCBM, DBCM, and bromoform levels and compared type of water source (surface, shallow well, deep well).	Low birth weight, prematurity, intrauterine growth retardation.	Statistically significant increased risk for intrauterine growth retardation effects from chloroform exposure were observed. Non-significant increased risks were observed for low birth weight and chloroform and for intrauterine growth retardation and DCBM. No intrauterine growth retardation or low birth weight effects were seen for the other THMs, and no effects on prematurity were observed for any of the THMs.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Findings
Shaw *et al.* 1991 (and Shaw *et al.* 1990)	Small case-control study: Santa Clara County, CA, 1981-1983.	Estimated chlorinated tap water consumption, mean maternal TTHM level, showering/bathing exposure at residence during first trimester.	Congenital cardiac anomalies.	Following reanalysis, no association between cardiac anomalies and TTHM level were observed.
Aschengrau *et al.* 1989	Case-control study in Massachusetts, 1976-1978.	Source of water and exposure to metals and other contaminants.	Spontaneous abortion.	A statistically significantly association was detected between surface water source and frequency of spontaneous abortion.
Reviews/Meta-analyses				
Hwang and Jakkola 2003	Review and meta-analysis of 5 studies.	Compared DBP levels, source of water, chlorine residual, color (high/low), and 2 types of disinfection: chlorination and chloramination.	Birth defects (respiratory system, urinary system, neural tube defects, cardiac, oral cleft).	The meta-analysis supports an association between exposure to chlorination by-products and the risk of any birth defect, particularly the risk of neural tube defects and urinary system defects.
Bove *et al.* 2002	Qualitative review of 14 studies.	Examined THM levels. Compared drinking water source and type of water treatment.	Birth defects, small for gestational age, low birth weight, preterm delivery, spontaneous abortion, fetal death.	Review found the studies of THMs and adverse birth outcomes provide moderate evidence for associations with small for gestational age, neural tube defects, and spontaneous abortions. Authors felt risks may have been underestimated and exposure-response relationships distorted due to exposure misclassification.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Findings
Graves *et al.* 2001	Review of toxicological and epidemiological studies using a weight of evidence approach.	Examined water consumption, duration of exposure, THM levels, HAA levels, and other contaminants. Compared source of water, water treatment, water color (high/low), etc.	Low birth weight, preterm delivery, small for gestational age, intrauterine growth retardation, specific birth defects, neonatal death, decreased fertility, fetal resorption, and other effects.	Weight of evidence suggested positive association with DBP exposure for growth retardation such as small for gestational age or intrauterine growth retardation and urinary tract defects. Review found no support for DBP exposure and low birth weight, preterm delivery, some specific birth defects, and neonatal death, and inconsistent findings for all birth defects, all central nervous system defects, neural tube defects, spontaneous abortion, and stillbirth.
Villanueva *et al.* 2001	Qualitative review of 14 reproductive and developmental health effect studies.	Compared exposure to TTHM levels, mutagenic drinking water, water consumption, source water, types of disinfection (chlorination and chloramination), and residence times.	Spontaneous abortion, low birth weight, small for gestational age, neural tube defects, other reproductive and developmental outcomes.	Review found positive associations between increased spontaneous abortion, low birth weight, small for gestational age, and neural tube defects and drinking chlorinated water in most studies although not always with statistical significance.
Nieuwenhuijsen *et al.* 2000	Qualitative review of numerous toxicological and epidemiological studies.	Examined levels of various DBPs, water consumption, and duration of exposure. Compared water color, water treatment, source of water, etc.	Low birth weight, preterm delivery, spontaneous abortions, stillbirth, birth defects, etc.	The review supports some evidence of association between THMs and low birth weight, but inconclusive. Review found no evidence of association between THMs and preterm delivery, and that associations for other outcomes (spontaneous abortions, stillbirth, and birth defects) were weak but gaining weight.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Findings
Reif *et al.* 2000	Qualitative reviews of numerous epidemiological studies.	Compared source of water supply and methods of disinfection. Estimated TTHM levels.	Birth weight, low birth weight, intrauterine growth retardation, small for gestational age, preterm deliver, somatic parameters, neonatal jaundice, spontaneous abortion, stillbirth, developmental anomalies.	Weight of evidence suggested DBPs are reproductive toxicants in humans under appropriate exposure conditions. The review reports findings between TTHMs and effects on fetal growth, fetal viability, and congenital anomalies as inconsistent. Reviewers felt data are at the stage of hazard identification and did not suggest a dose-response pattern of increasing risk with increasing TTHM concentration.
WHO 2000	Qualitative reviews of various studies in Finland, U.S., and Canada.	Various exposures to THMs.	Various reproductive and developmental effects.	Review found some support for an association between increased risks of neural tube defects and miscarriage and THM exposure. Other associations have been observed, but the authors believed insufficient data exists to assess any of these associations.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Findings
Craun, ed. 1998	Qualitative review of 10 studies, focus on California cohort study.	Examined THM levels and water consumption, and compared source of water and water treatment (chlorine, chloramines, chlorine dioxide).	Stillbirth, neonatal death, spontaneous abortion, low birth weight, preterm delivery, intrauterine growth retardation, neonatal jaundice, birth defects.	Associations between DBPs and various reproductive effects were seen in some epidemiological studies, but the authors felt these results do not provide convincing evidence for a causal relationship between DBPs and reproductive effects.
Mills *et al.* 1998	Qualitative review of 22 studies.	Examined TTHM levels and water consumption. Compared source of water and 2 types of water treatment (chlorination and chloramination).	Various reproductive and developmental effects.	Review found studies suggest possible increases in adverse reproductive and developmental effects, such as increased spontaneous abortion rates, small for gestational age, and fetal anomalies, but that insufficient evidence exists to establish a causal relationship.

Author(s)	Study Type	Exposure(s) Studied	Outcome(s) Measured	Findings
Reif *et al.* 1996	Review of 3 case-control studies and 1 cross-sectional study.	Examined THM levels at residences, dose consumption, chloroform. Compared source of waters and 2 types of water treatment (chlorination and chloramination).	Birth defects (central nervous system, neural tube defects, cardiac, oral cleft, respiratory, urinary tract), spontaneous abortion, low birth weight, growth retardation, preterm delivery, intrauterine growth retardation, stillbirth, neonatal death.	Studies reviewed suggest that exposure to DBPs may increase intrauterine growth retardation, neural tube defects, major heart defects, and oral cleft defects. Review found epidemiologic evidence supporting associations between exposure to DBPs and adverse pregnancy outcomes to be sparse and to provide an inadequate basis to identify DBPs as a reproductive or developmental hazard.
Swan *et al.* 1992	Qualitative review of 5 studies in Santa Clara County, CA (Deane *et al.* 1992, Wrensch *et al.* 1992, Hertz-Picciotto *et al.* 1992, Windham *et al.* 1992, Fenster *et al.* 1992).	Compared maternal consumption of residence tap water to bottled water.	Spontaneous abortion.	Four of the studies reviewed suggest that women drinking bottled water during the first trimester of pregnancy may have reduced risk of spontaneous abortion relative to drinking tap water. No association seen in the fifth study. Review concluded that if findings are causal and not due to chance or bias, data suggest a 10-50% increase in spontaneous abortion risk for pregnant women drinking tap water over bottled water.

Critical review of epidemiology literature by Reif et al. (2000)

Reif et al. (2000) conducted a critical review of the epidemiology literature pertaining to potential reproductive and developmental effects of exposure to DBPs in drinking water. Reif presented much of this data during the FACA process and the critical review of the literature was important in this process. The review included 16 peer-reviewed scientific manuscripts and published reports of which 10 were previously discussed in the Stage 1 DBPR. The authors evaluated associations between DBPs and outcomes grouped as effects on (1) fetal growth (birth weight [as a continuous variable]; low birth weight [defined as <2,500 grams]; term low birth weight [defined as <2,500 grams]; very low birth weight [defined as <1,500 grams]; preterm delivery [defined as <37 weeks of gestation] and intrauterine growth retardation [or decreased rate of growth of the fetus]); (2) fetal viability (spontaneous abortion and stillbirth); and, (3) risk of fetal malformations (all malformations, oral cleft defects, major cardiac defects, neural tube defects, and chromosomal abnormalities).

Reif et al. (2000) found mixed evidence in the epidemiological literature they reviewed for associations between DBPs and effects on fetal growth. Studies using TTHM concentrations reached differing conclusions. Some studies found weak but statistically significant associations (Gallagher et al. 1998, Bove et al. 1992b, Bove et al. 1995), but two found none (Dodds et al. 1999, Savitz et al. 1995). Studies with qualitative exposure assessment designs are similarly variable in their findings (Kanitz et al. 1996, Källén and Robert 2000, Yang et al. 2000).

For effects on fetal viability, the authors reported that some evidence exists for an increased risk of spontaneous abortion and stillbirth. Increased rates of spontaneous abortion associated with TTHM levels of 75 µg/L or more were reported by Waller et al. (1998). Aschengrau et al. (1989) reported a doubling of risk of spontaneous abortion for exposure to surface water compared to ground and mixed water. Although Savitz et al. (1995) found an association between high levels of THMs and spontaneous abortion, no relationship with dose or water source was discovered. As discussed previously, an increased risk of stillbirth was found to be associated with THM and BDCM exposure (Dodds et al. 1999, King et al. 2000b). Aschengrau et al. (1993) found an association between stillbirth and the use of chlorinated versus chloraminated water systems. A weak association was found for the use of surface water systems and risk of stillbirth, but these authors found little evidence for an association between TTHM and risk of stillbirth (Bove et al. 1992a, Bove et al. 1995).

For congenital abnormalities related to DBP exposure, Reif et al. (2000) reported that the relatively few studies available in the technical literature provide an inconsistent pattern both in terms of associating exposure with the occurrence of anomalies in general, and with respect to identifying specific anomalies that result from exposure. The authors conceded that an assessment of congenital anomalies is difficult due to the small number of cases available for evaluation and possible selection bias due to elective terminations of pregnancy. In addition, the authors stated that (1) categorizing defects may yield etiologically dissimilar aggregations and may dilute the estimated risk; (2) at higher DBP concentrations, multiple or lethal defects may be induced and the outcomes may be expressed as spontaneous abortion or stillbirth, or cause unrecognized fetal loss; and (3) cases with recognized, single anomalies may represent only a portion of the full range of the potential effects.

Reif et al. provide several possible explanations for the discrepancies and inconsistencies between the epidemiologic studies: (1) substantial differences existed between methods of exposure assessment and, in some cases, definition of the outcome; (2) referent groups varied across studies; (3) the composition of DBP mixtures may have varied across locales and studies; and (4) other classes of DBPs may be the causal agents and THMs may or may not be an appropriate exposure indicator for those DBPs. Exposure misclassification in the studies may either hide a true effect or, in rare circumstances, create an artificial effect.

Reif et al. also reviewed the epidemiology literature for dose-response relationships. The researchers did not find a continuous pattern of increasing risk with increasing concentration of TTHM, but they did observe a general trend of small increases in risk for concentrations of TTHM greater than 100 µg/L.

Based on information provided in the literature, Reif et al. estimated PAR for each outcome in each study. Appendix E provides a detailed discussion of the derivation of PAR values from epidemiological studies and their use in risk and benefits assessments.

Reif et al. explored the difference in potential health risk across TTHM thresholds of 80 and 60 µg/L. ORs with 95 percent confidence intervals from various studies are compared in Exhibit 6.14 and PAR values with 95 percent confidence intervals (truncated at zero to represent biological relevance) from various studies are compared in Exhibit 6.15. The distribution of exposure levels differed among the studies, but when normalized in this way the studies appear to provide some support for establishing a threshold level for TTHM. The point estimate of PAR in Exhibit 6.15 are generally higher when 60 µg/L is used as the cut-point rather than 80 µg/L. This seems to indicate that an important reduction in disease occurrence may be obtained by eliminating not only TTHM exposure levels above 80 µg/L, but also levels between 60 µg/L and 80 µg/L. The authors note that this conclusion is tentative because many of the 95 percent confidence intervals on the ORs were very wide and extended to values of one and lower. Moreover, they suggest caution when interpreting the PAR values and note that "[s]ince a number of assumptions regarding attributable fraction do not appear to hold, population attributable risks are unlikely to be useful with the current data set."

The findings for low birth weight are varied and do not strongly support a threshold of 80 or 60 µg/L. Reif et al. noted that the higher outcomes in the Gallagher et al. (1998) study may result from decreased non-differential misclassification (a type of bias) by taking spatial variability into account. Also, the DBP mixture may have been different from the mixtures used in other studies. There does not appear to be an increased association between TTHM and intrauterine growth retardation or preterm birth above the thresholds in question, based on the findings presented in Exhibit 6.14. The Waller et al. (1998) study presents higher ORs for spontaneous abortions than Savitz et al. (1995). The ORs for spontaneous abortion varied from region to region, possibly due to a difference in concentrations of BDCM and other byproducts (Waller et al. 1998). The ORs for neural tube defects were generally higher than for other defects above both thresholds. There was no strong evidence of increased risk, however, for oral cleft defects or major cardiac defects (the ORs for both defects, based on Bove et al. (1995), were high). Overall, the ORs across the 60 and 80 µg/L thresholds were similar, but tended to be slightly higher for 80 µg/L.

Exhibit 6.14 Odds Ratios (and 95 Percent Confidence Intervals [1]) Calculated by Reif et al. (2000) for Reproductive and Developmental Health Endpoints at TTHM Levels of > 80 µg/L versus < 80 µg/L and > 60 µg/L versus < 60 µg/L

Health Endpoint	Dodds et al. (1999)	Bove et al. (1995)	Klotz and Pyrch (1998)	Savitz et al. (1995)	Waller et al. (1998)	Gallagher et al. (1998)
> 80 µg/L versus < 80 µg/L TTHM						
Low Birth Weight	1.09 (0.99,1.19)	1.20 (1.02,1.41)	N/A	1.01 (0.69,1.50)	N/A	N/A
Intrauterine Growth Retardation	1.05 (0.98,1.12)	1.12 (1.03,1.22)	N/A	N/A	N/A	N/A
Preterm Birth	1.01 (0.92,1.10)	1.09 (0.99,1.19)	N/A	0.74 (0.51,1.07)	N/A	N/A
Spontaneous Abortion	N/A	N/A	N/A	1.06 (0.63,1.78)	1.29 (0.98,1.69)	N/A
Stillbirths	1.59 (1.21,2.10)	0.65 (0.45,0.95)	N/A	N/A	N/A	N/A
Neural Tube Defects	1.37 (0.88,2.15)	2.12 (1.00,4.49)	1.35 (0.65,2.79)	N/A	N/A	N/A
Oral Cleft Defects	1.01 (0.63,1.63)	1.95 (0.87,2.90)	N/A	N/A	N/A	N/A
Major Cardiac Defects	0.87 (0.70,1.08)	1.59 (0.87,2.90)	N/A	N/A	N/A	N/A
> 60 µg/L versus < 60 µg/L TTHM						
Low Birth Weight	1.06 (0.98,1.16)	1.07 (0.96,1.18)	N/A	1.35 (0.90,2.01)	N/A	2.24 (1.03,4.88)
Intrauterine Growth Retardation	1.05 (0.99,1.12)	1.04 (0.99,1.09)	N/A	N/A	N/A	N/A
Preterm Birth	0.98 (0.91,1.06)	0.96 (0.91,1.02)	N/A	1.01 (0.71,1.44)	N/A	N/A
Spontaneous Abortion	N/A	N/A	N/A	0.97 (0.56,1.67)	1.22 (0.98,1.53)	N/A
Stillbirths	1.56 (1.18,2.06)	0.80 (0.65,0.97)	N/A	N/A	N/A	N/A
Neural Tube Defects	1.01 (0.66,1.56)	1.34 (0.76,2.38)	1.79 (1.08,2.95)	N/A	N/A	N/A
Oral Cleft Defects	0.91 (0.59,1.40)	1.25 (0.78,2.02)	N/A	N/A	N/A	N/A
Major Cardiac Defects	0.94 (0.78,1.14)	0.93 (0.59,1.45)	N/A	N/A	N/A	N/A

Notes: [1]Lower confidence limit is truncated at zero
N/A indicates that data for that health endpoint was not presented in the study.

Source: Adapted from Reif et al. (2000).

Exhibit 6.15 PAR Values (and 95 Percent Confidence Intervals [1]) Calculated by Reif et al. (2000) for Reproductive and Developmental Health Endpoints at TTHM Levels of > 80 µg/L versus < 80 µg/L and > 60 µg/L versus < 60 µg/L (Values are Percentages)

Health Endpoint	Dodds et al. (1999)	Bove et al. (1995)	Klotz and Pyrch (1998)	Savitz et al. (1995)	Waller et al. (1998)	Gallagher et al. (1998)
> 80 µg/L versus < 80 µg/L TTHM						
Low Birth Weight	2.4% (0,4.9)	1.5% (0.1,2.9)	N/A	0.5% (0,13.1)	N/A	N/A
Intrauterine Growth Retardation	1.3% (0,3.1)	0.9% (0.2,1.6)	N/A	N/A	N/A	N/A
Preterm Birth	0.2% (0,2.2)	0.7% (0,1.5)	N/A	N/A	N/A	N/A
Spontaneous Abortion	N/A	N/A	N/A	1.9% (0,18.2)	4.5% (0,9.5)	N/A
Stillbirths	14.1% (4.6,22.7)	N/A	N/A	N/A	N/A	N/A
Neural Tube Defects	9.8% (0,23.3)	7.6% (0,17.0)	3.0%(0,10.2)	N/A	N/A	N/A
Oral Cleft Defects	0.4% (0,13.1)	6.4% (0,13.9)	N/A	N/A	N/A	N/A
Major Cardiac Defects	N/A	4.1% (0,10.2)	N/A	N/A	N/A	N/A
> 60 µg/L versus < 60 µg/L TTHM						
Low Birth Weight	3.2% (0,7.3)	1.8% (0,4.6)	N/A	18.8% (0,39.0)	N/A	6.4% (0,14.1)
Intrauterine Growth Retardation	2.7% (0,5.8)	1.0% (0,2.4)	N/A	N/A	N/A	N/A
Preterm Birth	N/A	N/A	N/A	0.7% (0,20.4)	N/A	N/A
Spontaneous Abortion	N/A	N/A	N/A	N/A	6.5% (0,13.6)	N/A
Stillbirths	22.5% (7.7,34.9)	N/A	N/A	N/A	N/A	N/A
Neural Tube Defects	0.5% (0,20.0)	7.8% (0,22.5)	14.1% (1,25.5)	N/A	N/A	N/A
Oral Cleft Defects	N/A	5.9% (0,18.0)	N/A	N/A	N/A	N/A
Major Cardiac Defects	N/A	N/A	N/A	N/A	N/A	N/A

Notes: [1]Lower confidence limit is truncated at zero
N/A indicates that data for that health endpoint were not presented in the study. Note that Reif et al. (2000) did not present PAR values for effects where the OR as shown in Exhibit 6.14 was < 1 (PAR considered by the authors in those cases as undefined).
Source: Adapted from Reif et al. (2000).

Critical review of epidemiology literature by Bove et al. (2002)

Bove et al. (2002) conducted a qualitative review of 14 reproductive and developmental epidemiology studies on exposure to chlorination byproducts in drinking water (many studies are the same as those reviewed by Reif et al. [2000]). Endpoints reviewed include small size for gestational age, birth defects (e.g., neural tube defects, cleft defects, and cardiac effects), and spontaneous abortions.

Studies that evaluated the end point of "small for gestational age" were limited due to lack of adequate exposure information and low study participation rate. Studies conducted in Denver (Gallagher et al. 1998), northern New Jersey (Bove et al. 1995), central North Carolina (Savitz et al. 1995), and Nova Scotia (Dodds et al. 1999) based their exposure estimates on tap water samples of THMs taken concurrently with the pregnancy period. However, only one study (Gallagher et al. 1998) involved modeling the distribution system characteristics and matching the residence with the appropriate sample location; this likely minimized exposure misclassification, and further strengthened the relationship found in the Denver study between TTHM and small for gestational age (OR = 5.9; no confidence intervals reported).

Bove et al. (2002) believed that there was some consistency in the findings for neural tube defects and oral cleft defects, but not for cardiac defects. In the two studies that evaluated neural tube defects and individual THMs, one obtained similar associations for neural tube defects for chloroform and BDCM (Klotz and Pyrch 1998), while the other study found a much stronger association with BDCM (Dodds and King 2001). Of the two studies that evaluated oral cleft defects and levels of THMs, one found an association with TTHM (Bove et al. 1995) and the other found an association with chloroform, but not TTHM (Dodds and King 2001).

The California prospective cohort study (Waller et al. 1998) found a correlation between spontaneous abortion and specific THMs, especially BDCM. An association was also reported for spontaneous abortion when TTHM levels were evaluated, but this relationship disappeared when water consumption habits were taken into account. Bove et al. (1995) noted that this study's low participation rate was a notable weakness. In addition, because the maternal interviews were conducted after the loss had occurred, the potential for recall bias in water consumption habits during pregnancy was introduced. A Massachusetts study (Aschengrau et al. 1993) found no excess spontaneous abortion correlating with treatment type (i.e., chlorination vs. chloramination), but significant effects were found for water source (surface water, ground water).

Bove et al. (2002) evaluated three studies on the incidence of fetal deaths and THM levels that had very different results. The Nova Scotia study (Dodds and King 2001) found a strong association, especially with BDCM levels. In contrast, the northern New Jersey study (Bove et al. 1995) could not evaluate the individual THM levels or information on the cause of death. Therefore, its finding of no excess could be the result of misclassification biases due to the failure to evaluate individual THMs and specific causes of death. The Massachusetts study (Aschengrau et al. 1993) found an association between stillbirths and chlorinated surface water when compared with chloraminated surface water.

Critical review of epidemiology literature by Nieuwenhuijsen et al. (2000)

Nieuwenhuijsen et al. (2000) reviewed the toxicological and epidemiological literature and evaluated the potential risk of chlorination DBPs on human reproductive health. The authors reviewed 10 epidemiological studies according to the exposure measure used: water source and water treatment, routinely collected measurements of THMs, and routinely collected THM measurements and estimation of individual THM ingestion. The authors commented that assessment of exposure is one of the weakest aspects of the available epidemiological studies.

The authors concluded that the evidence from a small number of studies suggests a weak association for spontaneous abortions, stillbirths, and birth defects, and the weight of evidence for a stronger association is increasing as more quality studies are completed. Nieuwenhuijsen et al. concluded that, "although studies report small risks that are difficult to interpret, the large number of people exposed to chlorinated water supplies constitutes a public health concern."

Critical review of epidemiology literature by Graves et al. (2001)

Graves et al. (2001) considered the toxicological and epidemiological evidence for various reproductive and developmental effects based on outcome, using a weight-of-evidence procedure. The studies included in the review examined water consumption, duration of exposure, THM levels, HAA levels, and presence of other contaminants. Many compared source water type, water treatment method, water color (high/low), and other physical properties. Endpoints which the authors found that the weight of evidence showed no association included low birth weight (5 articles), very low birth weight (2 articles), preterm delivery (7 articles), cesarean delivery (1 article), congenital anomalies by severity (1 article), spina bifida (1 article), cleft lip and palate (4 articles), cardiac anomalies (4 articles), gastrointestinal anomalies (1 article), genital anomalies (1 article), integument anomalies (1 article), musculoskeletal anomalies (1 article), chromosomal abnormalities (1 article), and neonatal death (1 article). Endpoints which the authors found that the weight of evidence showed mixed, inconsistent or weak results included neonatal jaundice (1 article), all congenital anomalies/birth defects (3 articles), all CNS anomalies (2 articles), neural tube defects (4 articles), respiratory anomalies (2 articles), SAB/miscarriage (3 articles), and stillbirth/fetal death (4 articles). Those endpoints that were suggestive of an association included growth retardation including term low birth weight (3 articles), IUGR or SGA (3 articles), and small body length and cranial circumference (1 article), and urinary tract defects (2 articles). The authors note that the exposure characterization in the epidemiological studies to may not be adequate to show an association of small magnitude. The authors also caution the use of quarterly or routine monitoring of THMs matched to maternal residence as a representation of exposure.

Critical review of the epidemiology literature by Hwang and Jaakkola (2003)

Hwang and Jaakkola (2003) reviewed epidemiological studies for birth defects and performed a meta-analysis of the studies which provided estimates of exposure on one or more birth defects. The review presented studies including the following endpoints: any birth defect (3 studies), neural tube defect (4 studies), major cardiac effect (3 studies), respiratory defect (2 studies), oral cleft defect (3 studies), and urinary system defect (2 studies). The meta-analysis supports an association between exposure to chlorination by-products and the risk of any birth defect, particularly the risk of neural tube defects and urinary system defects. Results for cardiac defects, respiratory defects, and oral clefts were inconsistent.

EPA's epidemiology research program

EPA's epidemiology research program continues to examine the relationship between exposure to DBPs and adverse developmental and reproductive effects. The Agency is supporting several studies using improved study designs to provide better information for characterizing potential risks.

6.2.2.2 Toxicological Evidence of Adverse Reproductive and Developmental Health Effects

EPA has evaluated published studies of the potential adverse effects of DBPs on the reproductive and developmental health of laboratory animals. Especially pertinent information comes from reviews of the toxicology literature by Dr. Rochelle Tyl (2000): "Review of Animal Studies for Reproductive and Developmental Toxicity Assessment of Drinking Water Contaminants: DBPs" and by the World Health Organization (2000): "Environmental Health Criteria 216: Disinfectants and Disinfection Byproducts."

Review of Tyl (2000)

Tyl evaluated the literature using the EPA developmental (USEPA 1991b) and reproductive (USEPA 1996d) toxicity risk assessment guidelines. Tyl presented this critical review during the FACA process, and the analysis was important in deliberations. Tyl focused her analysis on making determinations regarding hazard identification (that is, identifying the specific types of adverse effects caused by these substances) and the adequacy of data from the available studies to support the development of dose-response assessments.

Exhibit 6.16, adapted and updated from Tyl (2000), lists the types of reproductive and developmental toxicology studies that have been performed for various disinfectants and specific DBPs. In Exhibit 6.16, the study types are classified as either screening studies or as dose-response studies.

Tyl concluded, based upon a weight-of-evidence approach to the analysis of the available, relevant literature, that "some of the DBPs have the intrinsic capacity to do harm, specifically to the developing conceptus and the male (and possibly the female) reproductive system." Specific reproductive and developmental hazards that have been identified and associated with exposure to various DBPs are summarized in Exhibit 6.17.

Notwithstanding the evidence supporting the identification of developmental and reproductive effects from DBP exposure, Tyl also concluded that the weight of evidence does not support a dose-response evaluation based on existing studies. (She notes as "one possible exception" the 1996 Chemical Manufacturers Association's two-generation rat study on chlorite.)

Tyl also noted in her summary and conclusions that in a review of animal literature for the purpose of risk assessment, "biological plausibility" is a major concern. Tyl pointed to several aspects of both the *in vitro* and *in vivo* studies that support the biological plausibility that DBPs can cause adverse reproductive and developmental effects. In particular, there was an observed temporal relationship between the exposures in toxicological studies and the occurrence of the developmental (e.g., embryonic neural tube, embryonic heart) or reproductive process (e.g., spermatogenesis). The observed effects were reproducible in the same or similar study designs. The effects were consistent across study designs. The effects observed in animal toxicological studies were comparable to those observed in some human epidemiological studies (e.g., embryonic heart and neural tube defects, full litter resorption/miscarriage, spontaneous abortion, or stillbirth).

Exhibit 6.16 Availability of Reproductive and Developmental Toxicology Studies for Specific DBPs

Disinfectant or DBP	Screens - Hazard Identification					Dose Response	
	WEC	NTP 35 Day	CKA	CKA++	Male Repro	Seg II	Multi-GEN
DISINFECTANTS							
Chlorine						X	
Chlorine Dioxide					X	X	
Chloramine						X	
TRIHALOMETHANES							
Chloroform	X				X	X	X
Bromoform			X			X	X
Bromodichloromethane		X	X		X	X	X
Dibromochloromethane		X				X	
HALOACETIC ACIDS							
Monochloroacetic acid	X					X	
Dichloroacetic acid	X				X	X	
Trichloroacetic acid	X				X	X	
Monobromoacetic acid	X				X	X	
Dibromoacetic acid	X	X	X		X	X	X
Tribromoacetic acid	X	X					
Bromochloroacetic acid	X	X			X		P
Bromodichloroacetic acid	X						
Dibromochloroacetic acid	X	X					
HALOACETONITRILES							
Chloroacetonitrile			X				
Dichloroacetonitrile				X		X	
Trichloroacetonitrile			X			X	
Bromoacetonitrile		X				X	
Dibromoacetonitrile		X		X			
Tribromoacetonitrile							
Bromochloroacetonitrile			X			X	
ALDEHYDES							
Formaldehyde	X		X			X	X
Acetaldehyde	X					X	
Propanal			X			X	
MISCELLANEOUS							
1,1-Dichloropropanone			X				
Hexachloropropanone		X					
Dichloromethane	X						
Dibromomethane	X						
MX	X					X	
Bromate		X					
Chlorite					X	X	X

Notes: X = Completed and published in the literature; P = In planning stage; WEC = Whole embryo culture; NTP 35 Day = NTP 35-day reproductive/ developmental toxicity screen; CKA = Chernoff-Kavlock Assay; CKA (++) = Chernoff-Kavlock Assay (modified); Male Repro. = Short-term adult male reproductive toxicity screen; Seg II = Segment II developmental toxicity study; Multi-GEN = Multigeneration reproductive toxicity study.

Source: Adapted and updated from Tyl (2000).

Exhibit 6.17 Reproductive and Developmental Health Effects Associated with DBPs in Toxicological Studies

Type of Effect	DBP
Developmental defects	Trichloroacetic acid (TCAA), dichloroacetic acid (DCAA), and monochloroacetic acid (MCAA)
Whole litter resorption (miscarriage/spontaneous abortion)	Chloroform, bromoform, bromodichloromethane (BDCM), dibromochloromethane (DBCM), DCAA, TCAA, dichloroacetonitrile (DCAN), and trichloroacetonitrile (TCAN)
Fetotoxicity (reduced fetal body weights, increased anomalies like chromosomal defects)	Chloroform, BDCM, DBCM, DCAA, TCAA, DCAN, TCAN, dibromoacetonitrile (DBAN), bromochloroacetonitrile (BCAN), monochloroacetonitrile (MCAN) acetaldehyde, formaldehyde
Male reproductive defects	DCAA, dibromoacetic acid (DBAA), BDCM, formaldehyde

Source: Adapted from Tyl (2000).

Critical Review of Toxicological Literature by Graves et al. (2001)

As described in the prior section 6.2.2.1 on epidemiological evidence**,** Graves, et al. conducted a weight of evidence analysis on epidemiologic and toxicologic studies of the association between DBPs and reproductive or developmental effects. Study results for the epidemiological and toxicological weight of evidence analyses were combined and are explained in summary form in section 6.2.2.1.

The authors noted that the toxicological data support that normal exposure to DBPs through tap water would generally not cause "adverse effects," however, for the effects listed as suggestive of positive associations or producing mixed, inconsistent, or weak results, further epidemiological research is warranted. One problem highlighted by the authors is that the current literature lacks accurate or detailed exposure assessment data. Accurate measurement of consumption (and exposure through dermal contact and inhalation) is needed, along with information on the DBP components of the drinking (or bathing) water. Alternatively, the authors indicate that when biomarkers are developed, they will potentially provide information on individual exposure.

Review of WHO (2000)

The International Programme on Chemical Safety (IPCS) of the World Health Organization (WHO) published an evaluation of Disinfectants and DBPs in its Environmental Health Criteria monograph series (WHO 2000). In this review of the toxicology data on reproductive and developmental effects from DBP exposure, the WHO concludes that although the data on these effects are not as robust as the cancer database, these effects are of potential health concern. They also conclude that reproductive effects in females have been principally embryolethality and fetal resorptions associated with the haloacetonitriles (HANs) and the dihaloacetates, while DCAA and DBAA have both been associated with adverse effects on male reproduction, including testicular toxicity and spermatoxic effects.

New Toxicology Data Since the Stage 1 DBPR

Since promulgating the Stage 1 DBPR, more research on DBPs is underway at EPA and other research institutions. For more information, on-going studies may be found on EPA's DRINK website (http://www.epa.gov/safewater/drink/intro.html). Summaries of new studies are provided below.

Chen et al. (2003) studied the in vitro effect of bromodichloromethane on chorionic gonadotropin (CG) secretion by human placental trophoblast cultures. Exposure to bromodichloromethane caused a significant dose-dependent decrease in the secretion of immunoreactive and bioactive CG. The lowest concentration that produced a statistically significant response was 0.02 μM, the lowest concentration tested. Chen et al. (2004) also reported that addition of 0.02 to 2 mM of bromodichloromethane inhibited morphological differentiation of human mononucleated cytotrophoblast cells to multinucleated syncytiotrophoblast-like colonies. The significance of the findings reported by Chen et al. (2003, 2004) for human health is that placental trophoblasts are the sole source of CG during normal human pregnancy and play a major role in the maintenance of the conceptus.

Christian et al. (2001) conducted a developmental toxicity study with pregnant New Zealand White rabbits exposed to BDCM in drinking water at concentrations of 0, 15, 150, 450, and 900 parts per million (ppm) in drinking water on gestation days 6-29. The No-Observed-Adverse-Effect-Level (NOAEL) and Lowest-Observed-Adverse-Effect-Level (LOAEL) identified for maternal toxicity in this study were 13.4 milligrams per kilogram per day (mg/kg-day) (150 ppm) and 35.6 mg/kg-day (450 ppm), respectively, based on decreased body weight gain. The developmental NOAEL was 55.3 mg/kg-day (900 ppm) based on the absence of statistically significant, dose-related effects at any tested concentration. Christian et al. also conducted a developmental study of BDCM in a second species, Sprague-Dawley rats. Rats were exposed to BDCM in the drinking water at concentrations of 0, 50, 150, 450, and 900 ppm on gestation days 6 to 21. The concentration-based maternal NOAEL and LOAEL for this study were 150 ppm and 450 ppm, respectively, based on statistically significant, persistent reductions in maternal body weight and body weight gains. Based on the mean consumed dosage of bromodichloromethane, these concentrations correspond to doses of 18.4 mg/kg-day and 45.0 mg/kg-day, respectively. The concentration-based developmental NOAEL and LOAEL were 450 ppm and 900 ppm, respectively, based on a significantly decreased number of ossification sites per fetus for the forelimb phalanges (bones of the hand) and the hindlimb metatarsals and phalanges. These concentrations correspond to mean consumed doses of 45.0 mg/kg-day and 82.0 mg/kg-day, respectively.

Christian et al. (2002a) summarized the results of a two-generation reproductive toxicity study on bromodichloromethane conducted in Sprague-Dawley (SD) rats. Bromodichloromethane was continuously provided to test animals in the drinking water at concentrations of 0, 50, 150, or 450 ppm. Average daily doses estimated for the 50, 150 and 450 ppm concentrations were reportedly 4.1 to 12.6, 11.6 to 40.2, and 29.5 to 109 mg/kg-day, respectively. The parental NOAEL and LOAEL were 50 and 150 ppm, respectively, based on statistically significant reduced body weight and body weight gain; F1 and F2 generation pup body weights were reduced in the 150 and 450 ppm groups during the lactation period after the pups began to drink the water provided to the dams. Body weight and body weight gain were also reduced in the 150 and 450 ppm F1 generation males and females. A marginal effect on estrous cyclicity was observed in F1 females in the 450 ppm exposure group. Small ($\leq$6 percent), but statistically significant, delays in F1 generation sexual maturation occurred at 150 ppm (males) and 450 ppm (males and females) as determined by timing of vaginal patency or preputial separation. The study authors considered these effects to be a secondary response associated with reduced body weights cause appears to be dehydration brought about by taste aversion to the compound. The results of this study identify NOAEL and LOAEL values for reproductive effects of 50 ppm (4.1 to 12.6 mg/kg-day) and 150 ppm (11.6 to 40.2 mg/kg-day), respectively, based on delayed sexual maturation.

Bielmeier et al. (2001) conducted a series of experiments to investigate the mode of action in bromodichloromethane-induced full litter resorption (FLR). The study included a strain comparison of F344 and SD rats. In the strain comparison experiment, female SD rats (13 to 14/dose group) were dosed with 0, 75, or 100 mg/kg-day by aqueous gavage in 10 percent Emulphor® on GD 6 to 10. F344 rats (12 to 14/dose group) were dosed with 0 or 75 mg/kg-day administered in the same vehicle. The incidence of FLR in the bromodichloromethane-treated F344 rats was 62 percent, while the incidence of FLR in SD

rats treated with 75 or 100 mg/kg-day of bromodichloromethane was 0 percent. Both strains of rats showed similar signs of maternal toxicity, and the percent body weight loss after the first day of dosing was comparable for SD rats and the F344 rats that resorbed their litters. The rats were allowed to deliver and pups were examined on postnatal days 1 and 6. Surviving litters appeared normal and no effect on post-natal survival, litter size, or pup weight was observed. The series of experiments conducted by Bielmeier et al. identified a LOAEL of 75 mg/kg-day (the lowest dose tested) based on FLR in F344 rats. A NOAEL was not identified. Mechanistic studies reported by Bielmeier et al. indicate that BDCM-induced pregnancy loss is likely to be luteinizing hormone (LH)-mediated (Bielmeier et al. 2004). In this more recent study, Bielmeier et al. hypothesizes that BDCM alters LH levels by disrupting the hypothalamic-pituitary-gonadal axis or by altering the responsiveness of the corpora lutea to LH. These possible mechanisms are potentially relevant to pregnancy maintenance in humans, EPA believes the finding of BDCM-induced pregnancy loss in F344 rats is relevant to risk assessment, and may provide insight into the epidemiological finding of increased risk of spontaneous abortion associated with consumption of BDCM (Waller et al. 1998, 2001).

Christian et al. (2002b) performed a two-generation drinking water study of DBAA in rats. Male and female Sprague-Dawley rats (30/sex/exposure group) were administered DBAA in drinking water at concentrations of 0, 50, 250, or 650 ppm continuously from initiation of exposure of the parental (P) generation male and female rats through weaning of the F_2 offspring. Based on testicular histomorphology indicative of abnormal spermatogenesis in P and F_1 males, the parental and reproductive/developmental toxicity LOAEL and NOAEL are 250 and 50 ppm, respectively.

Previous studies by EPA have reported adverse effects of DBAA, administered via oral gavage, on spermatogenesis that impacted male fertility (Linder et al. 1994, 1995, 1997) at doses comparable to those achieved in the Christian et al. (2002b) study. Based on these studies collectively, DBAA is spermatotoxic. Moreover, Veeramachaneni et al. (2000) reported in an abstract that sperm from male rabbits exposed to DBA *in utero* from gestation days 15 and throughout life reduced the fertility of artificially inseminated females as evidenced by reduced conceptions. When published, this study may support the evidence that DBA is a male reproductive system toxicant.

In addition, research on DBAA by Klinefelter et al. (2001) has demonstrated statistically significant delays in both vaginal opening and preputial separation using the body weight on the day of acquisition (at postnatal day 45) as the co-variant. This was not found by Christian et al. (2002b) using the body weight at weaning as the statistical covariant. However, the authors analyzed the data for preputial separation and vaginal opening with body weight on the day of weaning as a co-variant rather than body weight on the day of acquisition, i.e. the day that the prepuce separates or the day the vagina opens. It is likely that there was an increase in body weight from postnatal day 21 (weaning) until preputial separation (day 45) that was independent of the delay in sexual maturation. A more recent study by Klinefelter et al. (2004) found that exposure to either 4, 40, or 400 ppm of DBAA from gestation day (GD) 15 through post-natal day (PND) 21 did not result in any significant reproductive alterations, but effects were seen with continuous exposure until adulthood. Males and females exposed to 400 ppm DBAA were reported to have delayed preputial separation and vaginal openings by 4 and 3 days, and also an increased responsiveness of both the testis ad ovary to human choriogonadotropin (hCG). At 4 ppm DBAA and higher, hCG-stimulated testosterone production by testicular parenchyma on PND 56 was increased. Also, continuous exposure to DBAA compromised the quality of proximal cauda epididymal sperm.

Kaydos et al. (2004) administered DBA and BCA, individually and in combination to investigate the effect on fertility and spermatogenesis in the rat. Since humans are exposed to a complex mixture of DBPs in disinfected drinking water, it is important to study the potential effects of mixtures of DBPs that

may elicit similar reproductive effects. The authors of this study were able to find dose and effect additivity, and in some cases synergism, for haloacid-induced decrease in fertility.

Although the Christian et al. (2002b) study was conducted in accordance with EPA's 1998 testing guidelines, EPA has incorporated newer, more sophisticated measures into recent intramural and extramural studies that have not yet been incorporated into the testing guidelines. Such measures include changes in specific proteins in the sperm membrane proteome and fertility assessments via in utero insemination. EPA believes that additional research is needed, using these newer toxicological measures, to clarify the extent to which DBAA poses human reproductive or developmental risk. The database on male reproductive effects from exposure to DBAA is incomplete and is not suitable for quantitative risk assessment at this time. It does identify reproductive effects as an area of concern.

In addition, EPA has prepared individual supporting documents that provide detailed summaries of the relevant new information, as well as an overall characterization of the human health risks from exposure to these DBPs (USEPA 2000f, 2005b-e, 2005j; IRIS 2000, 2001a-b, 2003). Overall, reproductive and developmental toxicology studies indicate a possible reproductive/developmental health hazard although they are preliminary in nature for the majority of DBPs, and the dose-response characteristics of most DBPs have not been quantified. Some of the reproductive effects of DCAA were quantified as part of the RfD development process, and impacts of DCAA on testicular structure are one of the critical effects in the study that is the basis of the RfD (IRIS 2003).

Biological plausibility for the effects observed in reproductive and developmental epidemiological studies has been demonstrated through various toxicological studies on some individual DBPs (e.g., Bielmeier et al. 2001, Bielmeier et al. 2004, Narotsky et al. 1992, Chen et al. 2003, Chen et al. 2004). Some of these studies were conducted at high doses, but similarity of effects observed between toxicology studies and epidemiology studies strengthens the weight of evidence for a possible association between adverse reproductive and developmental health effects and exposure to chlorinated surface water.

6.2.2.3 Conclusions

EPA believes that toxicology and epidemiology data suggest that exposure to chlorinated drinking water has the potential to cause adverse reproductive and developmental effects. Although scientific knowledge about the association of reproductive and developmental health effects with DBP exposure is not known well enough to fully quantify these risks or the benefits of reduced DBP exposure, EPA concludes that the data are sufficient to determine that a concern exists that warrants additional regulatory action. The following are the specific key factors used to support EPA's weight-of-evidence conclusion regarding this conclusion:

- The results of several studies performed by different researchers with different methods at different research sites show similar trends.

- Some health effects observed in animal toxicological studies are comparable to those observed in some human epidemiological studies (e.g., embryonic heart and neural tube defects, full litter resorption/miscarriage, spontaneous abortion, or stillbirth) showing similarity of effects between animal toxicity and human epidemiology studies.

- Difficulties in assessing exposure to DBPs, resulting in exposure misclassification, may underestimate reproductive and developmental risks associated with DBPs. It is possible that some of the inconsistencies reported in epidemiological and toxicological study

results are due to these misclassifications, and the true effects may be greater than demonstrated. A spurious effect would be produced only in rare cases, and is unlikely as described in Reif et al. (2000) and Bove et al. (2002).

EPA's epidemiology and toxicology research programs continue to examine the relationship between exposure to DBPs and potential adverse reproductive and developmental health effects. EPA is also supporting several studies using improved study designs to provide better information for characterizing potential risks.

6.3 Exposure Assessment

6.3.1 Population Exposed

Because DBPs are formed when disinfectants combine with organic compounds, the population at risk is identified as the population served by drinking water systems that disinfect. A very large portion of the United States population—approximately 94 percent—is potentially exposed to DBPs in disinfected drinking water. Exhibit 6.18 contains EPA's estimates of the population potentially exposed. Nearly 260 million people in the United States are served by community water systems (CWSs) that apply a disinfectant to water to protect against microbial contaminants. In addition to those served by CWSs, just over 2 million individuals are served regularly by nontransient noncommunity water systems (NTNCWSs). (See Exhibit 3.3 for population served by different system types.)

Two population subgroups of concern are women of child-bearing age and developing fetuses. Women of child-bearing age are generally considered to be those in the age range of 15 to 45. The estimated U.S. population for the year 2000 is 281 million, of which approximately 64 million (23 percent) are females between the ages of 15 and 45. Because approximately 94 percent of the population is served by PWSs that disinfect, it can be estimated that about 60 million women of child-bearing age are served by these water supplies. Currently, there are approximately 4 million live births each year. Again, using the factors above, it can roughly be estimated that more than 3.8 million infants are born each year to mothers served by a disinfecting water supply.

Exhibit 6.18 Estimated Population Exposed to DBPs in Drinking Water

System Size (Population Served)	Population Served by Disinfecting Systems	Percent of Total Population Served by Disinfecting Systems
<100	387,001	0.15%
101-500	2,898,196	1.10%
501-1,000	3,210,348	1.22%
1,001-3,300	10,776,884	4.10%
3,301-10,000	19,664,185	7.48%
10,001-50,000	51,311,073	19.51%
50,001-100,000	26,218,703	9.97%
100,001-1,000,000	88,996,647	33.84%
1,000,000 +	59,561,481	22.64%
Total	263,024,518	100.00%

Source: Derived from the Stage 2 DBPR population baseline for surface and disinfecting ground water CWSs in Exhibit 3.3.

6.3.2 Routes of Exposure

An important route of exposure to DBPs is from the direct ingestion of drinking water and from the consumption of food that has been cleaned, processed or prepared with drinking water. EPA has examined drinking water consumption data from the *1994–1996 USDA Continuing Survey of Food Intakes by Individuals* (USDA 1997) and determined that mean daily drinking water consumption across all ages, sexes, and regions in the United States ranges from 0.9 to 1.2 liters per day, with an upper 95th percentile range of 2.5 to 2.9 liters per day (USEPA 2000i).

People also can be exposed to some contaminants in drinking water by routes of exposure other than ingestion, particularly by inhalation and dermal contact from showering, bathing, washing dishes, washing clothes, or swimming. An international work group was convened in 2000 to assess the challenges involved in assessing exposure to DBPs in epidemiological studies. The workgroup concluded that accurate exposure characterization (from all routes) is extremely important for a valid risk assessment (Arbuckle et al. 2002). The remainder of this section focuses on routes of exposure other than direct ingestion.

Some studies have found that exposure due to inhalation and skin absorption during showering may actually be higher than ingestion-related exposure (Kuo et al. 1998, Backer et al. 2000, Miles et al. 2002). Backer et al. (2000) found that when volunteers either showered with tap water for 10 minutes, bathed in tap water for 10 minutes, or drank 1 liter of tap water over 10 minutes, the highest levels of THMs were found in the blood samples from people who took 10 minute showers, whereas the lowest levels were found in the blood samples from people who drank 1 L of water in 10 minutes. The results from this study indicate that household activities such as bathing and showering are important routes for human exposure to THMs.

Singer et al. (2003) examined the extent to which everyday uses of disinfected drinking water activities in the household effect levels of THMs in the blood. It was concluded that the average ratio of

chloroform in blood to chloroform in water is greatest for activities where there is a potential for significant inhalation or dermal exposure (i.e. showering, bathing, and washing dishes by hand).

The route of exposure may depend on the volatility and chemical phase of the DBP in question (Weisel et al. 1999, Xu et al. 2002, Xu and Weisel 2003, 2004, 2005). THMs are more volatile than HAAs and exist in the air at background levels (Weisel et al. 1999). Xu and Weisel (2003) found that the estimated dose from inhalation of particulate-phase DBPs represented less than 1 percent of the ingestion dose, and the vapor-phase DBPs can contribute to over 10 percent of the ingestion dose during a shower. Weisel et al. (1999) found a significant correlation between breath concentrations of chloroform after showering and water concentration. They were unable to show a relationship between breath concentration and overall exposure due to variability in when breath samples were taken and the fast rate of THM metabolization. However, almost all breath concentrations, except for chloroform, were below the detection limit, most likely due to low water concentrations. Weisel et al. also found a link between urinary trichloroacetic acid (TCAA) excretion rates and TCAA exposure, calculated as the water's TCAA concentration multiplied by the volume of water consumed by volunteers over a 48 hour period, adjusted for home filters and boiling. TCAA exposure generally fell below 10 ng over 48 hours, but ranged up to 50 ng. In addition, Batterman et al. (2000) quantified volatization rates for several TTHMs when preparing, storing and serving tap water and found that heating up tap water (as in hot beverages) reduces the amount of exposure upon ingestion.

Exposure appears to differ between males and females, with males absorbing more chloroform than females (Corley et al. 2000). Most significantly, dermal absorption, especially in women, is significantly affected by water temperature, since at higher temperatures blood flow to the skin is higher, allowing the blood to take in more DBPs (Corley et al. 2000, Gordon et al. 1998). Measuring the chloroform breath concentrations of test subjects immersed in bath water at concentrations of ~90 µg/L at 35°C for 30 minutes, Corley et al. calculated that men would absorb 42 µg and women would absorb 12 µg of chloroform. These exposures were based on models taking blood flow to the skin and skin permeability into consideration. At 40°C, this increased to 44 µg for men and 40 µg/L for women. (This includes chloroform exhaled, metabolized, and maintained in the body.) At 30°C, on the other hand, most subjects had chloroform breath levels below detection limits. For example in comparison to dermal absorption, if 2 liters of water with the same chloroform concentration were ingested, the exposure from ingestion would range from 79 to 194 µg.

6.3.2.1 Special Exposure Issues for Pregnant Women

Because of the potential reproductive and developmental effects of DBPs, pregnant women represent a population subset of special concern with respect to the intake of DBPs from drinking water. Because the kidneys work harder in pregnancy to expel waste material from the body, drinking an adequate volume of water is extremely important. Pregnant women can become dehydrated easily, which can lead to fetotoxicity. Thus, women who are pregnant are encouraged to drink a minimum of eight 8-ounce glasses of water a day to ensure proper hydration (March of Dimes 1999).

Pregnant women cannot avoid tap water completely. As discussed in the previous section, DBP exposure can occur through inhalation and dermal contact from a variety of activities, including showering and bathing. Zender et al. (2001) found that pregnant women bathed more often and for a longer duration than non-pregnant women but showering patterns were similar. Bottled water is not necessarily safer than tap water and is more expensive. Bottled water, even if safer, may not be an option for economically disadvantaged pregnant women. Because pregnant women cannot avoid tap water, the expected reduction in DBP exposure that is estimated for the Stage 2 DBPR is especially important in providing public health protection to them and their developing children.

6.3.3 Exposure Reduction

It is well recognized that DBP concentrations can vary greatly throughout a distribution system and over time at the same location in a distribution system. The Stage 1 DBPR requires systems to meet the maximum contaminant level (MCL) standards and associated compliance monitoring requirements as running annual averages (RAAs) of 80 μg/L for TTHM and 60 μg/L for HAA5 as averaged across all monitoring locations. It is possible that some systems can achieve the average concentration targeted by the Stage 1 DBPR, and yet still have some locations in the distribution system where average DBP levels are far in excess of the system-wide target at some, or even at all, times. The peak exposures resulting from these high concentrations are of particular concern in regard to potential adverse reproductive and developmental health effects. Exposure at locations having repeatedly high sample concentrations are of particular concern for pregnant women, who are encouraged to drink more water than the average person and who may be especially sensitive to the potential effects of DBPs, as explained in the previous section.

Under the Stage 2 DBPR preferred regulatory alternative (which includes a requirement for the IDSE), TTHM and HAA5 MCLs will remain at 80 μg/L and 60 μg/L, respectively, but compliance will be based on the locational running annual average (LRAA). Exhibits 1.3 and 4.1 illustrate how the LRAA and RAA are calculated. This revised compliance calculation requirement will reduce average DBP levels in the entire distribution system as well as avoid having average DBP levels at any sampling location exceed 80 and 60 μg/L for TTHM and HAA5, respectively. Systems are required to meet the Stage 2 DBPR MCLs at revised sampling locations that will be identified through the IDSE to further ensure that peak occurrence events are captured and controlled.

The Stage 2 DBPR Preferred Regulatory Alternative is expected to yield health benefits by achieving the following effects in those systems subject to the rule:

1) Reducing exposures to all DBPs levels.

2) Reducing exposures to single peak occurrences or repeated peak occurrence at location that consistently exceed TTHM and HAA5 MCL levels.

The next sections discuss these two ways that the Stage 2 DBPR reduces exposures to DBPs.

6.3.3.1 Reducing Exposure to All Levels of DBPs

In Chapter 5, EPA estimates the reduction in the national average TTHM and HAA5 concentrations occurring in drinking water distribution systems as a result of new treatment to meet Stage 2 DBPR requirements. Results from this analysis for TTHM are summarized below in Exhibit 6.19.

The average reduction in plant-mean TTHM and HAA5 concentrations is assumed to represent the range of reductions for all chlorination DBPs. Using these two DBP classes as "indicators" for all chlorination DBPs may overestimate or underestimate the true concentration reduction (see Section 6.6 for a summary of uncertainties). However, because measurable halogen-substituted DBP concentrations, comprised primarily of TTHM and HAA5, are estimated to make up 30 to 60 percent of the measured total organic halide (TOX) concentration (Singer 1999), TTHM and HAA5 reductions are assumed to be reasonable indicators of the overall chlorination DBP reductions. Separate evaluations for TTHM and HAA5 are carried throughout the analyses.

The average reduction in TTHM and HAA5 concentration is a key input in the estimation of benefits of the Stage 2 DBP Rule. The reduction in concentration leads to a reduction in exposure, which

in turn reduces the incidence of disease. Section 6.4 details the estimation of the benefits of the Stage 2 DBP Rule.

Exhibit 6.19 National Average TTHM[1] Reduction Estimates

	Mean and 90% Confidence Bounds on Percent TTHM Reduction from Pre-Stage 2 to Post-Stage 2		
	Mean	5th %ile Lower CB	95th %ile Upper CB
Preferred Alternative	7.76%	4.48%	11.06%
Alternative 1	7.07%	5.85%	8.28%
Alternative 2	26.32%	23.03%	29.62%
Alternative 3	36.14%	35.03%	37.26%

Note: Estimates of mean and 90% confidence bounds (CB) incorporate uncertainty in the impacts of the IDSE and uncertainty in SWAT predictive equations on TTHM reduction.
[1] Reductions in HAA5s are very similar. See Section 5.5 for more detail.
Source: Stage 2 Benefits Model

6.3.3.2 Reducing Exposure to Peak DBP Occurrences

EPA used distribution system data from the Information Collection Rule (ICR) to estimate the reduction in occurrences of peak DBP concentrations that result from the Stage 2 DBPR. Section 5.6.1 provides a detailed explanation of the methodology used to generate these estimates and presents results in Exhibit 5.27. Note that since the developmental and reproductive health data described in Section 6.2 do not conclusively identify the peak level of concern, the analysis in Section 5.6 provides an analysis for several possible peak TTHM and HAA5 concentrations, or study levels.

Exhibit 5.27 shows that, at a TTHM study level of 75 µg/L, the percent of distribution system sampling locations with at least one peak observation declines from 20.1 percent for pre-Stage 1 to 8.2 percent for pre-Stage 2 to 3.3 percent for post-Stage 2 DBPR conditions. To translate estimated changes in peak DBP *occurrence* as a result of the Stage 2 DBPR to changes in peak DBP *exposure*, the following assumptions are used:

1) Each ICR sampling-location (DSE, AVG1, AVG2, and DS Maximum) represents an equal portion (25 percent) of the total population served by the plant.

2) Peak DBP occurrence for the 311 large ICR surface and ground water plants evaluated in Section 5.5 is representative of the peak DBP occurrence for all plants (large and small).

The first assumption may overestimate the population represented by the DS Maximum location (i.e., 25 percent may be too high) and thus, may overestimate the population exposed to peaks. This potential overestimate, however, is minimized because ICR data showed that the peak TTHM level occurred somewhere other than the DS maximum location approximately 52 percent of the time (see Chapter 3 of the Stage 2 DBPR Occurrence Document (USEPA 2005k)). The rationale for the second assumption is provided in the next three paragraphs.

ICR data pertains to all systems serving 100,000 or more people. The 311 plants evaluated represent 62 percent (311/500) of all plants in the ICR. Systems serving 100,000 or more people serve approximately 149 million people, or 56 percent (149 million/264 million) of the total population served

by disinfecting systems (Exhibit 6.18 provides a summary of the population served by each disinfecting system size category). Thus, the 311 plants encompasses approximately *35 percent* (56 percent x 62 percent) of the total population served by disinfecting systems.

Because medium-sized systems serving 10,000 to 99,999 people are expected to have treatment technologies and source water quality very similar to large systems serving 100,000 or more people, EPA believes that ICR large-system data is adequate for characterizing peak DBP occurrence for medium systems. (See Appendices A and B for comparisons of source water quality data and treatment technologies in place for medium and large systems.)

For small systems serving fewer than 10,000 people, using ICR data to characterize pre-Stage 1 peak occurrence may bias the results of this analysis for two reasons. First, small systems serving fewer than 10,000 people were not required to comply with the 1979 TTHM standard of 100 µg/L and may have higher DBP levels than indicated by ICR data. On the other hand, small systems may have lower DBP levels than indicated by ICR data since they are made up of a higher proportion (more than 75 percent) of ground-water-only systems compared to large systems. It is expected that these two biases offset each other to some extent in the analysis of pre-Stage 1 data. It is important to note that biases in characterization of DBP peaks nationally that are caused by differences in small-system occurrence are minimized because systems serving fewer than 10,000 people represent only 14.8 percent of the total population served.

TTHM and HAA5 concentrations are highly variable in distribution systems; it is probable that this analysis does not capture the true variability in exposure to peaks. Uncertainties with interpretation of ICR data for the purposes of this exposure assessment include:

- The extent to which small-system occurrence is represented;
- Year-to-year variability of DBP occurrence data that might be affected by changes in source water quality (e.g., drought years versus non-drought years);
- The extent to which each ICR sampling point represents an equal fraction of the population served; and
- The extent to which ICR sampling locations represent compliance monitoring locations when trying to estimate reductions in exposure resulting from compliance with Stage 1 and Stage 2 DBPRs.

The assumptions in this section are necessary, however, for predicting exposure changes given the limited data on DBP occurrence in small systems and in distribution systems in general. Using the two assumptions listed above, the reduction in plant-locations with peaks as a result of the Stage 2 DBPR (shown in Exhibit 5.21) can be taken to represent the reduction in exposure to peaks nationally as a result of the Stage 2 DBPR. For example, for a TTHM study level of 80 µg/L, the percent of the population exposed to peak DBPs is predicted to decline from 6.0 to 1.7 percent (a 70 percent reduction) as a result of the Stage 2 DBPR.

As stated previously in this chapter, EPA predicts that a significant portion of the total benefit of this rule could come from reductions in developmental and reproductive health effects, although the relationship of these effects to DBP exposure is not well enough known to fully quantify risks or benefits. EPA was able to do a preliminary calculation of the benefits of reducing the potential risk of fetal loss, the non-cancer effect for which the most epidemiological data exist in relation to DBP exposure (see Section 6.8). Reductions in the number of peak DBPs events due to the Stage 1 DBPR and the Stage 2

DBPR were estimated. Reductions in exposure to peak DBPs were assumed to be proportional to reductions in peak DBP events. Like the analysis of bladder cancer, there is uncertainty in fetal loss PAR values, incorporated in the range of values used in the analysis. There are other important uncertainties in this illustrative calculation, including the assumed proportional relationship between reduction in fetal losses and reduction in exposure to peak levels due to the Stage 2 DBPR. More detail on the illustrative calculation showing hypothetical reproductive and developmental benefits resulting from peak exposure reduction is provided in Appendix G.

6.4 Benefits of the Stage 2 DBPR: Reduced Incidence of Adverse Effects

6.4.1 Reduced Incidence of Bladder Cancer Cases

This section presents EPA's estimates of the expected reduction in the incidence rate of new bladder cancer cases as a result of the Stage 2 DBPR. The methodology used to obtain these estimates is also discussed in this section. Additional details on the methodology are provided in Appendix E. Also, Section 6.2.1 presents information on the annual incidence of new bladder cancer cases attributable to all sources and, in particular, to DBPs prior to Stage 1, that is used as a key input to the estimation of the reduction in annual cases due to the Stage 2 DBPR. The estimates of Pre-Stage 1 bladder cancer cases attributable to DBPs are presented in Section 6.2.1 for PAR values derived from three data sources: five studies used for Stage 1 and Stage 2 Proposal, Villanueva et al. (2003), and Villanueva et al. (2004). Similarly, this section provides separate estimates of the avoidable cases based on the attributable cases estimated from those three sources.

Several key assumptions underlie the calculation of bladder cancer cases avoided by the Stage 2 DBPR. The most important one is that a causal relationship exists between exposure to chlorinated surface water and bladder cancer. However, EPA and the international bodies (e.g. WHO) that classify risk recognize that such causality has not yet been established.

Other important assumptions regarding the bladder cancer risk from DBPs, and the risk reduction from lower DBP levels, are:

- That there is no threshold below which there is no risk,
- That the risk is linearly related to DBP exposure levels resulting from the range of DBP levels in drinking water, and
- That reduction in bladder cancer risks can be estimated from reduction in levels of TTHMs and HAA5s acting as indicators of chlorination DBPs in drinking water.

Taken together, these assumptions provide the basis for calculating the reductions in expected annual cases of bladder cancer in the population exposed to DBPs in drinking water resulting from the Stage 2 DBPR. So, for example, if the annual incidence of bladder cancer attributable to DBPs remaining after Stage 1 is X cases, and the Stage 2 DBPR is determined to reduce the overall average concentrations of TTHMs or HAA5s by 5 percent, then it would be estimated that, over time, there would be 0.05X fewer new bladder cancer cases occurring each year as a result of the Stage 2 rule.

The number of cases avoided (and the resulting monetized benefits discussed in subsequent sections) was calculated using TTHM and HAA5 as indicators for exposure to all chlorination DBPs (see Section 6.3.3.2 for discussion of the use of TTHM and HAA5 as indicators). However, for analyses presented in the rest of this chapter, only the results of calculations using TTHM are presented, to simplify the discussion. Benefits calculated using TTHM as an indicator are similar to those calculated using HAA5. Detailed results for all analyses using both TTHM and HAA5 as indicators are presented in Appendices E and F.

Another key set of assumptions used to estimate the reduction of bladder cancer incidence relates to when the expected reductions in new cancer cases begin to occur. Individual cancer risks at any point in time generally represent lifetime exposure levels and not just current or very recent exposure levels. Therefore, it would not be appropriate to assume that individuals exposed to some level of DBPs for a substantial portion of their lifetime would immediately attain a reduced risk of bladder cancer when the DBP levels in their water system are reduced as a result of compliance with the Stage 2 DBPR. A transition from pre-Stage 2 risks to the post-Stage 2 risks—referred to here as the "cessation lag"—has therefore been included in the calculation of cancer cases avoided each year to account for this factor.

Three subsections describing the estimation of cancer cases avoided follow. In the first, the annual cancer cases avoided are calculated without taking the cessation lag transition into account. This establishes the "annual cases ultimately avoidable" that will be achieved once the full effect of the reduced DBP exposure is realized. The second subsection takes into account the effect of the cessation lag transition period between current and post-regulatory risk levels. A final subsection further accounts for the timing of the avoided cancer cases by considering the implementation schedule of the rule (that is, not all affected systems will implement the rule simultaneously).

As noted previously, EPA has developed three equally valid approaches to estimating the number of bladder cancer cases attributable to DBPs (five studies; Villanueva et al. (2003); and Villanueva et al. (2004)). This section presents the estimates of the bladder cancer cases ultimately avoidable using all three methods for estimating the baseline population attributable risk (PAR). However, for the sake of simplicity, one method for estimating PAR based on Villanueva et al. (2003) is carried through the full benefits analysis to account for cessation lag, implementation schedule, and monetization. A perspective on how using one of the other two approaches would impact the benefits is provided in Section 6.5.

6.4.1.1 Annual Cancer Cases Ultimately Avoidable

Once the Stage 2 DBPR has been fully implemented, the incidence of bladder cancer cases annually is anticipated to decline to a new, lower value representing the lower average DBP exposure levels. That new value will be achieved over time as lifetime risks for individuals who currently consume water at the high, pre-Stage 2 DBP levels become more influenced by the lower, post-Stage 2 levels. Over the long-term, the lower incidence of new bladder cancer cases will represent the difference in the risk of new generations of individuals who are exposed largely or solely to the post-Stage 2 levels for their lifetimes instead of the higher pre-Stage 2 levels.

This long-term, steady-state difference between the annual bladder cancer cases attributable to DBPs before and after the Stage 2 rule is referred to as the "annual cases ultimately avoidable." Note that this term "ultimately avoidable" is different from the "total attributable" cases. The total attributable refers to all the annual bladder cancer cases due to DBPs as presented in Section 6.2; the cases ultimately avoidable refers to that portion of the total attributable cases that a specific reduction in average DBP concentrations would eliminate.

To calculate the post-Stage 2 ultimately-avoidable cancer cases, it is necessary to begin with the pre-Stage 1 cancer incidence from all causes, determine the total cases attributable to DBPs, determine the cases ultimately avoidable by Stage 1, and then determine the cases ultimately avoidable by Stage 2. This is done as follows:

- Estimate of the total cases attributable to DBPs (under pre-Stage 1 conditions) in drinking water by applying the age-based PAR values to each of the age-based cases per year attributable to all causes.

- Estimate the maximum number of those total attributable cases that are avoided by the Stage 1 rule based on the percent reduction in average DBP levels due to Stage 1.

- Subtract the maximum number avoidable by Stage 1 from the total pre-Stage 1 attributable cases to obtain the post-Stage 1 (pre-Stage 2) attributable cases.

- Estimate the maximum number of the remaining pre-Stage 2 attributable cases that are avoided by the Stage 2 rule based on the percent reduction in average DBP levels due to Stage 2.

As discussed in Section 6.2.1, EPA has developed three approaches for estimating the total attributable pre-Stage 1 cases:

- Using the range of Population Attributable Risk (PAR) values derived from consideration of 5 individual epidemiology studies used for the Stage 1 EA and the Stage 2 proposal EA (yields a pre-Stage 1 range of best estimates for PAR of 2% to 17%).

- Using the OR of 1.2 from the Villanueva et al. (2003) meta-analysis that reflects both sexes, ever exposed population from the studies considered (yields a pre-Stage 1 best estimate for PAR of ~16%)

- Using the Villanueva et al. (2004) pooled data analysis to develop a dose-response relationship for OR as a function of Average TTHM. The dose-response relationship was modeled as linear with an intercept of OR = 1.0 at TTHM exposure level = 0 (yields a pre-Stage 1 best estimate for PAR of ~17%)

EPA considers all three of these approaches to estimating the PAR for DBPs to be equally valid and to provide plausible quantitative estimates of bladder cancer risk, which are similar to each other. EPA has long recognized that while the several epidemiology studies described above indicate a potential association between exposure to DBPs in drinking water and bladder cancer incidence, uncertainty remains with respect to quantifying the number of new bladder cases that occur each year that can be attributed to that exposure.

Two basic methodologies for using the epidemiology data are represented in the three approaches. The first is to consider multiple studies separately rather than combining the information into a single estimate of the attributable risk. The second is to combine the information provided by multiple epidemiology studies using either a meta-analysis or a pooled data analysis. Each methodology has advantages and disadvantages.

One advantage to keeping estimates of individual studies separate and presenting them as a full range of plausible results, is that an explicit depiction of the extent of uncertainty that exists in the quantitative risk estimate is retained. EPA chose to consider studies separately in the economic analyses for both the Stage 1 DBP rule and the proposal for the Stage 2 DBP rule. EPA relied upon a range of risk estimates derived separately from 5 key studies that were published in the 1980's and 1990's. The individual estimates of the fraction of bladder cancer cases attributable to DBP exposure (or more specifically to chlorinated water exposure) obtained from each of these five studies covered a wide range: 2% to 17%. Further, as EPA noted, consideration of uncertainty for each of the individual estimates leads a wider range of values and, on the low end, includes the possibility of 0%.

One criterion to consider when deciding whether or not to combine multiple studies is the heterogeneity of the data. In developing the Stage 1 rule, EPA evaluated two meta-analyses available at that time (Poole et al. 1997, Morris et al. 1992) and concluded that the existing studies were too heterogeneous to be combined in any way.

Meta-analyses and pooled data analyses are two approaches that are used to combine the information provided by multiple epidemiology studies. In a meta-analysis, the measures of an effect size obtained in the individual studies (such as the OR) are weighted, typically by the inverse of the variance of the effect size, and the weighted values combined to obtain the overall estimate of that effect. In a pooled data analysis, the underlying data of the multiple studies are combined together, typically without weighting, and an estimate of the effect is made from the combined data as though it were obtained from a single study.

Meta-analysis is more commonly used for combining multiple epidemiology studies than is pooled data analysis. If heterogeneity is not properly controlled for across the studies used, pooled data analysis can be subject to outcomes that are greater, less, and often opposite that of the outcomes observed in the individual studies (Bravata and Olkin 2001). Although the results of meta-analysis can also be affected by heterogeneity across the studies used, it is not as subject to these same effects. Meta-analysis can also combine data by weighting certain studies more than others, while pooled data analysis cannot do this. However, whereas meta-analysis is limited to consideration of the specific effect measures studied by the author's of the underlying studies, pooled data analysis can provide an opportunity to evaluate an effect that was not specifically considered in some or all of the underlying studies.

EPA determined that the meta-analysis published by Villanueva et al. (2003) and the pooled data analysis published by Villanueva et al. (2004), both of which combine the results of multiple select studies, offer reasonable approaches to arriving at a single, overall estimate of attributable risk while still retaining an appropriate characterization of the uncertainty in that risk estimate.

The Villanueva et al. (2003) meta-analysis, which considered four of five same studies that EPA has used historically for its PAR analyses in addition to two other lower weighted studies, obtained results that are consistent with the five study estimates. The meta-analysis found a relationship between duration of exposure to DBPs (or chlorinated water) and risk of bladder cancer, which EPA used to inform the relationship between exposure and risk. With this approach to estimating risk, EPA assumes that the exposure of the study populations is characteristic of the National pre-Stage 1 exposure without knowing the exposure levels explicitly.

The Villanueva et al. (2004) pooled data analysis produced results that are consistent with the other approaches. The Villanueva et al. (2004) paper provided a dose response relationship between OR and TTHM concentrations that allowed EPA to estimate PAR values based specifically on the estimated average concentrations of TTHMs before and after implementation of the Stage 2 rule, a unique feature not possible with the other two approaches. A variety of methods, including modeling, were used to estimate TTHM concentrations. In using the Villanueva et al. (2004) analysis to estimate risk, EPA assumes that these estimated exposures represent the exposure of the study populations and that the study population exposures are characteristic of the National pre-Stage 1 exposure. In addition, the Villanueva et al. (2004) paper used different studies, one of which is unpublished, than the other approaches. In using the analysis, EPA assumes that the relationship found between exposure and risk is valid for the US population although the study populations in the pooled analysis are from Italy, Canada, France, and Finland as well as the U.S.

Exhibit 6.20 summarizes the estimates of ultimately avoidable cases based on these three sets of PAR value estimates. The details for the calculations resulting in the estimates provided in Exhibit 6.20 are presented in Appendix E.

There are two major sources of uncertainty reflected in the estimates presented in Exhibit 6.20 for each of the three PAR estimate sources.

First, each shows three "rows" indicating the uncertainty in the percent DBP reductions that are predicted to occur between Stage 1 and Stage 2. These three estimates provided for each of the PAR estimate sources correspond to the Best Estimate of the Stage 2 reduction in DBPs, along with the lower and upper 95 percent CI bounds on those percent DBP reductions.

The second source of uncertainty reflected in each estimate corresponds to uncertainty in the OR values provided in each of the data sets and the PAR values derived from them. The low and high estimates shown in each row correspond to the lower and upper 95 percent confidence intervals on the OR/PAR estimates, with the best estimates reflected in the numbers circled between them. Note that for the five studies used for Stage 1 and the Stage 2 proposal, the "best estimates" include numbers based on both the 2 percent and 17 percent PAR values that underlie these calculations.

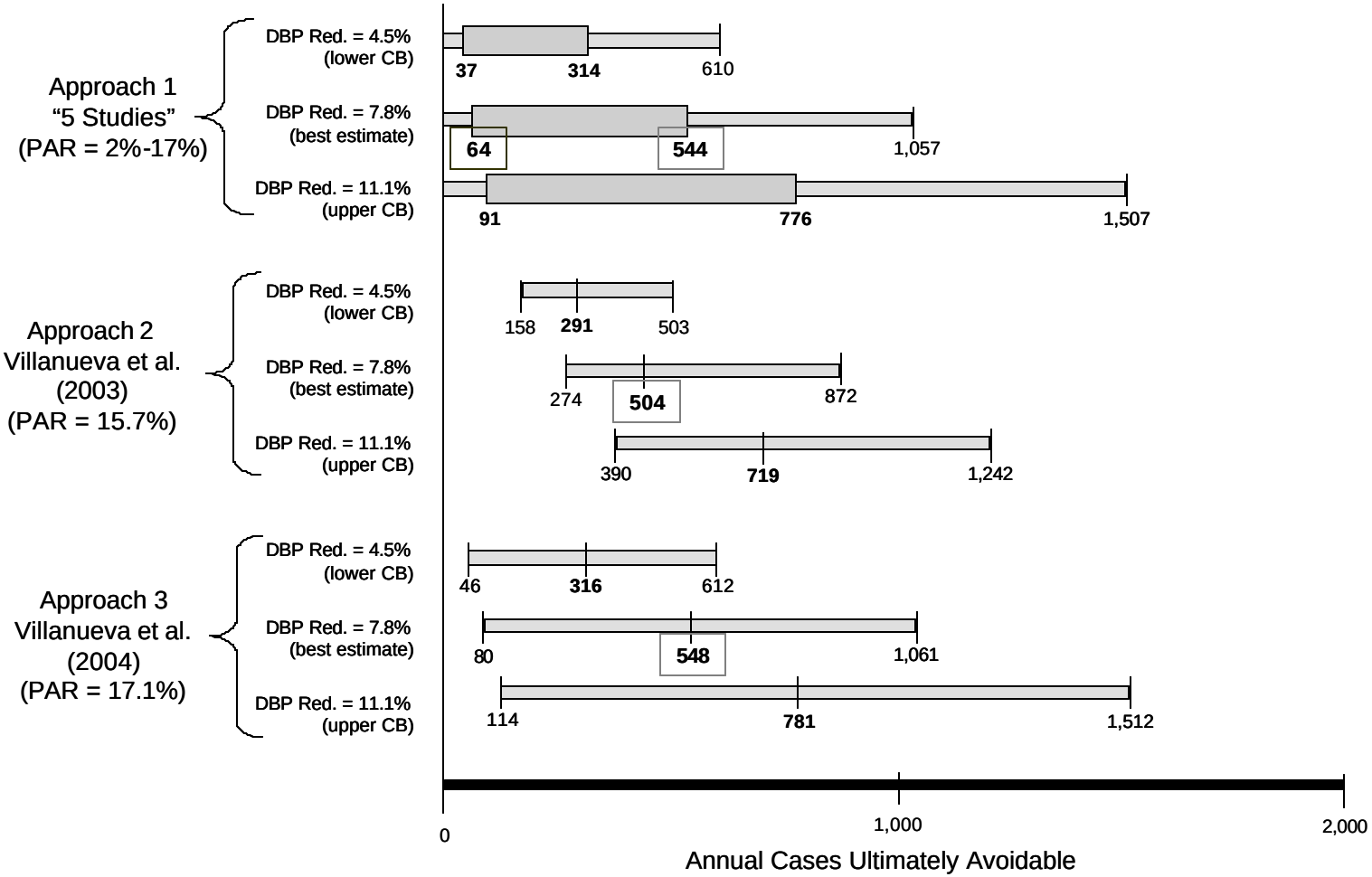
Focusing on the best estimate of percent DBP reductions, the range of estimates of Stage 2 annual bladder cancer cases ultimately avoidable derived from the "five studies" set of PARs extends from 0 cases to 1,057 cases per year, with best estimates of 64 (for the 2 percent PAR estimate) and 544 for the 17 percent PAR estimate. For the estimates derived from the Villanueva et al. (2003) PAR values, the annual cases ultimately avoidable for the best estimate of percent DBP reductions ranges from 274 to 872, with a best estimate of 504. For the estimates derived from the Villanueva et al. (2004) PAR values, the annual cases ultimately avoidable for the best estimate of percent DBP reductions ranges from 80 to 1,061, with a best estimate of 548.

As noted previously, the estimates of ultimately avoidable cases from Stage 2 shown here set an upper bound on the annual reduction in bladder cancer cases due to the DBP reductions from this rule. As a result of cessation lag and the phasing in of reductions over time in accordance with the implementation schedule, these annual reductions are not expected to be realized for a substantial number of years after the rule is promulgated. The next sections that follow account for both of these factors in estimating the annual benefits of the Stage 2 rule.

For the calculation of the annual benefits that include consideration of cessation lag, implementation schedule and monetization, EPA is using as its starting point the annual cases ultimately avoidable derived using the OR and PAR values obtained from the Villanueva et al. (2003) study. The estimates of total attributable cases and cases ultimately avoidable for Stage 2 based on Villanueva et al. (2003) fall in the middle of all of the estimates and capture a substantial portion of the overall range reflecting the uncertainty in both the underlying OR and PAR values as well as the range of uncertainty in DBP reductions for Stage 2.

It is important to note that in running the full benefits simulation model using the Villanueva et al. (2003) inputs for PAR and incorporating all of the uncertainties for DBP concentration changes, the mean estimate of annual cases ultimately avoidable produced by the full model is 577 (CB=229-1,079) as compared to the "best estimate" of 504 (CB=274-872) calculated above.

Exhibit 6.20 Comparison of Range of Estimates of Stage 2 Cases Ultimately Avoidable for Three PAR Approaches and DBP Reductions



Abbreviation: PAR = Population Attributable Risk (values shown are best estimates). CB = Confidence Bound

Notes: Estimated annual cases ultimately avoidable are based on predicted DBP reduction from Stage 1 to Stage 2. Results shown assume that percent reduction in average TTHM concentrations is an indicator of percent reduction in concentrations of all DBPs. Three contributions to the uncertainty in the estimate of the annual cases ultimately avoidable by Stage 2 are displayed in this exhibit: (1) uncertainty in the approach used to estimate PAR; (2) uncertainty in the underlying data used to derive the PAR estimates for each approach, represented by the 95 percent confidence intervals displayed in each horizontal bar; and (3) uncertainty in the percent reduction in the national average DBP levels achieved by Stage 2 is represented by the lower 90 percent CB, best estimate, and upper 90 percent CB values shown for each approach. For Approach 1, the hatched boxes represent the 2 percent to 17 percent range of best estimates from the five separate studies considered.in the Odds Ratios underlying the PAR values. The estimates in boxes are the overall mean (best) estimates for each approach.

6.4.1.2 Annual Cancer Cases Avoided Accounting for Cessation Lag

Recently, the Arsenic Rule Benefits Review Panel (ARBRP) of EPA's Science Advisory Board (SAB) addressed cessation lag in detail and provided guidance to account for the transition period between higher and lower steady-state risks (USEPA 2001d). The ARBRP coined the term "cessation-lag" to emphasize the focus on the timing of the attenuation of risk after reduction in exposures. They did this to avoid confusion with the more traditional term of "latency," which represents the time period from when initial exposure occurs to when an increase in risk from a carcinogen occurs.[3]

Although the focus of the cessation lag discussion in the SAB review was on reducing levels of arsenic in drinking water, much of their consideration of this issue had more general applications beyond the arsenic issue they were considering at that time. In particular, the SAB noted that:

- The same model should be used to estimate the time pattern of exposure and response as is used to estimate the potency of the carcinogen.

- If possible, information about the mechanism by which cancer occurs should be used in estimating the cessation lag (noting that late-stage mechanisms in cancer formation imply a shorter cessation lag than early-stage mechanisms). The cessation lag tends to be shorter (i.e. the curve steeper) in late-stage mechanisms such as cancer because a small reduction in exposure leads to a large decrease in risk.

- If specific data are not available for characterizing the cessation lag, an upper bound for benefits can be provided based on the assumption of immediately attaining steady-state results.

- In the absence of specific cessation lag data, other models should be considered to examine the influence of the lag.

Following the release of the SAB's report, EPA began to explore approaches for including the cessation lag in risk reduction models and for calculating benefits for the arsenic regulation. EPA recognized, however, that the concept of cessation lag may be applicable not only to arsenic, but also to other carcinogenic drinking water contaminants having a cancer end-point.

In response to the SAB cessation lag recommendations, EPA has:

- Conducted a study that resulted in the 2003 final report *Arsenic in Drinking Water: Cessation Lag Model* (USEPA 2003r).

- Conducted an expert scientific peer review of the draft report (Schulman et al. 2004).

- Initiated development of general criteria for incorporating cessation lag modeling in benefits analyses for other drinking water regulations.

[3] The SAB included the following statement in its report on arsenic, to emphasize this difference: "An important point is that the time to benefits from reducing arsenic in drinking water may not equal the estimated time since first exposure to an adverse effect. A good example is cigarette smoking: the latency between initiation of exposure and an increase in lung cancer risk is approximately 20 years. However, after cessation of exposure, risk for lung cancer begins to decline rather quickly. A benefits analysis of smoking cessation programs based on the observed latency would greatly underestimate the actual benefits."

In the effort to develop a cessation lag model specific to DBPs, EPA reviewed the available epidemiological literature for information relating to the timing of exposure and response, but could not identify any studies that were adequate, alone or in combination, to support a model specifically for DBPs in drinking water. Thus, in keeping with the SAB recommendation to consider other models in the absence of substance-specific cessation lag information, EPA explored the use of information on other carcinogens that could be used as an indicator to characterize the influence of cessation lag in calculating benefits. EPA investigated three different models and determined that using all three as separate alternatives would better characterize the uncertainty than selecting one or combining the three together into a single cessation lag model.

The carcinogen for which the most extensive database was available for characterizing cessation lag was for cigarette smoking. EPA examined several extensive epidemiological studies on the risks of adverse health effects, including lung cancer and bladder cancer, for smokers and former smokers. In addition, EPA included data for arsenic in drinking water and bladder cancer. The three studies used, and the cancer end-point and risk factor they each consider, are:

- Hrubec and McLaughlin (1997a) : Smoking and Lung Cancer
- Hartge et al. (1987): Smoking and Bladder Cancer
- Chen and Gibb (2003): Arsenic and Bladder Cancer

Each of these studies provides information on how the cancer risk for individuals having some high level of exposure to the risk factor for a substantial portion of their lives changes over time toward the risk observed for other individuals who have experienced some lower level of exposure. The first two involve a change from smoking to non-smoking (complete cessation) while the third involves a change from a high arsenic exposure level of 50 μg/L in drinking water to a lower, but non-zero, level of 10 μg/L. The Hrubec and McLaughlin (1997a) report is a comprehensive study involving a 26-year follow-up of almost 300,000 U.S. male veterans. Hartge et al. (1987) used data from 8,764 subjects in the National Bladder Cancer Study and their cigarette smoking histories. In addition, EPA selected Chen and Gibb (2003) to develop a cessation lag model based on arsenic exposure in drinking water and bladder cancer.

Aside from chloroform, no mode of action has been established either for specific DBPs or for chlorinated water in general related to bladder cancer. Thus, EPA assumes that the mode of action may be adequately represented by the mixed initiator and promoter aspects of the cigarette smoking model. As discussed in the SAB report and the EPA Cessation Lag report (USEPA 2001d and USEPA 2003r), carcinogens that act solely or primarily as initiators would tend to show a longer cessation lag (lower rate of risk reduction following reductions in exposure) than carcinogens that act solely or primarily as promoters. The available information on tobacco smoke and lung cancer suggests that it involves both initiators and promoters, so the cessation lag derived from smoking data is expected to represent the combined influence of these different mechanisms.

The smoking/bladder cancer data is appropriate to use because the target organ is the same. "Portal of entry" differences are particularly important in differentiating between smoking/lung cancer and DBPs/bladder cancer. The route of exposure for smoking/bladder cancer is similar to DBP ingestion in that there is expected to be a first pass through the liver followed by entry into the bloodstream prior to reaching the bladder.

In the case of dermal exposure, which is considered a major route, DBPs enter the bloodstream directly and can reach the bladder without that "first pass" through the liver. This could argue for a similarity with the smoking/lung cancer model because it involves a more direct "portal of entry".

While there are some reasons to favor the smoking/bladder cancer data, the largest area of uncertainty is the appropriateness of using any smoking/cancer data to derive a cessation lag model for DBPs. In light of the overarching uncertainties in the use of smoking data, developing separate cessation lag models based on smoking/lung cancer data and smoking/bladder cancer data is a reasonable approach. EPA has therefore judged that these two models, plus the arsenic/bladder cancer model, are equally plausible for characterizing cessation lag in order to estimate benefits attributable to DBP reduction. The equations representing the three cessation lag models as well as details regarding their derivation and implementation can be found in Appendix E.

Exhibit 6.21, at the end of this subsection, the cases avoided factoring in the cessation lag models. The results from the cessation lag models show that the majority of the potential cases avoided occur within the first several decades after the rule is promulgated, but with diminishing incremental increases in later years. For example, the smoking/lung cancer cessation lag model indicates that approximately 38 percent of the cases ultimately avoidable are achieved by the end of the tenth year, with more than 50 percent achieved by the end of the twelfth year, and approximately 81 percent by the twentieth year. The arsenic/bladder cancer model shows a faster increase in achieving cases ultimately avoidable, 57 percent by the tenth year, and the smoking/bladder cancer model is slower, 28 percent by the tenth year.

Another important consideration is that two out of three cessation lag models (those based on smoking) involve complete cessation of exposure, whereas in the case of DBPs, the exposure is only reduced. In some water systems the reduction is only 10 percent, whereas in others it may be as high as 60 percent, with an average of approximately 30 percent. This moderate reduction in exposure may prevent full DNA repair, which some scientists interpret as the basis for the short cessation lag associated with full cessation of smoking. However, the third cessation lag model considers only a partial reduction in exposure.

6.4.1.3 Adjustments in Annual Cancer Cases Avoided to Account for the Rule Implementation Schedule

In addition to the delay in reaching a steady-state level of risk reduction as a result of cessation lag, there is a delay in attaining maximum exposure reduction across the entire affected population that results from the Stage 2 DBPR implementation schedule. For example, large surface water PWSs have 6 years from rule promulgation to meet the new Stage 2 MCLs, with an additional 2-year extension possible for capital improvements. For the benefit and cost analysis, EPA estimates that some percentage will make treatment technology changes in year 4, some will make treatment technology changes in year 5, and so on. Appendix D shows the assumptions regarding the schedule for installation of treatment technologies to meet Stage 2 DBPR requirements. In general, EPA assumes that a fairly constant increment of systems will complete installation of new treatment technologies each year, with the last systems installing treatment by 2016.

The delay in exposure reduction resulting from the rule implementation schedule is incorporated into the benefits model by adjusting the cases avoided for the given year. For example, if 10 percent of systems install treatment equipment (and start realizing reductions in cancer cases) in year 1, only that portion of the cases will begin the cessation lag equilibrium process in that year.

EPA analyses of available data indicate that 26 percent of bladder cancers are fatal and 74 percent are non-fatal (USEPA 1999a). Annual cases avoided were apportioned to each category proportionately.

Exhibit 6.21 Cases Avoided (TTHM as Indicator) Using Three Cessation Lag Models

	Smoking/Lung Cancer Cessation Lag Model		Smoking/Bladder Cancer Cessation Lag Model		Arsenic /Bladder Cancer Cessation Lag Model	
Year	Total	Percent[1]	Total	Percent[1]	Total	Percent[1]
1	0	0%	0	0%	0	0%
2	0	0%	0	0%	0	0%
3	0	0%	0	0%	0	0%
4	0	0%	0	0%	0	0%
5	0	0%	0	0%	0	0%
6	24	4%	23	4%	45	8%
7	61	11%	53	9%	109	19%
8	110	19%	90	16%	186	32%
9	168	29%	131	23%	273	47%
10	218	38%	159	28%	331	57%
11	263	46%	183	32%	376	65%
12	303	53%	202	35%	409	71%
13	339	59%	220	38%	435	75%
14	369	64%	236	41%	456	79%
15	394	68%	250	43%	473	82%
16	414	72%	264	46%	486	84%
17	431	75%	276	48%	497	86%
18	446	77%	288	50%	507	88%
19	459	79%	299	52%	514	89%
20	469	81%	310	54%	521	90%
21	479	83%	320	55%	527	91%
22	487	84%	329	57%	531	92%
23	495	86%	338	59%	535	93%
24	501	87%	346	60%	539	93%
25	507	88%	354	61%	542	94%

Note: [1]Percent of annual cases ultimately avoidable achieved during each of the first 25 years. The benefits model estimates 577 (90% CB = 229-1,079) annual cases ultimately avoidable using the Villanueva et al. (2003) PAR inputs and including uncertainty in these and DBP reductions.

Source: Exhibits E.38a, E.38e and E.38i.

6.4.2 Reduced Incidence of Reproductive and Developmental Effects

As discussed earlier, both epidemiological and toxicological evidence suggest the potential for increased health risk for pregnant women and their fetuses exposed to DBPs in drinking water. While the levels of DBPs associated with specific potential adverse reproductive and developmental effects is not known, EPA believes that lowering the overall levels of DBPs in distribution systems and in particular by reducing the incidence of peak levels is important from a public health perspective.

EPA believes that the current scientific knowledge on reproductive and developmental health effects is not strong enough to quantify risk in the primary benefits analysis. However, an illustrative calculation considering the range of possible benefits for one specific effect in this category—avoided cases of fetal loss—is presented in Section 6.8. The discussion in Section 6.2 and the illustrative calculation in Section 6.8 suggest that the benefits from reduced DBP exposure in terms of both avoided incidence of reproductive and developmental effects and in terms of the potential monetized value of those avoided cases could be significant.

6.4.3 Other Health-Related Benefits

The scientific literature indicates that exposure to DBPs may be related to health effects other than reproductive, developmental, and bladder cancer effects. Some studies have indicated an association between consumption of chlorinated drinking water and colon and rectal cancer, while other studies have shown no association. Since 1998, several new studies have been published that contribute to the weight of evidence relating DBP exposure with colon and rectal cancer. As TTHM and HAA5 levels are reduced under the Stage 2 DBPR, other potentially carcinogenic chlorination DBPs (both known and unknown) will be reduced as well. These collateral effects may further reduce the number of colon and rectal cancer cases. Both toxicology and epidemiology studies indicate that other cancers may be associated with DBP exposure but currently there is not enough data to quantify or monetize these risks. However, EPA believes that the association between exposure to DBPs and colon and rectal cancers is possibly significant, so an analysis of benefits is presented as a sensitivity analysis (see Section 6.7).

6.4.4 Non-Health-Related Benefits

The Stage 2 DBPR may increase consumer confidence in the quality of drinking water. Drinking water consumers may be willing to pay a premium for regulatory action if it reduces their risk of becoming ill. Consumers' WTP depends on several factors, including their degree of risk aversion, their perceptions about drinking water quality, and the expected probability and severity of potential human health effects associated with DBPs.

Most people who switch to bottled water or use filtration devices do so because of taste and odor problems and health-related concerns. Chlorine dioxide, ozone, and chloramines have historically been used to address taste and odor. To the extent that the Stage 2 DBPR changes perceptions of the health risks associated with drinking water and improves taste and odor, it may reduce actions such as buying bottled water or installing filtration devices. Any resulting cost savings would be a regulatory benefit.

As PWSs move away from conventional treatment to more advanced treatment technologies, other non-health benefits are anticipated besides better-tasting and smelling water. For example, chlorine dioxide is effective in controlling the spread of zebra mussels, an invasive species that has caused significant ecological damage in some U.S. waterways (Sprecher and Getsinger, 2000). Installation of certain advanced treatment technologies can remove many contaminants in addition to those specifically targeted by the Stage 2 DBPR, including those that EPA may regulate in the future. For example, membrane technology (depending on pore size), can be used to lower DBP formation, but it can also remove many other contaminants (e.g. bacteria and protozoans) that EPA is in the process of regulating. Removal of any contaminants that may face regulation could result in future cost savings to a water system.

6.4.5 Potential Increases in Health Risks

It is important to maintain a balance between the risks from DBPs and those from microbial pathogens in drinking water. The Microbial-Disinfectants/Disinfection Byproducts (M-DBP) Advisory Committee considered the impact of DBP control on microbial protection when they recommended the MCLs in the Stage 2 DBPR. For example, as described in Chapter 4 of this EA, the M-DBP Advisory Committee debated whether the bromate MCL should be lowered. The Stage 1 DBPR set the MCL for bromate at 10 µg/L, partly because that was the limit of EPA's measuring capability at that time. Methods now exist to measure lower concentrations of bromate, which would allow a lower limit to be set. However, the committee was concerned that a lower bromate MCL might discourage systems from

switching to (or continuing to use) ozone to increase microbial protection. Unlike chlorine, ozone can inactivate *Cryptosporidium*, a focus of Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR). Therefore, to encourage the use of ozone, M-DBP Advisory Committee recommended that EPA not change the bromate MCL.

Along with the reduction in chlorination DBPs such as TTHM and HAA5, there may be increases in other DBPs as systems change from chlorine to more advanced disinfectants. Exhibits 6.22 and 6.23 compare the SWAT-predicted monthly average and plant-mean average concentrations for chlorite (a potential byproduct of chlorine dioxide disinfection) and bromate (a potential byproduct of ozone disinfection) for pre-Stage 2 and post-Stage 2 conditions. These exhibits show that the predicted changes in bromate and chlorite concentration as a result of the Stage 2 DBPR are expected to be minimal. These changes are minimal in part because bromate and chlorite MCLs already exist.

Another potential increase in health risks is due to increases in N-nitrosodimethylamine (NDMA), which is formed during both the chlorination and the chloramination process (see Section 6.2). Chapter 5 shows that many systems that do not currently meet the Stage 2 requirements will do so by switching to chloramines.

In addition, the baseline of disinfecting systems will increase as ground water systems begin adding disinfection by complying with the Ground Water Rule. In these circumstances, it is assumed that when a system adds disinfection, it will ensure compliance with the Stage 2 DBPR. Essentially, these systems will move from a position of little to no risk (non-disinfecting) to a Post-Stage 2 risk. This increase in risk due to the Ground Water Rule will be small on a national level because of the small population served by most non-disinfecting systems. More detail on this analysis can be found in Appendix M.

Exhibit 6.22a Predicted Chlorite Plant-Mean Concentration for Pre-Stage 2 and Post-Stage 2

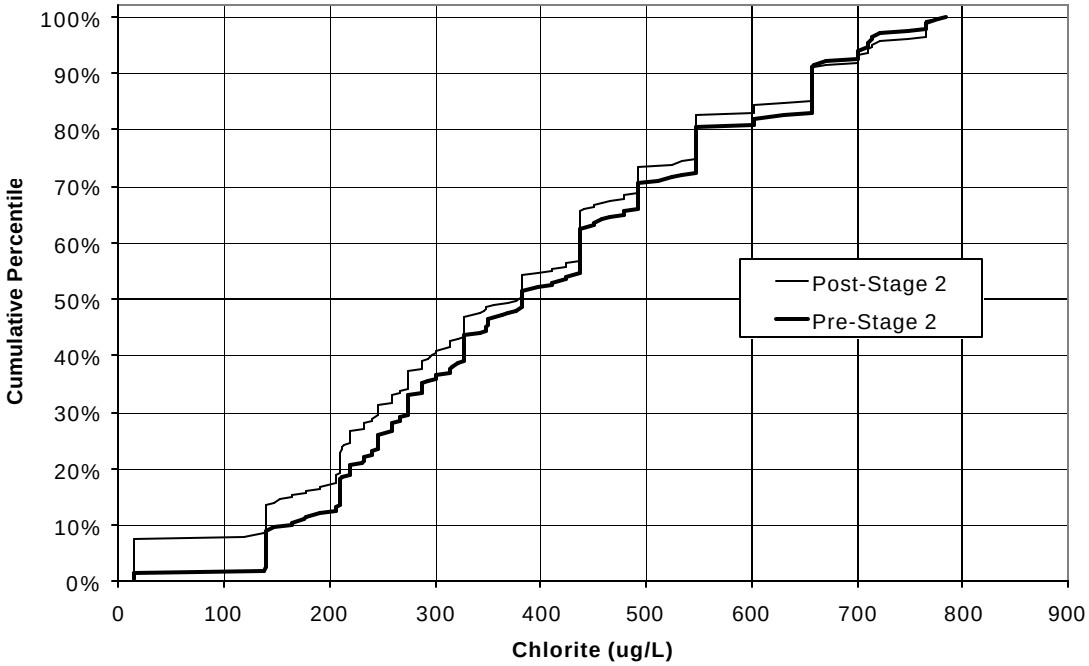
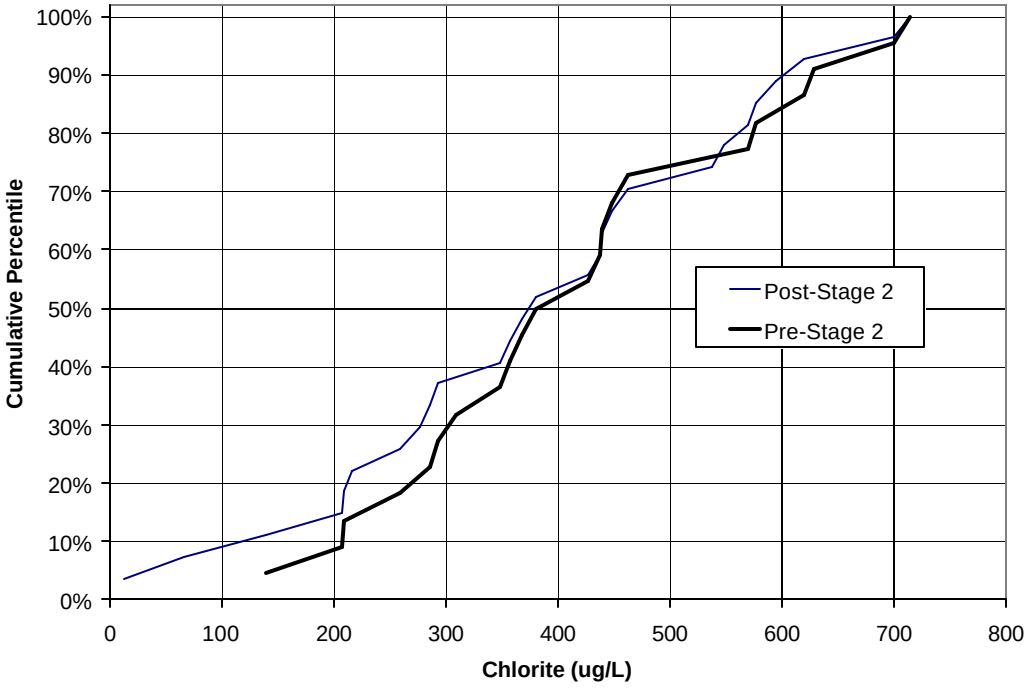


Exhibit 6.22b Predicted Chlorite Monthly Average Concentrations for Pre-Stage 2 and Post-Stage 2



Source: DS Average data from SWAT runs 300 and 303 (USEPA 2001b).

Exhibit 6.23a Predicted Bromate Plant-Mean Concentrations for Pre-Stage 2 and Post-Stage 2

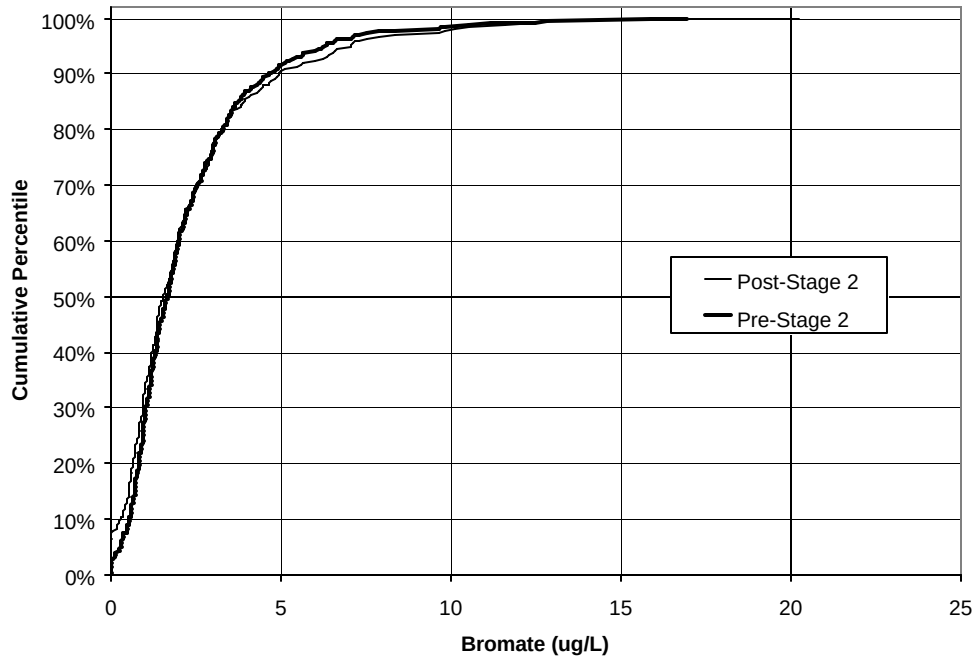
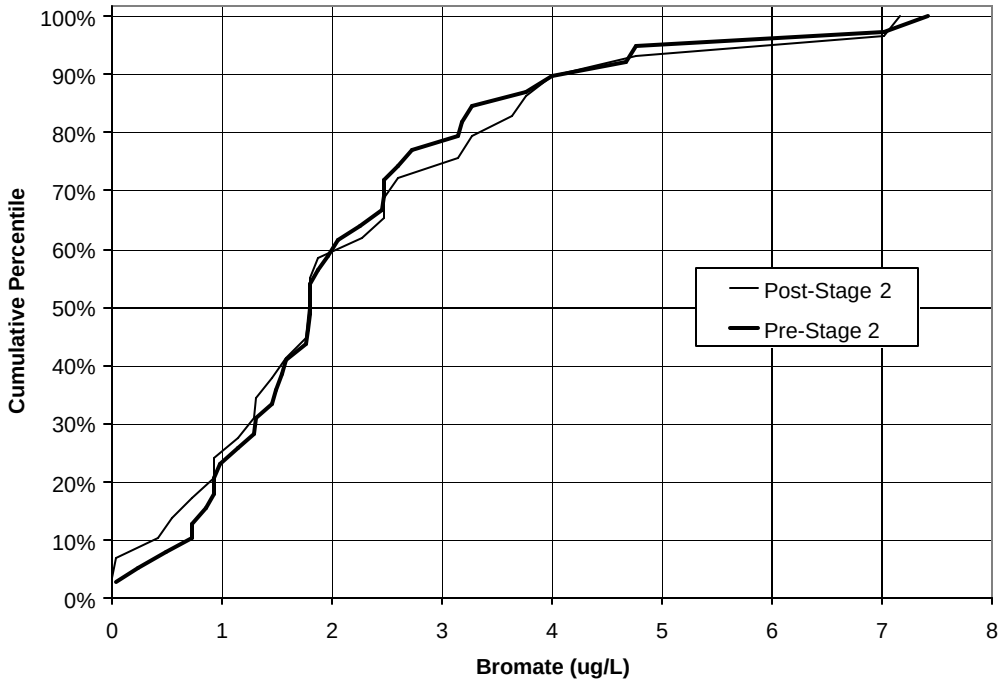


Exhibit 6.23b Predicted Bromate Monthly Average Concentrations for Pre-Stage 2 and Post-Stage 2



Source: DS Average data from SWAT runs 300 and 303 (USEPA 2001b).

6.5 Valuation of Health Benefits for the Stage 2 DBPR

Once the benefits of implementing the Stage 2 DBPR have been identified, a monetary value must be assigned to allow comparison with the costs of the regulation. The following sections draw on the valuation literature to attribute the most appropriate values to each type of benefit derived from the rule. Where the available information is not sufficient to quantify monetary benefits, a qualitative discussion of potential value is presented.

To augment the valuation data from the literature, EPA incorporated into the Stage 2 DBPR analyses recommendations stemming from reviews of previous regulations. In particular, recommendations made by EPA's SAB with regard to the benefits analysis of the recently promulgated Arsenic Rule (66 FR 6976, January 22, 2001) were incorporated into the Stage 2 DBPR analyses as appropriate. Even though these recommendations were made in the context of the arsenic regulation (USEPA 2001d), certain recommendations regarding methodology (e.g., incorporation of cessation lag, calculation and presentation of uncertainties, etc.) are applicable to other impact analyses, including the Stage 2 DBPR. This section is organized as follows:

Section 6.5.1 Presents a qualitative discussion of the value of reductions in potential adverse reproductive developmental health effects derived from the Stage 2 DBPR.

Section 6.5.2 Explains the methodology used for quantitative valuation of reductions in bladder cancer cases attributable to the Stage 2 DBPR.

Section 6.5.3 Summarizes the total potential benefits attributable to the Stage 2 DBPR from implementation of the preferred regulatory alternative (which includes the requirement for the IDSE).

Section 6.5.4 Compares estimated benefits attributable to the preferred regulatory alternative (which includes a requirement for the IDSE) to those estimated for other alternatives.

6.5.1 Value of Reductions in Potential Adverse Reproductive and Developmental Health Effects

Potential adverse reproductive and developmental effects may impose a large economic cost on the nation. Although many miscarriages do not have associated medical costs, some do, with costs ranging from $5,000 to $11,000 depending on the conditions of the miscarriage and the length of stay in the hospital (HCUPnet 2000). The full economic benefit of avoiding a miscarriage would also include the monetary value of forgoing the associated pain, suffering, and loss. Another potential benefit is that the life of the fetus is saved. Avoiding these costs represents one potential economic benefit of the rule.

Low birth weight also imposes costs on society. A report from *The Future of Children* (Lewit et al. 1995) estimates that approximately 40,000 infants die each year as a result of low birth weight and that $5.4 billion is spent each year on the additional services that low-birth-weight children require for health care and, eventually, special education and child care. The Lewit et al. (1995) study also estimates that $5.5 to $6 billion are spent each year caring for low-birth-weight infants and children. It estimates that such children are almost 50 percent more likely than normal-birth-weight children to require special education. Additionally, the costs of caring for low-birth-weight infants is increasing as their chances for survival increase.

The cost for treating and caring for those with birth defects is high. For example, the lifetime cost for a case of spina bifida is estimated at $300,000. Estimates for the lifetime cost of a heart defect range from $100,000 to $400,000 (CDC 1995). These costs account only for the estimated medical, developmental, and special education services attributed to each case. They do not include the pain and suffering of the children with these conditions or the emotional strain on their parents and other family members.

If even a small proportion of fetal losses, low birth weights, premature births, congenital anomalies, and infertility problems are attributable to DBPs, the associated monetary value of benefits from the Stage 2 DBPR would still be great. Given the high cost of medical care, the many ways to value a pregnancy saved, the unknown pain and suffering as a result of potential adverse reproductive and developmental effects, the high percentage of the U.S. population exposed to DBPs, and the large number of pregnant women, the Stage 2 DBPR presents a potential for substantial savings to society. Although uncertainties in the estimation of potentially avoided adverse reproductive and developmental health effects preclude a definitive evaluation of associated benefits in the primary analysis, EPA has conducted a illustrative calculation to estimate a range of possible benefits associated with fetal losses (see Section 6.8).

6.5.2 Value of Reductions in Bladder Cancer Cases

Valuation data for fatal and non-fatal bladder cancer cases are summarized below. This is followed by an explanation of how these data are adjusted to current price levels and for income elasticity effects, allowing proper incorporation into the Stage 2 DBPR benefits model. The next section (6.5.3) describes how these values are combined with the bladder cancer case reductions to yield the total estimated benefits resulting from the Stage 2 DBPR.

Value of Avoiding a Fatal Case of Bladder Cancer

For fatal bladder cancer cases, the value of a statistical life (VSL) is used to calculate the value of benefits. The VSL represents an estimate of the monetary value of reducing risks of premature death from cancer. The VSL does not represent the value of saving a particular individual's life; it represents the sum of the values placed on small individual risk reductions across an exposed population. For example, if a regulation were to reduce the risk of premature death from cancer by 1/1,000,000 for 1 million exposed individuals, the regulation would "save" one statistical life (1,000,000 × 1/1,000,000). If each of the 1,000,000 people were (on average) willing to pay $5 to achieve their risk reduction of 1/1,000,000 anticipated from the regulation, the VSL would be $5 million ($5 × 1,000,000).

An EPA study characterized the range of possible VSL values as a Weibull distribution with a mean of $4.8 million (1990 price level), based on 26 studies (USEPA 1997a). This is the value recommended for use in EPA's *Guidelines for Preparing Economic Analyses* (USEPA 2000j) and endorsed by the SAB (USEPA 2001d). For purposes of the Stage 2 DBPR benefits analysis, the VSL Weibull distribution (with parameters of location = 0, scale = 5.32, shape = 1.51) was incorporated into the benefits model using a Monte Carlo simulation. This allows quantification of the uncertainty surrounding the benefit estimates.

Value of Avoiding the Morbidity Increment of a Fatal Case of Bladder Cancer

The VSL represents the value of avoiding a premature death. This valuation, however, does not explicitly take into account the medical costs associated with the period of illness (morbidity increment) leading up to death. In its review of the Arsenic Rule, the SAB suggested that the appropriate measure to use in valuing the avoidance of the morbidity increment is the medical cost attributable to a cancer case

(USEPA 2001d). Based on available data, EPA estimates the medical costs for a fatal bladder cancer case to be $93,927 at 1996 price levels (USEPA 1999a). This cost (updated to 2003 price levels) is applied as a point estimate to each fatal case of bladder cancer in the benefits model.

Value of Avoiding a Non-fatal Case of Bladder Cancer

For a case of non-fatal bladder cancer, a willingness to pay (WTP) measure is used to estimate the value a person would place on reducing the risk of a case of non-fatal bladder cancer. It accounts for the desire to avoid treatment costs, pain and discomfort, productivity losses, and any other adverse consequences related to contraction of a non-fatal case of bladder cancer. As is the case with VSL valuation, the cumulative WTP for this risk reduction across an exposed population can be used to represent the statistical value of avoiding the illness itself. WTP is a more comprehensive measure of the total value that a person would place on avoiding a cancer case than the much simpler cost of illness (COI) measure.

A review of the available literature did not reveal any studies that specifically measured the WTP to avoid the risk of non-fatal bladder cancer. Instead, two surrogate estimates are used: one based on avoiding a case of curable lymph cancer (lymphoma) and the other based on avoiding a case of chronic bronchitis[4]. Results using both WTP estimates are presented throughout the remainder of the analyses.

The WTP to avoid the risk of contracting curable lymphoma is derived from a survey by Magat et al. (1996) that evaluates the risk-risk trade-off between curable lymphoma and death using a reference lottery metric. A reference lottery is a methodology that educates survey respondents of the health consequences of a particular disease (in this case curable lymphoma) and, based on this information, presents them with choices related to health outcomes. The choices in health outcomes made by the respondents can be further evaluated to derive quantitative measures of relative risk aversion. Based on the outcomes of the Magat et al. study, it was determined that the median risk-risk trade-off (relative risk aversion) for contracting a curable case of lymphoma was equivalent to 58.3 percent of the risk attributed to reducing the chances of sudden death (i.e., the average person would pay 58.3 percent of what they would pay to reduce the risk of sudden death to achieve an equal risk reduction for contracting curable lymphoma). Based on the Magat et al. study results, EPA calculated a WTP distribution for non-fatal bladder cancer as a percentage of the VSL distribution, resulting in a mean WTP value of $2.8 million ($4.8 million × 58.3 percent) at 1990 price levels (see Appendix F, Section F.1 for additional information on the derivation of this WTP estimate).

The WTP values for avoiding the risk of chronic bronchitis are consistent with those defined for the Stage 1 DBPR. They are best represented by a lognormal distribution with a mean of $587,500, standard deviation of $264,826, and a maximum value of $1.5 million at 1998 price values (USEPA 1998a, Viscusi et al. 1991).

Although the WTP to avoid curable lymphoma or chronic bronchitis is not a perfect substitute for the WTP to avoid a case of non-fatal bladder cancer, it is a reasonable value to use in a benefits transfer methodology. Non-fatal internal cancers, regardless of type, generally present patients with very similar treatment, health, and long-term quality of life implications, including surgery, radiation or chemotherapy

[4] Previous EPA analyses (Stage 1 DBPR and Arsenic Rule) used the WTP value for avoiding a case of chronic bronchitis for benefits transfer calculations. The SAB review of the Arsenic benefits analysis identified the curable lymphoma WTP value as another metric that could be used in benefits valuation because "…the endpoint being valued more nearly corresponds to nonfatal bladder cancer…" (USEPA 2001d). The SAB suggested, however, that calculations using the WTP for chronic bronchitis also be presented. This analysis follows the SAB's recommendation.

treatments (with attendant side effects), and generally diminished vitality over the duration of the illness. In the absence of more specific studies, the WTP values for avoiding a case of curable lymphoma or a case of chronic bronchitis provide a reasonable, though not definitive, substitute for the value of avoiding non-fatal bladder cancer.

Updating Price Levels

All valuation parameters must be updated to the same price level so comparisons can be made in real terms. Values for VSL, WTP, and the morbidity increment used in the model are updated based on adjustment factors derived from Bureau of Labor Statistics (BLS) consumer price index (CPI) data so that each represents a year 2003 price level. Exhibit 6.24 presents these updates.

Exhibit 6.24 VSL, WTP, and Morbidity Increment Price Level Updates

Valuation Parameter	Base Year	Mean Value in Base Year (Millions)	CPI Update Factor	Values at Year 2003 Price Level (Millions)			
				Mean	Median	5th %tile	95th %tile
Morbidity Increment	1996	$ 0.1	1.30	$ 0.1	N/A	N/A	N/A
VSL	1990	$ 4.8	1.41	$ 7.8	$ 6.7	$ 1.2	$ 17.9
WTP - Non-Fatal Lymphoma	1990	$ 2.8	1.41	$ 4.4	$ 3.8	$ 0.7	$ 10.1
WTP - Chronic Bronchitis	1998	$ 0.6	1.13	$ 0.8	$ 0.7	$ 0.4	$ 1.4

Note: Morbidity increment value is presented as a point estimate.
Source: Derived from Appendix F (Exhibits F.1a and F.1b).

Adjustments for Real Income Growth and Elasticity

Although the price level (year 2003) is held constant throughout the benefits model, projections of benefits in future years are subject to income elasticity adjustments. These represent changes in valuation in relation to changes in real income. For example, if, for every 1 percent increase in real income, a particular consumer's WTP for a particular item increases by 1 percent, this would be represented by an income elasticity of 1. For most items, income elasticity values are actually less than 1, indicating that valuation of most items does not increase as fast as real income levels.

Based on an evaluation of the income elasticity literature, Kleckner and Neuman (2000) identified published studies from which elasticity values could be derived for both fatal and non-fatal potential health effects. For fatal cancers, they identified a triangular distribution with a central estimate of 0.40 (low end: 0.08; high end:1.00) to represent the uncertainty of that income elasticity value. For non-fatal cancers, a triangular distribution with a central estimate of 0.45 (low end: 0.25; high end: 0.60) best represents the value. These distributions are used as assumptions in the Monte Carlo simulation to further characterize uncertainty in benefits estimates.

To apply the income elasticity values in the model, they must be combined with projections of real income growth over the time frame for analysis. Population and real gross domestic product (GDP)

projections are combined to calculate per-capita real GDP values.[5] Percent changes in these values over time can then be combined with income elasticity figures to derive a single adjustment factor.[6] Given any two time periods, this factor can be calculated as follows:

$$\text{Income elasticity adjustment factor} = (eI_1 - eI_2 - I_2 - I_1) / (eI_2 - eI_1 - I_2 - I_1)$$

where: e = income elasticity
I_1 = real income (per-capita GDP) in the base year
I_2 = real income (per-capita GDP) in the year of analysis

Income elasticity adjustment factors are calculated from the same base year as the values subject to adjustment. For example, income elasticity factors for fatal cancers are calculated from a 1990 base year because that is the base year used in the study from which VSL estimates are derived.[7] The mean values of the income adjustment factors calculated for the Stage 2 benefits model range from 1.160 to 1.488 for fatal cancer valuation and 1.063 to 1.400 for non-fatal valuation over the 25-year analysis time frame (Appendix F presents detailed spreadsheets of these calculations). The adjusted yearly values for the VSL and WTP (at a 2003 price level) are then calculated by multiplying the base value of each by the appropriate income elasticity adjustment factor.[8] Exhibit 6.25 presents the results of the income elasticity adjustments for the 25-year analysis time frame.[9]

In the Stage 2 benefits analysis the income-adjusted VSL estimates are applied to the year in which cases have been avoided. An alternative approach supported by some economists, and used in other EPA analyses, is for the income adjustments to be applied only up to the time that exposures are reduced rather than over the cessation lag. Because of the shorter time period over which income growth would be calculated the alternative would result in smaller income adjustment. To use the alternative EPA would need to link the year cancers are avoided to a specific year of exposure reduction. This cannot be done with the risk assessment and cessation lag application in the Stage 2 analysis, where estimated cases avoided are based on a transition from one steady state to another. The VSL income adjustment approach used in this EA will tend to overstate benefits somewhat relative to the alternative described above. EPA

[5] Ideally, income elasticity adjustments would be calculated using real per capita personal income growth. However, real per capita GDP is used as a proxy for real per capita personal income growth due to lack of appropriate projections for real personal income growth. Historical data suggests that GDP and personal income grow at similar rates (i.e., Table B-31 of the 2002 Economic Report of the President shows that both real per capita GDP and disposable personal income grew at an average annual rate of 2.3 percent between 1959 and 2000).

[6] See Appendix A of Kleckner and Neuman (2000) for additional information on the derivation and application of income elasticity adjustments.

[7] The distribution of VSL values used in this EA is derived from a meta-analysis of 26 different VSL studies, all representing different years price levels. These price levels were updated to a common 1990 price level as part of the analysis in "The Benefits and Costs of the Clean Air Act, 1970-1990" (USEPA 1997b), from which the distribution used in this EA is taken.

[8] Because the morbidity increment represents a point estimate of direct medical costs, and income elasticity figures used in this analysis are based on WTP values, income elasticity adjustments were not applied to the projected morbidity increment values (only the CPI update factor is applied).

[9] A 25-year analysis time frame was chosen to represent the period before which most systems would need to reinvest in capital equipment replacement (a 20-year useful life is assumed for the analysis). Since the benefits, as derived in this analysis, are a result of installing treatment equipment, this time frame was also applied to benefit projections.

recognizes this potential bias, but notes that is small in comparison to other uncertainties in valuation, as well as uncertainties in the risk assessment and estimates of cases avoided.

Exhibit 6.25 Value of Morbidity Increment, VSL, and WTP by Year, Adjusted for Income Elasticity

	Fatal Cancer Cases					Non-Fatal Cancer Cases							
	Morbidity Increment	VSL				WTP - Non-Fatal Lymphoma				WTP - Bronchitis			
				90% Confidence Interval				90% Confidence Interval				90% Confidence Interval	
Year	Point Estimate	Mean Value	Median Value	5th %tile	95th %tile	Mean Value	Median Value	5th %tile	95th %tile	Mean Value	Median Value	5th %tile	95th %tile
2005	0.12	7.76	6.73	1.19	17.91	4.43	3.85	0.68	10.13	0.80	0.74	0.36	1.45
2006	0.12	7.85	6.81	1.20	18.12	4.48	3.89	0.69	10.24	0.81	0.75	0.37	1.46
2007	0.12	7.95	6.88	1.21	18.33	4.53	3.93	0.70	10.36	0.82	0.75	0.37	1.48
2008	0.12	8.03	6.95	1.23	18.55	4.57	3.97	0.70	10.45	0.82	0.76	0.37	1.49
2009	0.12	8.12	7.03	1.24	18.76	4.61	4.00	0.71	10.57	0.83	0.77	0.38	1.51
2010	0.12	8.22	7.10	1.25	18.99	4.66	4.04	0.71	10.67	0.84	0.78	0.38	1.52
2011	0.12	8.31	7.18	1.26	19.24	4.70	4.08	0.72	10.76	0.85	0.78	0.38	1.54
2012	0.12	8.40	7.25	1.28	19.43	4.74	4.12	0.73	10.85	0.86	0.79	0.39	1.55
2013	0.12	8.49	7.33	1.29	19.64	4.79	4.16	0.74	10.95	0.86	0.80	0.39	1.56
2014	0.12	8.59	7.41	1.30	19.87	4.83	4.20	0.74	11.07	0.87	0.81	0.40	1.58
2015	0.12	8.68	7.48	1.31	20.13	4.88	4.24	0.75	11.16	0.88	0.81	0.40	1.60
2016	0.12	8.78	7.57	1.32	20.34	4.92	4.28	0.76	11.27	0.89	0.82	0.40	1.61
2017	0.12	8.88	7.64	1.34	20.62	4.97	4.32	0.77	11.38	0.90	0.83	0.41	1.63
2018	0.12	8.98	7.72	1.35	20.86	5.02	4.36	0.77	11.49	0.91	0.84	0.41	1.64
2019	0.12	9.08	7.81	1.36	21.15	5.06	4.40	0.78	11.61	0.91	0.85	0.41	1.66
2020	0.12	9.18	7.89	1.37	21.40	5.11	4.44	0.79	11.72	0.92	0.85	0.42	1.67
2021	0.12	9.28	7.97	1.38	21.67	5.16	4.48	0.79	11.82	0.93	0.86	0.42	1.69
2022	0.12	9.38	8.05	1.40	21.95	5.20	4.52	0.80	11.94	0.94	0.87	0.43	1.71
2023	0.12	9.49	8.15	1.41	22.20	5.25	4.56	0.81	12.06	0.95	0.88	0.43	1.72
2024	0.12	9.59	8.23	1.42	22.45	5.30	4.60	0.82	12.17	0.96	0.89	0.43	1.74
2025	0.12	9.70	8.32	1.43	22.71	5.34	4.64	0.82	12.28	0.97	0.89	0.44	1.76
2026	0.12	9.80	8.41	1.45	22.96	5.39	4.69	0.83	12.40	0.98	0.90	0.44	1.78
2027	0.12	9.91	8.49	1.46	23.28	5.44	4.73	0.84	12.52	0.99	0.91	0.45	1.79
2028	0.12	9.87	8.46	1.46	23.17	5.42	4.71	0.84	12.48	0.98	0.91	0.44	1.79
2029	0.12	9.95	8.52	1.47	23.40	5.46	4.74	0.84	12.56	0.99	0.91	0.45	1.80

Source: Exhibit F.1f

6.5.3 Value of Benefits Resulting from the Stage 2 DBPR for the Preferred Alternative

To assess the total value of benefits resulting from the Stage 2 DBPR, both the qualitative and quantitative benefits must be considered. Although information is not sufficient to quantify the value of preventing potential adverse reproductive and developmental health effects in the primary benefits analysis, the number of cases avoided and associated value could be significant (see Section 6.8). Likewise, the value of other health and non-health benefits could be substantial, for example reduction in risk of other cancers and reductions in other regulated contaminants. Thus, the primary, quantitative benefits analysis is a conservative estimate of the total benefits of this regulation.

To calculate the total value of benefits derived from reductions in bladder cancer cases as a result of the Stage 2 DBPR, a stream of monetary benefits is calculated by combining the annual cases avoided (Exhibit 6.21) with valuation inputs (Exhibit 6.25) using a Monte Carlo simulation. The Monte Carlo simulation allows the characterization of uncertainty around the modeling outputs based on the uncertainty in the various inputs. The benefits model uses distributions of VSL, WTP, and income elasticity values to attribute monetary values (with uncertainty bounds) to the number of bladder cancer cases avoided. The values for cancer cases avoided for the three cessation lag models and for both WTP estimates (for curable lymphoma and chronic bronchitis) were calculated and carried through the Stage 2 DBPR benefits model. The results for fatal, non-fatal, and total benefits are presented in Exhibits 6.26 (note that the alternative analysis assumptions, e.g. Arsenic/Bladder Cancer Cessation Lag model, WTP for Lymphoma, are shown in the table headings).

Calculating and Discounting the Stream of Benefits

To allow comparison of future streams of costs and benefits, it is common practice to adjust both streams to a present value (PV) using a discount rate. This process takes into account the time preference that society places on expenditures and benefits and allows comparison of cost and benefit streams that vary over a given time period.[10] A present value for any future period can be calculated using the following equation:

$$PV = V(t) / (1 + R)^t$$

Where: t = The number of years from the reference period (year 0 of the benefits stream)
R = Discount rate
V(t) = The benefits occurring t years from the reference period

There is much discussion among economists of the proper discount rate to use for policy analysis. Therefore, for Stage 2 DBPR benefits analyses, PV calculations are made using two rates thought to best represent current policy evaluation methodologies, 3 and 7 percent. Historically, the use of 3 percent is based on rates of return on relatively risk-free investments, as described in the *Guidelines for Preparing Economic Analyses* (USEPA 2000j). The rate of 7 percent is recommended by OMB as an estimate of "before-tax rate of return to incremental private investment" (USEPA 1996b). To allow evaluation on an annual basis, the PV of benefits is annualized using the same discount rates. Exhibit 6.28 presents the annualized present value of estimated benefits for the Stage 2 DBPR over the 25-year time frame for analysis.

[10] See EPA's *Guidelines for Preparing Economic Analyses* (USEPA 2000j) for a full discussion of the use of discount rates in the evaluation of policy decisions.

Exhibit 6.26a Non-Discounted Stream of Benefits from the Stage 2 DBPR Preferred Regulatory Alternative, All Systems, WTP Curable Lymphoma, TTHM as Indicator

	Smoking/Lung Cancer Cessation Lag Model			Smoking/Bladder Cancer Cessation Lag Model			Arsenic/Bladder Cancer Cessation Lag Model		
		90% Confidence Interval			90% Confidence Interval			90% Confidence Interval	
Year	Mean Value	5th %tile	95th %tile	Mean Value	5th %tile	95th %tile	Mean Value	5th %tile	95th %tile
2005	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2006	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2007	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2008	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2009	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2010	$ 133	$ 20	$ 307	$ 126	$ 19	$ 291	$ 250	$ 38	$ 575
2011	$ 345	$ 53	$ 794	$ 300	$ 46	$ 689	$ 613	$ 94	$ 1,409
2012	$ 625	$ 96	$ 1,435	$ 511	$ 78	$ 1,173	$ 1,058	$ 162	$ 2,429
2013	$ 968	$ 148	$ 2,223	$ 755	$ 116	$ 1,735	$ 1,568	$ 240	$ 3,602
2014	$ 1,264	$ 193	$ 2,906	$ 925	$ 141	$ 2,127	$ 1,924	$ 294	$ 4,422
2015	$ 1,543	$ 236	$ 3,549	$ 1,072	$ 164	$ 2,465	$ 2,205	$ 337	$ 5,072
2016	$ 1,798	$ 275	$ 4,134	$ 1,200	$ 183	$ 2,759	$ 2,427	$ 371	$ 5,580
2017	$ 2,028	$ 310	$ 4,668	$ 1,316	$ 201	$ 3,030	$ 2,606	$ 398	$ 5,999
2018	$ 2,230	$ 340	$ 5,138	$ 1,425	$ 217	$ 3,284	$ 2,757	$ 420	$ 6,352
2019	$ 2,403	$ 366	$ 5,546	$ 1,529	$ 233	$ 3,528	$ 2,886	$ 440	$ 6,660
2020	$ 2,554	$ 389	$ 5,897	$ 1,627	$ 248	$ 3,757	$ 2,998	$ 457	$ 6,922
2021	$ 2,687	$ 409	$ 6,204	$ 1,722	$ 262	$ 3,976	$ 3,098	$ 471	$ 7,152
2022	$ 2,806	$ 427	$ 6,489	$ 1,813	$ 276	$ 4,194	$ 3,187	$ 485	$ 7,370
2023	$ 2,913	$ 443	$ 6,739	$ 1,901	$ 289	$ 4,399	$ 3,267	$ 497	$ 7,558
2024	$ 3,011	$ 458	$ 6,969	$ 1,987	$ 302	$ 4,598	$ 3,341	$ 508	$ 7,733
2025	$ 3,102	$ 471	$ 7,179	$ 2,070	$ 314	$ 4,790	$ 3,410	$ 518	$ 7,893
2026	$ 3,186	$ 483	$ 7,381	$ 2,150	$ 326	$ 4,981	$ 3,475	$ 527	$ 8,049
2027	$ 3,266	$ 494	$ 7,576	$ 2,229	$ 337	$ 5,171	$ 3,536	$ 535	$ 8,203
2028	$ 3,297	$ 500	$ 7,646	$ 2,276	$ 345	$ 5,277	$ 3,548	$ 538	$ 8,226
2029	$ 3,360	$ 508	$ 7,797	$ 2,344	$ 355	$ 5,441	$ 3,594	$ 544	$ 8,342
Ann. Avg.	$ 1,741	$ 265	$ 4,023	$ 1,171	$ 178	$ 2,707	$ 2,070	$ 315	$ 4,782

Notes: All values in millions of year 2003 dollars. Detail may not add to totals due to independent rounding.
EPA recognizes that benefits may be as low as zero since causality has not yet been established between exposure to chlorinated water and bladder cancer.

Source: Exhibit F.2u.

Exhibit 6.26b Non-Discounted Stream of Benefits from the Stage 2 DBPR Preferred Regulatory Alternative, All Systems, WTP Chronic Bronchitis, TTHM as Indicator

	Smoking/Lung Cancer Cessation Lag Model			Smoking/Bladder Cancer Cessation Lag Model			Arsenic/Bladder Cancer Cessation Lag Model		
		90% Confidence Interval			90% Confidence Interval			90% Confidence Interval	
Year	Mean Value	5th %tile	95th %tile	Mean Value	5th %tile	95th %tile	Mean Value	5th %tile	95th %tile
2005	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2006	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2007	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2008	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2009	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
2010	$ 66	$ 15	$ 145	$ 62	$ 14	$ 137	$ 124	$ 27	$ 272
2011	$ 171	$ 38	$ 376	$ 148	$ 33	$ 326	$ 303	$ 67	$ 667
2012	$ 309	$ 68	$ 680	$ 253	$ 55	$ 556	$ 523	$ 115	$ 1,151
2013	$ 479	$ 105	$ 1,054	$ 374	$ 82	$ 823	$ 776	$ 170	$ 1,708
2014	$ 626	$ 137	$ 1,379	$ 458	$ 100	$ 1,009	$ 953	$ 209	$ 2,098
2015	$ 765	$ 167	$ 1,687	$ 531	$ 116	$ 1,172	$ 1,093	$ 239	$ 2,411
2016	$ 892	$ 195	$ 1,966	$ 595	$ 130	$ 1,312	$ 1,204	$ 263	$ 2,654
2017	$ 1,007	$ 220	$ 2,224	$ 654	$ 143	$ 1,443	$ 1,294	$ 282	$ 2,858
2018	$ 1,108	$ 241	$ 2,448	$ 708	$ 154	$ 1,565	$ 1,370	$ 298	$ 3,027
2019	$ 1,195	$ 260	$ 2,647	$ 760	$ 165	$ 1,684	$ 1,435	$ 312	$ 3,178
2020	$ 1,271	$ 276	$ 2,817	$ 810	$ 176	$ 1,795	$ 1,492	$ 324	$ 3,307
2021	$ 1,338	$ 290	$ 2,970	$ 858	$ 186	$ 1,903	$ 1,543	$ 334	$ 3,424
2022	$ 1,399	$ 303	$ 3,110	$ 904	$ 196	$ 2,010	$ 1,589	$ 344	$ 3,532
2023	$ 1,454	$ 314	$ 3,232	$ 949	$ 205	$ 2,109	$ 1,630	$ 352	$ 3,625
2024	$ 1,504	$ 324	$ 3,345	$ 992	$ 214	$ 2,207	$ 1,669	$ 360	$ 3,712
2025	$ 1,550	$ 334	$ 3,451	$ 1,034	$ 223	$ 2,303	$ 1,705	$ 367	$ 3,794
2026	$ 1,594	$ 342	$ 3,549	$ 1,076	$ 231	$ 2,395	$ 1,738	$ 373	$ 3,871
2027	$ 1,635	$ 351	$ 3,650	$ 1,116	$ 239	$ 2,491	$ 1,770	$ 380	$ 3,952
2028	$ 1,650	$ 354	$ 3,681	$ 1,139	$ 244	$ 2,541	$ 1,776	$ 381	$ 3,960
2029	$ 1,683	$ 361	$ 3,759	$ 1,174	$ 252	$ 2,623	$ 1,800	$ 386	$ 4,022
Ann. Avg.	$ 868	$ 188	$ 1,927	$ 584	$ 126	$ 1,296	$ 1,032	$ 223	$ 2,289

Notes: All values in millions of year 2003 dollars. Detail may not add to totals due to independent rounding.
EPA recognizes that benefits may be as low as zero since causality has not yet been established between exposure to chlorinated water and bladder cancer.

Source: Exhibit F.3u.

Exhibit 6.27 Benefits Summary for the Stage 2 DBPR, Preferred Regulatory Alternative (Millions, 2003$)

Approach (PAR Source)	Best Estimate Pre-Stage 1 PAR	Best Estimate Annual Cases Ultimately Avoided[2]	Annualized Expected Benefits 3%[3] (Millions, 2003$)	Annualized Expected Benefits 7%[3] (Millions, 2003$)
	A	B	C	D
Approach 1: "5 Studies"	2% or 17% (0%, 33%)	64 or 544 (0, 1057)	$352 or $2,988 ($0, $6,884)	$286 or $2,432 ($0, $5,600)
Approach 2: Villaneuva 2003	15.7% (8.5%, 27.2%)	504 (274, 872)	$2,768 ($627, $5,677)	$2,253 ($510, $4,619)
Approach 3: Villaneuva 2004	17.1% (2.5%, 33.1%)	548 (80, 1061)	$3,008 ($183, $6,911)	$2,449 ($149, $5,622)

Notes: Detail may not add to totals due to independent rounding.
[1] Based on TTHM as indicator. EPA recognizes that benefits may be as low as zero since causality has not yet been established between exposure to chlorinated water and bladder cancer.
[2] The estimate of annual cases ultimately avoided shown here are those calculated from the PAR values as described in 6.4.1.1. The full benefits simulation model, which incorporates uncertainty in the impacts of the IDSE and uncertainty in SWAT predictive equations, and in the estimates of PAR, produces slightly higher mean estimates. Specifically, the model estimates 577 cases versus the 504 cases shown here for Approach 2. Cases avoided have not yet been discounted.
[3] The 90 percent confidence bounds for benefits incorporates uncertainty in the cases avoided as well as the VSL, WTP, and income elasticity adjustment.
Source: (A) Exhibit 6.20.
(B) Exhibit E.19.
(C, D) The cases avoided from column B multiplied by the annualized benefits per case, derived from Exhibit 6.28.

Exhibit 6.28 Benefits Summary for the Stage 2 DBPR, Preferred Regulatory Alternative (Millions, 2003$)

Adverse Reproductive and Developmental Health Effects Avoided							
Causality has not been established, and numbers and types of cases avoided, as well as the value of such cases, were not quantified in the primary benefits analysis. Given the numbers of women of child-bearing age exposed (58 million), the evidence indicates that the number of cases and the value of preventing those cases could be significant. See results of the illustrative calculation in Section 6.8.							
Number and Value of Estimated Bladder Cancer Cases Avoided [1]							
Causality has not been established; however, the weight of evidence supports PAR estimates of potential benefits.							
Cessation Lag Model used to estimate Annual Bladder Cancer Cases Avoided	**Annual Average Bladder Cancer Cases Avoided for the first 25 years [2]**			**Discount Rate, WTP for Non-Fatal Bladder Cancer Cases**	**Annualized Benefits of Bladder Cancer Cases Avoided (Millions, 2003$)**		
	Mean	**5th**	**95th**		**Mean**	**5th**	**95th**
Smoking/Lung Cancer Model	277	101	540	3 %, Lymphoma	$ 1,523	$ 232	$ 3,518
				7 % Lymphoma	$ 1,240	$ 189	$ 2,862
				3 % Bronchitis	$ 759	$ 164	$ 1,684
				7 % Bronchitis	$ 617	$ 134	$ 1,368
Smoking/Bladder Cancer Model	187	60	398	3 %, Lymphoma	$ 1,027	$ 156	$ 2,373
				7 % Lymphoma	$ 840	$ 128	$ 1,940
				3 % Bronchitis	$ 512	$ 111	$ 1,135
				7 % Bronchitis	$ 418	$ 91	$ 927
Arsenic/Bladder Cancer Model	332	136	610	3 %, Lymphoma	$ 1,842	$ 280	$ 4,254
				7 % Lymphoma	$ 1,537	$ 234	$ 3,547
				3 % Bronchitis	$ 918	$ 199	$ 2,035
				7 % Bronchitis	$ 765	$ 166	$ 1,694
Other Health Benefits							
Qualitative assessment indicates that the value of other health benefits could be positive and significant.							
Non-Health Benefits							
Qualitative assessment indicates that the value of non-health benefits could be positive.							

Notes: Detail may not add to totals due to independent rounding.
[1] Based on TTHM as indicator. EPA recognizes that benefits may be as low as zero since causality has not yet been established between exposure to chlorinated water and bladder cancer.
[2] The 90 percent confidence bounds for annual average cases avoided incorporates uncertainty in the impacts of the IDSE and uncertainty in SWAT predictive equations, and in the estimates of PAR. Cases avoided have not yet been discounted.
[3] The 90 percent confidence bounds incorporates uncertainty in the cases avoided as well as the VSL, WTP, and income elasticity adjustment.
Source: Summarized from detailed figures presented in Appendix E (Exhibits E.38d, E.38h, E.38i) and F (Exhibits F.2v and F.2w, F.3v and F.3w).

6.5.4 Comparison of the Value of Benefits for Regulatory Alternatives

This section compares the benefits of decreasing DBP occurrence under the Stage 2 DBPR preferred alternative with the three evaluated alternatives. The alternatives are summarized below (see Chapter 4 for a more detailed discussion):

Preferred Alternative: 80 µg/L TTHM and 60 µg/L HAA5 as an LRAA; bromate MCL of 10 µg/L as an RAA based on monthly samples taken at the finished water point (no change from the Stage 1 DBPR for bromate); compliance monitoring proceeded by the IDSE.

Alternative 1: 80 µg/L TTHM and 60 µg/L HAA5 as an LRAA; bromate MCL of 5µg/L as an RAA based on monthly samples taken at the finished water point.

Alternative 2: 80 µg/L TTHM and 60 µg/L HAA5 as the single maximum value for any sample taken during the year; bromate MCL of 10 µg/L as an RAA based on monthly samples taken at the finished water point (no change from the Stage 1 DBPR for bromate).

Alternative 3: 40 µg/L TTHM and 30 µg/L HAA5 as an RAA of all distribution samples taken; bromate MCL of 10 µg/L as an RAA based on monthly samples taken at the finished water point (no change from the Stage 1 DBPR for bromate).

Exhibit 6.29 compares the value of benefits for all Stage 2 DBPR regulatory alternatives, using TTHM as an indicator for reduction in all chlorination DBPs. Although the primary objective of the Stage 2 DBPR is to reduce the non-quantified risks of adverse potential reproductive and developmental health effects, the exhibit also shows that the quantified benefits of reducing cancer cases are considerable regardless of which alternative is chosen. Chapter 7 examines the costs of these alternatives, and Chapter 9 compares their benefits and costs.

Exhibit 6.29 Number and Annualized Value of Estimated Bladder Cancer Cases Avoided for All Stage 2 DBPR Regulatory Alternatives, Villanueva et al. (2003) for Baseline Risk (Millions, 2003$) [1]

	Discount Rate, WTP for Non-Fatal Cases	Preferred Alternative			Alternative 1			Alternative 2			Alternative 3		
		Mean	5th	95th	Mean	5th	95th	Mean	5th	95th	Mean	5th	95th
Average Annual Number of Cases Avoided [2]	–	277	101	540	249	126	395	928	477	1,449	1,273	663	1,954
Annualized Benefits of Cases Avoided[3]	3%, Lymphoma	$ 1,523	$ 232	$ 3,518	$ 1,368	$ 208	$ 3,160	$ 5,103	$ 776	$ 11,787	$ 7,005	$ 1,066	$ 16,181
	7%, Lymphoma	$ 1,240	$ 189	$ 2,862	$ 1,119	$ 170	$ 2,583	$ 4,174	$ 636	$ 9,636	$ 5,731	$ 873	$ 13,230
	3%, Bronchitis	$ 759	$ 164	$ 1,684	$ 682	$ 148	$ 1,512	$ 2,542	$ 551	$ 5,640	$ 3,490	$ 756	$ 7,743
	7%, Bronchitis	$ 617	$ 134	$ 1,368	$ 557	$ 121	$ 1,235	$ 2,078	$ 451	$ 4,606	$ 2,853	$ 619	$ 6,324

Notes: [1]Based on TTHM as indicator, and the smoking and lung cancer cessation lag model. EPA recognizes that benefits may be as low as zero since causality has not yet been established between exposure to chlorinated water and bladder cancer.
[2]The 90 percent confidence bounds for annual average cases avoided incorporates uncertainty in the impacts of the IDSE and uncertainty in SWAT predictive equations, and in the estimates of PAR.
[3]The 90 percent confidence bounds incorporates uncertainty in the cases avoided as well as the VSL, WTP, and income elasticity adjustment.
[4]The Preferred Alternative avoids more cases of bladder cancer than the next least expensive alternative (Alternative 1) because incorporating the IDSE, which increases benefits, is only considered under the Preferred Alternative (explained further in Chapter 4). Additionally, Alternative 1 would capture more benefits if potential cancer cases avoided by lowering the bromate standard (included only in Alternative 1) were quantified.

Source: Summarized from detailed figures presented in Appendix E (Exhibits E.38d, E.38h, E.38i) and Appendix F (Exhibits F.2v and w, F.3v and w, F.6b, F.7b, F.8b, F.9b, F.10b, F.11b).

6.6 Uncertainties

Many factors contribute to uncertainty in national benefits estimates. Uncertainty exists in model inputs such as the estimated PAR values and the cessation lag models. To assess uncertainty in the approach used to estimate the number of bladder cancer cases in the baseline that can be attributed to DBP occurrence and exposure, and the number of cases that can be avoided by implementation of the Stage 2 DBPR, three approaches were used to estimate Pre-Stage 1 PAR (see Appendix E for more detail). To quantify uncertainty in cessation lag, three independent cessation lag models derived from three different epidemiological studies are used. Also, two functional forms are used for each of these data sets and uncertainty in the parameters of those functions is included in the analysis (see Appendix E for more detail). For monetization of benefits, EPA uses two alternatives for valuing non-fatal bladder cancer. Other uncertainties, such as the linear relationship between DBP reductions and reductions in bladder cancer cases avoided, are discussed qualitatively. A summary of the key uncertainties and the effects of uncertainty in those assumptions on the benefits and cost analyses are presented in Exhibit 6.29.

EPA believes that uncertainty in the compliance forecast has a potentially large influence on benefit (and cost) estimates in this EA. Thus, the Agency has attempted to quantify the most important uncertainties in the compliance forecast (see Chapter 5). The predicted reductions in DBPs resulting from the use of alternative compliance forecast methodologies are incorporated into the cost model using Monte Carlo probability functions.

Two of the greatest uncertainties affecting the benefits of the Stage 2 DBPR are related to non-quantified benefits estimates. Both of these factors result in an underestimation of quantified Stage 2 DBPR benefits. To inform the reader of the potential magnitude of these benefits, Section 6.7 provides results from a sensitivity analysis for colon and rectal cancers combined. An illustrative analysis of potential developmental and reproductive benefits of the Stage 2 DBPR is discussed in Section 6.8.

In addition to the uncertainties listed in Exhibit 6.30, the potential costs or benefits of a possible interactive effect from the promulgation of more than one rule in a short period of time are also not quantified. EPA has taken into account compliance with the Stage 1 DBPR and considered the potential impacts of the Ground Water Rule on non-treatment costs in Appendix H, and considered potential impacts of the Arsenic Rule, and the LT2ESWTR. EPA addresses potential increased risk due to ground water systems adding disinfection under the Ground Water Rule in Appendix M.

Exhibit 6.30 Uncertainties and Possible Effect on Estimate of Benefits

Uncertainty	Section with Full Discussion of Uncertainty	Effect on Benefit Estimate		
		Under-estimate	Over-estimate	Unknown Impact
Uncertainty in DBP reductions for surface water systems	Chapter 5	Quantified in the primary analysis (accounts for potential underestimate or overestimate)		
Uncertainty in DBP reductions for ground water systems	Chapter 5			X
Analysis of reduction in DBP occurrence does not include results of IDSE	5.3	Quantified in the primary analysis (accounts for potential underestimate)		

Uncertainty	Section with Full Discussion of Uncertainty	Effect on Benefit Estimate		
		Under-estimate	Over-estimate	Unknown Impact
Uncertainty in valuation inputs (WTP and VSL)	6.5.2	Quantified in the primary analysis (accounts for potential underestimate or overestimate)		
Uncertainty in the bladder cancer PAR value[1]	6.1.1 Appendix E	Quantified in the primary analysis (accounts for potential underestimate or overestimate)		
Analysis of exposure reduction assumes TTHM and HAA5 to be proxies for all chlorination DBPs	6.3.3			X
DBPs have a linear no-threshold dose-response relationship for bladder cancer effects	6.2.1			X
Uncertainty in cessation lag function	6.4.2.2 Appendix E	Quantified in the primary analysis (accounts for potential underestimate or overestimate)		
Benefits of reduced cancers other than bladder cancer are not included in the quantitative analysis	6.7	Quantified in a sensitivity analysis (accounts for potential underestimate)		
Value of potential reproductive and developmental health effects avoided is not quantified in the primary analysis	6.8	Quantified in an illustrative calculation (accounts for potential underestimate)		

[1] To assess uncertainty in PAR estimates, three approaches were used to estimate Pre-Stage 1 PAR, as shown in Appendix E of the EA. PAR value average estimate of 16 percent used to calculate the number of bladder cancer cases avoided is not absolute. EPA recognizes that the number of cases may be as low as zero since causality has not yet been established between exposure to chlorinated water and bladder cancer.

6.7 Sensitivity Analysis for Other Cancers

Colon and rectal cancers combined are the third most common site (excluding skin) of new cases and deaths in both men and women in the U.S. The American Cancer Society (ACS) estimated that 104,950 new colon and rectal cancer cases will be diagnosed in 2005, with 56,290 resulting in deaths (ACS 2005). Human epidemiology studies on chlorinated surface water have reported associations with colon and rectal cancers.

In the development of the Stage 1 DBPR, EPA investigated estimating a PAR for colon and rectal cancers and concluded that the data was not conclusive enough to calculate a PAR. Prior to the Stage 1 DBPR, several population-based case control and prospective cohort studies had been published that evaluated the association between consumption of chlorinated drinking water and colon cancer (Cragle 1985, Young 1987, Doyle 1997, Hildesheim 1998). Cragle et al. (1985), a hospital-based case-control study, and Young et al. (1987), a case-control study, were excluded due to inadequate exposure assessment. Doyle et al. (1997), a prospective cohort study, indicated that in comparison with women who used municipal ground water sources, women with municipal surface water sources were at an increased risk of colon cancer and all cancers combined. Hildesheim et al. (1998) did not report a significant increase in risk of colon cancer associated with duration of chlorinated surface water use. Two epidemiological studies examined rectal cancer (Doyle 1997, Hildesheim 1998). Doyle (1997) did not

report an association between consumption of chlorinated surface water and cancer of the rectum and anus. Hildesheim (1998) indicated an association between rectal cancer and exposure to chlorinated water. Based on these studies for colon and for rectal cancer, it was not possible to estimate a PAR range at the time of the Stage 1 DBPR.

Since the Stage 1 DBPR, other human epidemiology studies have been conducted to investigate the potential relationship between colon and rectal cancers and exposure to chlorinated surface water (King et al. 2000a, Yang et al. 1998). The database of studies on colon and rectal cancers continues to support a possible association, but evidence remains mixed. King et al. (2000a), a population-based case-control study, found evidence of an increased colon cancer risk for males with cumulative exposure to THMs and duration of exposure to chlorinated surface water. No associations were observed between exposure measures and rectal cancer. Yang et al. (1998), a cross-sectional study, found an association between chlorinated drinking water exposure and rectal cancer, and the associations had a similar magnitude in both sexes. No association was seen for colon cancer.

Since the area of the colon and rectum is the third most common site (excluding skin) of new cases and deaths in both men and women in the U.S., and human epidemiology studies on chlorinated surface water have reported potential associations with colon and rectal cancers, EPA chose to perform a sensitivity analysis on benefits from avoiding colon and rectal cancers. In order to quantify the reduction in cases of colon and rectal cancer as a result of Stage 2, it is necessary to have an estimation of baseline colon and rectal cancer cases and an estimation of risk associated with drinking disinfected water. With this information, a parallel analysis can be performed to the bladder cancer analysis for the Stage 2 rule.

Similar to bladder cancer, the Surveillance, Epidemiology and End Result (SEER) cancer registry reports crude cancer incidence rates for colon and rectal cancer combined. These age-based rates can be applied to same age groups from the 2000 census population data to estimate the total baseline colorectal cancer cases (as was done in the primary analysis for bladder cancer). As described in Section 6.2.1.1, there were three recent quality studies published concerning the risks of disinfected drinking water and colon and rectal cancers (Yang et al. 1998, Hildesheim et al. 1998, King et al. 2000a). A brief review of the studies is presented below.

Hildesheim et al. (1998) conducted a population-based case-control study and found an association between duration of chlorinated surface water use and rectal cancer in Iowa residents in 1986-1989. It should be noted that this study is essentially the same research group and study setting as the Cantor et al. (1998) study on bladder cancer that was used in the main benefits analysis. No important association was found for colon cancer and related sites for either duration of exposure or TTHM estimates. ORs were presented for several characterizations of exposure such as whether the study group was exposed to chlorinated surface or ground water, duration of exposure, total lifetime THM level, and lifetime average THM concentration. This study was used to estimate a PAR for rectal cancer.

King et al. (2000a) conducted a population-based case-control study in southern Ontario, Canada. This study is essentially the same research group and study setting as the King and Marrett (1996) study that was used in the Villanueva et al. (2003) meta-analysis. An association was found among males for colon cancer risk with cumulative exposure to TTHMs, duration of exposure to chlorinated surface water, and duration of exposure to $\geq$50 µg/L and to 75 µg/L. These relationships were not observed in females. No association was found between rectal cancer risk by any of the measures of exposure to disinfection byproducts in this study. This study was used to estimate a PAR for colon cancer.

Yang et al. (1998) conducted a cross-sectional mortality study in Taiwan which compared cancer mortality rates from chlorinating municipalities and non-chlorinating municipalities. The resulting Ratios of Age-adjusted Mortality Rates (SRR) were significantly higher for males and for females for rectal

cancer but not for colon cancer. This study did not control for diet or smoking. Since this study is based on mortality, not incidence, it makes this study problematic for doing risk analysis and it was not considered in estimating a PAR.

PAR for colon cancer

A constant PAR value can be calculated by using the below equation from the OR presented for males exposed to greater than or equal to 35 μg/L TTHM in the King et al. (2000a) study. P_e is the population exposed to disinfected drinking water (93.5 percent as explained previously) and OR=1.68.

$$PAR = \frac{P_e \times (OR - 1)}{1 + [P_e \times (OR - 1)]}$$

The resulting PAR from this study for colon cancer in males is 0.39.

PAR for rectal cancer

A constant PAR value for rectal cancer can be calculated by using the same equation and from the OR presented for those exposed to greater than or equal to 46.4 μg/L lifetime average TTHM exposure in the Hildesheim et al. (1998). P_e is the population exposed to disinfected drinking water (94 percent) and OR = 1.66. The resulting PAR from this study for rectal cancer is 0.38.

PAR for colorectal cancer

The SEER cancer registry data sets that parallel the data sets used in the bladder cancer analysis provide incidence information for colon and rectal cancers combined. The website (SEER 2005) states that:

> Even though risk factors, incidence rates, and death rates are different for cancer of the colon and cancer of the rectum, the two are combined into colorectal cancer primarily because death certificates frequently do not accurately distinguish one from the other.

Many information resources present combined data for colon and rectal cancers (including the baseline SEER data), and EPA chose to average the resulting PAR for colon cancer with the resulting PAR for rectal cancer to come up with a combined estimate of PAR for colorectal cancer of 38.5 percent. This constant PAR value was used for all age groups and results are presented using TTHM as the representative DBP and smoking/lung cancer cessation lag model in Exhibit 6.31 (for simplicity, the model in the middle was chosen). EPA recognizes that actual risk and PAR could be zero due to uncertainties in the scientific evidence. Detailed benefits information can be found in Appendix F.

Exhibit 6.31 Annualized Value[1] of Estimated Bladder Cancer Cases Avoided for the Preferred Alternative, and Estimated Colorectal Cancer Cases Avoided in the Sensitivity Analysis (Millions, 2003$)[2]

Smoking/Lung Cancer Cessation Lag Model						
Discount Rate, WTP for Non-Fatal Cases	Preferred Alternative [3]			Sensitivity Analysis [4]		
	Mean	5th	95th	Mean	5th	95th
3 %, Lymphoma	$1,523	$232	$3,518	$8,749	$1,331	$20,210
7 % Lymphoma	$1,240	$189	$2,862	$7,117	$1,084	$16,431
3 % Bronchitis	$759	$164	$1,684	$4,359	$944	$9,672
7 % Bronchitis	$617	$134	$1,368	$3,544	$769	$7,856

Notes: [1]The 90 percent confidence bounds shown in the exhibit incorporate uncertainty in the VSL, WTP, and income elasticity adjustment.
[2] Based on TTHM as indicator. EPA recognizes that the benefits may be as low as zero since causality has not yet been established between exposure to chlorinated water and bladder cancer or colorectal cancer.
[3]The Preferred Alternative refers to bladder cancer cases only.
[4]The Sensitivity Analysis refers to colorectal cancers only.

Source: For Preferred Alternative, see Exhibit 6.28. For the sensitivity analysis, quantitative values are summarized from detailed figures presented in Appendix E (Exhibits E.43a-d) and Appendix F (Exhibits F.12b, F.13b).

6.8 Potential Fetal Losses Avoided

EPA predicts that a significant portion of the total benefits from this rule could come from reduction in developmental and reproductive health effects. EPA does not believe the available evidence provides an adequate basis for fully quantifying potential reproductive or developmental risks, especially as no causal link between DBPs and these risks has been demonstrated with certainty. (See Section 6.2.2 for a complete discussion of the reproductive and developmental health effects of DBPs.) Nevertheless, given the widespread exposure to DBPs, the importance society places on reproductive and developmental health, and the nearly 1 million fetal losses each year in the U.S., the Agency believes that it is important to provide some quantitative indication of the potential risk in these categories. To do this, PAR calculations from several studies on the relationship between chlorinated water exposure and fetal loss have been adapted and applied to national statistics on the annual incidence of fetal loss (shown in Section 6.8.1). Section 6.8.2 discusses valuation of these potential fetal losses avoided.

6.8.1 Reproductive Effects Illustrative Calculation

EPA has calculated the unadjusted ORs or RRs associated with each of three population-based epidemiological studies of fetal loss: Waller et al. 2001, King et al. 2000b, and Savitz et al. 1995. All are high-quality studies that have sufficient sample sizes and high response rates, adjustments for known confounders[11], have exposure assessment information from water treatment data, residential histories, and THM measurements. These are summarized in Exhibit 6.31. Because the populations in these three studies appear to have TTHM exposures significantly greater than those of the general U.S. population, EPA has chosen to scale the results using ICR data to derive PAR values that are more relevant to the general population (Appendix G).

The three studies (using unadjusted data to allow for comparability, and scaled to the TTHM levels reported in the ICR data base) yield median PARs of 0.4, 1.7, and 1.7 percent (with 95 percent confidence

[11]Use of unadjusted OR or RR estimates has the effect of excluding possible biases from known confounders; however, EPA believes the unadjusted estimates are adequate for purposes of the illustrative calculations presented here

intervals in each case of 0 to 4 percent[12]). Using the prevalence of fetal loss reported by CDC, the median PARs for these three studies suggest that the incidence of fetal loss attributable to exposure to chlorinated drinking water could range from 3,900 to 16,700 "cases" or "fetal losses" annually. As part of the analysis to evaluate potential reduction in fetal loss for the Stage 2 DBPR, EPA assumed that reductions in risk are proportional to the 28 percent reductions in the number of locations having one or more quarterly TTHM measurements that exceed the study population cut-offs (>75 to >81 µg/l, depending on study). This analysis would imply that a range of 250 to 4,100 fetal losses could be avoided per year as a result of the Stage 2 DBPR. Refer to Appendix G for derivation of PARs and detailed calculation of fetal losses avoided.

Caution is required in interpreting the numbers derived above because there may be significant differences in exposure patterns of the study populations and the national population (e.g., different types of DBP mixtures having similar TTHM levels). The estimates presented here are not part of EPA's primary benefits analysis, and the ranges are not meant to suggest upper and lower bounds. Rather, they are intended to illustrate quantitatively the potential risk implications of some of the published results.

Exhibit 6.32 Summary of the Fetal Loss Human Epidemiology Studies

Study	Population	Exposure Assessment	Outcome	Results[1]	Potential Confounders
Waller et al. 2001	Prospective cohort of 4,209 pregnant women in prepaid health plan in CA 1989-91	Estimated TTHM levels during first trimester of pregnancy via ingestion and showering.	Spontaneous abortion (≤20 weeks of gestation)	Recalculated 80 µg/L compared to <80 µg/L for unweighted utility-wide average RR=1.25 (0.99,1.6) Study based prevalence of exposure = 15%	Gestational age at interview, maternal age, cigarette smoking, history of pregnancy loss, maternal race, employment during pregnancy
King et al. 2000b	Population-based retrospective cohort of 47,275 births in Nova Scotia, Canada 1988-1995	Linked mother's residence at time of delivery to the levels of specific TTHMs monitored in the PWS and averaged predicted values of byproduct level for the months covering the pregnancy.	Stillbirth	Recalculated 75 µg/L compared to <75 µg/L RR=1.28 (95% CI 0.98, 1.7) Study based prevalence of exposure = 32%	Smoking, maternal age
Savitz et al. 1995	Population-based case-control study of 126 cases and 122 controls in NC 1988-91	Examined TTHM concentration at residences and water consumption (during first and third trimesters). The fourth week of pregnancy used to assign the reported quarterly average TTHM.	Spontaneous abortion	Recalculated 81 µg/L compared to <81 µg/L OR=1.06 (0.6,1.8) Study based prevalence of exposure = 35%	Maternal age, race, education, marital status, poverty level, smoking, alcohol use, nausea, employment

[1]EPA recalculated OR and RR values using crude Odds Ratios for the fetal loss sensitivity analysis.

[12]The calculated lower 95 percent confidence intervals on PAR for all three studies were less than zero; however, they were truncated at zero for this analysis.

6.8.2 Value of Reductions in Fetal Losses Avoided

EPA has not monetized the value of avoiding fetal loss but recognizes the significant value of improvement in developmental and reproductive health in general. See Section 6.5.1 for a discussion of the value of reducing reproductive and developmental health risks.

The agency is considering further work specific to fetal loss valuation. One possible area of further research is the value that prospective parents have for reducing risks during pregnancy. In this regard, the substantial lifestyle changes that prospective parents often undertake during pregnancy suggests that reducing these kinds of risks is of value. A second possible area would be benefit transfer methodologies that address how existing studies can inform the estimation of the benefits of reduced fetal loss.

When valuation studies specific to the health endpoints of a regulation are lacking, the Agency typically draws upon existing studies of similar health endpoints to estimate benefits. The "transfer" of the results of these studies to value similar health endpoints must be done carefully and methodically, controlling for differences in the health endpoints and in the relevant populations. Some researchers have attempted to transfer values using sophisticated analytical techniques such as preference calibration methods (e.g., Smith et al. 2002). Regardless of the approach used, "benefit transfer" requires systematic comparison of the similarities and differences in the health effects in the studies and those resulting from the regulation. Application of benefit transfer leads to a detailed qualitative examination of the implications of using those studies and potentially to empirical adjustments to the results of the existing studies.

Until more information on these subjects is available, EPA cannot fully consider and describe the implications of relying upon existing studies. However, research on valuation and benefit transfer continues to progress. The Agency anticipates that new research will support further efforts to value reproductive and developmental endpoints.

7. Cost Analysis

7.1 Introduction

This chapter estimates the national costs of the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR). National costs include treatment technology changes to comply with the rule as well as non-treatment costs, such as Initial Distribution System Evaluations (IDSEs), additional routine monitoring, and operational evaluations.

The data presented in this chapter are derived from analyses of Information Collection Rule (ICR) data, ICR Supplemental Survey data, National Rural Water Survey data, Surface Water Analytical Tool (SWAT) model results, the American Water Works Association Water Utility Database (Water:\STATS) (AWWA 2000), State/Primacy Agency data, and the results of two expert opinion processes for small systems. For a complete explanation of these data sources, see Chapter 3 and Appendices A and B.

Section 7.1.1 of this chapter summarizes the methodology and data inputs used to estimate national costs. Sections 7.2 through 7.4 discuss the inputs that are used in the cost model. These are: labor rates and laboratory fees (7.2), non-treatment costs (7.3), technology unit costs (7.4), and compliance forecasts (derived in Chapter 5). Section 7.5 discusses the cost model itself, including how it accounts for uncertainty in some inputs, the calculation of the costs, and projection and discounting of those costs. The results of the cost model are discussed in Section 7.6. Section 7.7 discusses unquantified costs and Section 7.8 gives a summary of the uncertainties in the cost calculations. Section 7.9 presents a comparison of the costs of the final rule option compared to other regulatory alternatives that were analyzed.

In support of this chapter:

- Appendix D contains the rule implementation schedule for different system types and rule activities (used in projecting and annualizing costs over a 25-year period).
- Appendix H offers a more complete explanation of the laboratory costs and labor hours for implementation, IDSE, monitoring plans, additional routine monitoring, as well as the assumptions and calculations for the operational evaluation costs.
- Appendix I presents additional detail for technology unit costs.
- Appendix J presents cost projections, present value estimates, and annualization of costs for all Stage 2 DBPR regulatory alternatives and sensitivity analyses.
- Appendix K contains documentation for the Stage 2 DBPR cost model, including a detailed file list and flow charts.

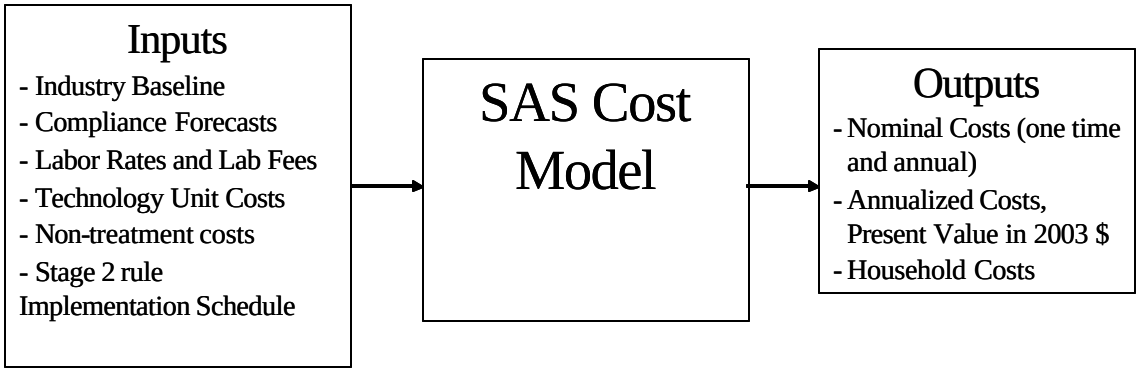
7.1.1 Overview of Methodology for Quantifying Stage 2 DBPR Costs

To estimate the national costs of the Stage 2 DBPR, the Environmental Protection Agency (EPA) calculated the incremental costs that public water systems (PWSs) and their States/Primacy Agencies are expected to incur from the Stage 1 DBPR to the Stage 2 DBPR. Cost analyses for PWSs include an identification of treatment process improvements that systems may make, as well as estimates of the costs to implement the rule[1], conduct IDSEs, prepare monitoring plans, perform additional routine monitoring, and perform operational evaluations. System costs were estimated for different system types (community water systems (CWS) or nontransient noncommunity water systems (NTNCWS)), source water types (ground or surface), and size categories (nine categories based on population served, consistent with the Drinking Water Baseline Handbook). Estimates of costs to State/Primacy Agencies represent estimated labor burdens that States/Primacy Agencies would face, such as training employees on the requirements of the Stage 2 DBPR, responding to PWS reports, and recordkeeping.

Costs were calculated using a cost model programmed in SAS version 9.1. Exhibit 7.1 summarizes the model inputs and outputs. The model combines baseline data discussed in Chapter 3 with inputs for labor rates, laboratory fees, non-treatment costs, technology unit costs, and compliance forecasts from Chapter 5 to calculate nominal costs for the rule. All costs are calculated in 2003 dollars. Costs are then distributed in the years in which they are expected to be incurred and are discounted to give a net present value of costs using both a 3 and 7 percent social discount rate. The present value costs are then annualized using the same social discount rate[2].

Household costs are also generated by the cost model using assumptions regarding household water usage and total households served per plant.

Exhibit 7.1 Stage 2 DBPR Cost Model Inputs and Outputs



[1]For the purposes of this Economic Analysis (EA), rule implementation activities are assumed to include activities such as reading the rule and training personnel. The activities are summarized in Section 7.3.1 and discussed in more detail in Appendix H.

[2] For more information on discounting costs see EPA's *Guidelines for Preparing Economic Analyses* (USEPA 2000j).

7.1.2 Cost Summary

Number of systems performing non-treatment activities

Exhibit 7.2a shows the baseline number of systems subject to the Stage 2 DBPR and the estimated number of those systems performing various rule activities (implementation, IDSE monitoring, monitoring plans, and operational evaluations). Appendix H provides the derivation of these values.

As shown in columns B and C, EPA estimates that all disinfecting CWSs and NTNCWSs will have to perform at least minimal implementation activities (reading and understanding the rule, training, etc.). All systems will also have to develop Stage 2 monitoring plans as shown in columns F and G. The number of systems performing IDSE monitoring (shown in columns D and E), however, is only a fraction of all systems because some will choose to perform studies, meet the criteria for a 40/30 certification, or receive waivers from IDSE requirements.

EPA has established a population-based monitoring approach for the Stage 2 DBPR, where monitoring requirements are no longer based on number of plants per system as under the Stage 1 DBPR. Depending on the number of plants in a given system, the number of Stage 2 compliance samples required per year may stay the same, decrease, or increase from Stage 1 requirements. The estimated number of plants per system from the 2000 Community Water System Survey (CWSS) is used to facilitate comparison between Stage 1 and Stage 2 DBPR requirements.

EPA expects that some number of Stage 2-compliant systems will find TTHM and HAA5 levels high enough to trigger the requirement for an operational evaluation. Column H shows the estimated number of systems that may require operational evaluations.

In addition to those ground water systems that currently disinfect, EPA predicts that some systems will install disinfection to comply with the anticipated Ground Water Rule (GWR). Exhibit 7.2b shows the number of systems predicted to install disinfection, as reported in the GWR Economic Analysis (USEPA 2004). Because the GWR is expected to be promulgated at the same time or just after the Stage 2 DBPR is promulgated, EPA expects new systems adding disinfection to meet GWR requirements to simultaneously achieve compliance with Stage 2 MCLs. Therefore, these systems are not included in the treatment baseline. The IDSE will likely not apply to these systems because they are expected to install disinfection after the IDSE requirement is complete. Systems installing disinfection for the GWR will, however, be required to prepare monitoring plans and monitor DBPs for the first time under Stage 2. Exhibit 7.2b shows that all newly disinfecting ground water systems will prepare monitoring plans and will be required to conduct monitoring for the first time.

Exhibit 7.2a Baseline Systems Subject to Non-Treatment-Related Rule Activities

System Size (Population Served)	Stage 2 DBPR System Baseline	Number and Percent of Systems Performing Various Rule Activities							
		Implementation		IDSE Monitoring		Stage 2 Monitoring Plans		Operational Evaluations	
	A	B	C=B/A*100	D	E=D/A*100	F	G=F/A*100	H	I=H/A*100
Surface Water and Mixed CWSs									
<100	1,085	1,085	100%	678	62%	1,085	100%	4	0%
100-499	2,212	2,212	100%	1,382	62%	2,212	100%	8	0%
500-999	1,470	1,470	100%	1,385	94%	1,470	100%	10	1%
1,000-3,299	2,588	2,588	100%	2,438	94%	2,588	100%	18	1%
3,300-9,999	2,042	2,042	100%	1,888	92%	2,042	100%	57	3%
10,000-49,999	1,773	1,773	100%	1,524	86%	1,773	100%	189	11%
50,000-99,999	334	334	100%	273	82%	334	100%	68	20%
100,000-999,999	281	281	100%	226	81%	281	100%	64	23%
1,000,000+	18	18	100%	15	83%	18	100%	6	33%
National Totals	**11,803**	**11,803**	100%	**9,809**	83%	**11,803**	100%	**424**	4%
Ground Water Only CWSs									
<100	7,935	7,935	100%	336	4%	7,935	100%	0	0%
100-499	9,821	9,821	100%	416	4%	9,821	100%	0	0%
500-999	3,998	3,998	100%	708	18%	3,998	100%	0	0%
1,000-3,299	4,852	4,852	100%	859	18%	4,852	100%	0	0%
3,300-9,999	2,200	2,200	100%	389	18%	2,200	100%	0	0%
10,000-49,999	1,222	1,222	100%	216	18%	1,222	100%	0	0%
50,000-99,999	136	136	100%	24	18%	136	100%	0	0%
100,000-999,999	63	63	100%	18	29%	63	100%	0	0%
1,000,000+	3	3	100%	0	15%	3	100%	0	0%
National Totals	**30,229**	**30,229**	100%	**2,966**	10%	**30,229**	100%	**0**	0%
Surface Water and Mixed NTNCWSs									
<100	231	231	100%	0	0%	231	100%	0	0%
100-499	317	317	100%	0	0%	317	100%	0	0%
500-999	106	106	100%	0	0%	106	100%	0	0%
1,000-3,299	93	93	100%	0	0%	93	100%	0	0%
3,300-9,999	24	24	100%	0	0%	24	100%	0	0%
10,000-49,999	5	5	100%	4	80%	5	100%	0	0%
50,000-99,999	0	0	-	0	-	0	-	0	-
100,000-999,999	1	1	100%	1	100%	1	100%	0	0%
1,000,000+	0	0	-	0	-	0	-	0	-
National Totals	**777**	**777**	100%	**5**	1%	**777**	100%	**0**	0%
Ground Water Only NTNCWSs									
<100	2,493	2,493	100%	0	0%	2,493	100%	0	0%
100-499	2,129	2,129	100%	0	0%	2,129	100%	0	0%
500-999	589	589	100%	0	0%	589	100%	0	0%
1,000-3,299	247	247	100%	0	0%	247	100%	0	0%
3,300-9,999	21	21	100%	0	0%	21	100%	0	0%
10,000-49,999	3	3	100%	1	18%	3	100%	0	0%
50,000-99,999	0	0	100%	0	18%	0	100%	0	0%
100,000-999,999	0	0	100%	0	100%	0	100%	0	0%
1,000,000+	0	0	-	0	-	0	-	0	-
National Totals	**5,483**	**5,483**	100%	**1**	0%	**5,483**	100%	**0**	0%
GRAND TOTAL	**48,293**	**48,293**	**100%**	**12,780**	**26%**	**48,293**	**100%**	**424**	**1%**

Notes:

Detail may not add to totals due to independent rounding.

Non-treatment-Related Rule Activities, in addition to those shown in the table, also include routine compliance monitoring. Some systems are expected to take more samples and some are expected to take less from Stage 1 to Stage 2 depending on the number of plants in their systems. Overall, the Stage 2 DBPR results in an increase in the total number of compliance samples taken from the Stage 1 DBPR. See Exhibit H.8a for column I, for the change in total samples for different system size categories.

Sources:

(A), (B), (D), (F), and (H): Appendix H, Exhibit H.12a.

Exhibit 7.2b Non-Treatment-Related Rule Activities for Systems Installing Disinfection to Comply with the Ground Water Rule

System Size (Population Served)	Baseline No. of Systems Adding Disinfection for the GWR	Stage 2 Monitoring Plans	
	A	B	C=B/A*100
Surface Water and Mixed CWSs			
<100	0	0	-
100-499	0	0	-
500-999	0	0	-
1,000-3,299	0	0	-
3,300-9,999	0	0	-
10,000-49,999	0	0	-
50,000-99,999	0	0	-
100,000-999,999	0	0	-
1,000,000+	0	0	-
National Totals	**0**	**-**	-
Ground Water Only CWSs			
<100	354	354	100%
100-499	439	439	100%
500-999	86	86	100%
1,000-3,299	104	104	100%
3,300-9,999	47	47	100%
10,000-49,999	10	10	100%
50,000-99,999	1	1	100%
100,000-999,999	2	2	100%
1,000,000+	0	0	100%
National Totals	**1,042**	**1,042**	100%
Surface Water and Mixed NTNCWSs			
<100	0	0	-
100-499	0	0	-
500-999	0	0	-
1,000-3,299	0	0	-
3,300-9,999	0	0	-
10,000-49,999	0	0	-
50,000-99,999	0	0	-
100,000-999,999	0	0	-
1,000,000+	0	0	-
National Totals	**0**	**-**	-
Ground Water Only NTNCWSs			
<100	669	669	100%
100-499	572	572	100%
500-999	184	184	100%
1,000-3,299	77	77	100%
3,300-9,999	7	7	100%
10,000-49,999	1	1	100%
50,000-99,999	0	0	100%
100,000-999,999	0	0	100%
1,000,000+	0	0	-
National Totals	**1,510**	**1,510**	100%
GRAND TOTAL	**2,552**	**2,552**	**100%**

Notes:
Detail may not add to totals due to independent rounding.

Non-treatment-Related Rule Activities, in addition to those shown in the table, also include routine compliance monitoring. Some systems are expected to take more samples and some are expected to take less from Stage 1 to Stage 2 depending on the number of plants in their systems. Overall, the Stage 2 DBPR results in an increase in the total number of compliance samples taken from the Stage 1 DBPR. See Exhibit H.8a for column I, for the change in total samples for different system size categories.

Sources:
(A), (B), (D): Appendix H, Exhibit H.12b.

Number of plants making treatment technology changes

Exhibit 7.3 shows the baseline number of plants and the estimated percentage of those plants that are predicted to make treatment technology changes. The mean estimated percentage of plants making treatment technology changes is approximately 4 percent for all systems, with a much higher percentage for surface water plants. The baseline number of ground water plants is larger than that of surface water plants, however, so there is a larger absolute number of ground water plants that are predicted to make treatment technology changes.

The 90-percent confidence interval around the mean for the surface water plant estimate accounts for alternative compliance forecast methodologies (SWAT and the ICR Matrix Method) and uncertainty in the potential impacts of the IDSE. Derivation of the compliance forecast is discussed in detail in Chapter 5.

One-time costs

One-time costs for systems include initial capital, implementation, IDSE, and monitoring plan costs. State/Primacy Agency costs include those associated with implementation, IDSEs, and monitoring plans. Exhibit 7.4 summarizes estimated total initial capital and other one-time costs of the Stage 2 DBPR for systems and States/Primacy Agencies.

Annualized Costs

Exhibit 7.5a and b summarize the average annualized costs for the Stage 2 DBPR at 3 and 7 percent discount rates, respectively. System costs range from approximately $59 to $114 million annually at a 3 percent discount rate, with a mean estimate of approximately $86 million per year. At a 7 percent discount rate, system costs range from approximately $58 to $112 million annually, with a mean estimate of approximately $84 million per year. State costs are estimated to be between $1.70 and $1.71 million per year, depending on the discount rate.

Exhibit 7.3 Number and Percent of Plants Making Treatment Technology Changes

System Size (Population Served)	Stage 2 DBPR Plant Baseline	Number of Plants Making Treatment Technology Changes			Percentage of Plants Making Treatment Technology Changes		
		Mean	5th Percentile	95th Percentile	Mean	5th Percentile	95th Percentile
	A	B	C	D	E=B/A	F=C/A	G = D/A
Primarily Surface Water CWSs							
<100	359	40	21	59	11.2%	5.8%	16.5%
100-499	767	71	36	104	9.2%	4.8%	13.6%
500-999	483	44	23	66	9.2%	4.8%	13.6%
1,000-3,299	1,129	109	57	162	9.7%	5.0%	14.3%
3,300-9,999	1,258	122	63	180	9.7%	5.0%	14.3%
10,000-49,999	1,292	206	91	338	16.0%	7.0%	26.1%
50,000-99,999	579	93	41	151	16.0%	7.0%	26.1%
100,000-999,999	610	98	43	160	16.0%	7.0%	26.1%
1,000,000+	74	12	5	19	16.0%	7.0%	26.1%
National Totals	**6,552**	**795**	**380**	**1,240**	**12.1%**	**5.8%**	**18.9%**
Primarily Ground Water CWSs							
<100	6,423	155			2.4%		
100-499	15,242	483			3.2%		
500-999	6,093	193			3.2%		
1,000-3,299	7,587	204			2.7%		
3,300-9,999	5,030	135			2.7%		
10,000-49,999	5,382	111			2.1%		
50,000-99,999	716	15			2.1%		
100,000-999,999	918	18			2.0%		
1,000,000+	27	1			2.1%		
National Totals	**47,419**	**1,314**			**2.8%**		
Primarily Suface Water NTNCWSs							
<100	226	25	13	37	11.2%	5.8%	16.5%
100-499	312	29	15	43	9.2%	4.8%	13.6%
500-999	106	10	5	14	9.2%	4.8%	13.6%
1,000-3,299	91	9	5	13	9.8%	5.1%	14.5%
3,300-9,999	25	2	1	4	9.7%	5.0%	14.3%
10,000-49,999	5	1	0	1	16.0%	7.0%	26.1%
50,000-99,999	0	0	0	0	-	-	-
100,000-999,999	1	0	0	0	16.0%	7.0%	26.1%
1,000,000+	0	0	0	0	-	-	-
National Totals	**766**	**76**	**39**	**113**	**9.9%**	**5.1%**	**14.7%**
Primarily Ground Water NTNCWSs							
<100	2,493	60			2.4%		
100-499	2,129	67			3.2%		
500-999	589	19			3.2%		
1,000-3,299	247	7			2.7%		
3,300-9,999	21	1			2.7%		
10,000-49,999	3	0			2.1%		
50,000-99,999	0	0			2.1%		
100,000-999,999	0	0			2.0%		
1,000,000+	0	0			-		
National Totals	**5,483**	**154**			**2.8%**		
Grand Total All Plants	**60,220**	**2,338**	**1,887**	**2,820**	**3.9%**	**3.1%**	**4.7%**

Note: Detail may not add to totals due to independent rounding.

Sources: (A) Exhibit 3.2, column AB.
(B)-(D) Compliance Forecast Inputs in Chapter 5, The Stage 2 DBPR Cost Model. The 90 percent confidence intervals for surface water systems represent alternative compliance forecast methodologies (SWAT and the ICR Matrix Method) and uncertainty in the potential impacts of the IDSE.

Exhibit 7.4 Initial Capital and One-Time Costs for the Stage 2 DBPR ($Millions)

	Surface Water Systems		Disinfecting Ground Water Systems		
	Serving < 10,000	Serving ≥ 10,000	Serving < 10,000	Serving ≥ 10,000	Total
Total Initial Capital Costs for the Rule	**$ 110.8**	**$ 495.19**	**$ 179.9**	**$ 107.3**	**$ 893.2**
(90% Confidence Bounds)	(56.62 - 168.45)	(253.45 - 719.91)	(148.93 - 211.07)	(96.31 - 118.23)	(555.31 - 1,217.66)
CWS Total Initial Capital	$ 104.17	$ 494.1	$ 167.2	$ 107.1	$ 872.6
(90% Confidence Bounds)	(53.26 - 158.28)	(252.90 - 718.39)	(138.18 - 196.30)	(96.18 - 118.06)	(540.52 - 1,191.04)
NTNCWS Total Initial Capital	$ 6.62	$ 1.1	$ 12.8	$ 0.1	$ 20.6
(90% Confidence Bounds)	(3.36 - 10.17)	(0.54 - 1.52)	(10.75 - 14.77)	(0.13 - 0.16)	(14.79 - 26.62)
CWS One-Time Costs	$ 21.8	$ 33.5	$ 14.2	$ 3.3	$ 72.8
Implementation	$ 2.4	$ 1.7	$ 6.0	$ 0.9	$ 11.0
IDSE	$ 18.4	$ 31.1	$ 5.8	$ 2.0	$ 57.4
Monitoring Plans	$ 1.0	$ 0.7	$ 2.3	$ 0.4	$ 4.4
NTNCWS One-Time Costs	$ 0.2	$ 0.1	$ 1.5	$ 0.0	$ 1.8
Implementation	$ 0.2	$ 0.0	$ 1.1	$ 0.0	$ 1.3
IDSE	$ -	$ 0.1	$ -	$ 0.0	$ 0.1
Monitoring Plans	$ 0.0	$ 0.0	$ 0.4	$ 0.0	$ 0.5
State/Primacy Agency One-Time Costs					$ 10.9
Implementation					$ 7.8
IDSE					$ 2.2
Monitoring Plans					$ 0.9

Note: Detail may not add due to independent rounding. 90-percent confidence bounds reflect uncertainty in unit treatment costs.
Sources: Initial Capital Costs from Exhibit 7.21. Implementation, IDSE, and Monitoring Plan costs from Exhibit 7.7.
Stage/Primacy Agency One-Time Costs from Exhibit H.21

Exhibit 7.5a Total Annualized Costs for Stage 2 DBPR Rule Activities ($Millions/Year, 3 Percent Discount Rate)

System Costs																Total Costs of the Rule		
	Capital Costs			O&M Costs			Non-Treatment Costs (Point Estimate)					Total System Costs						
		90 Percent Confidence Bound			90 Percent Confidence Bound								90 Percent Confidence Bound				90 Percent Confidence Bound	
System Size (Population Served)	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Implement-ation	IDSE	Monitoring Plans	Moni-toring	Operational Evalations	Mean Value	Lower (5th %tile)	Upper (95th %tile)	State Costs	Mean Value	Lower (5th %tile)	Upper (95th %tile)
Surface Water CWSs																		
< 10,000	$4.66	$2.38	$7.08	$6.83	$3.53	$10.16	$0.12	$0.92	$0.05	-$0.07	$0.02	$12.52	$6.95	$18.28				
≥ 10,000	$22.79	$11.66	$33.14	$16.03	$9.33	$24.79	$0.09	$1.59	$0.03	-$1.14	$0.11	$39.50	$21.67	$58.60				
Surface Water NTNCWSs																		
< 10,000	$0.30	$0.15	$0.45	$0.63	$0.33	$0.95	$0.01	$0.00	$0.00	$0.02	$0.00	$0.96	$0.50	$1.43				
≥ 10,000	$0.05	$0.02	$0.07	$0.03	$0.02	$0.05	$0.00	$0.00	$0.00	$0.00	$0.00	$0.09	$0.05	$0.12				
Ground Water CWSs																		
< 10,000	$7.47	$6.18	$8.78	$6.96	$6.39	$7.52	$0.30	$0.29	$0.12	$1.07	$0.00	$16.21	$14.35	$18.08				
> 10,000	$4.88	$4.38	$5.38	$6.05	$5.68	$6.41	$0.05	$0.10	$0.02	$2.33	$0.00	$13.42	$12.55	$14.29				
Ground Water NTNCWSs																		
< 10,000	$0.57	$0.48	$0.66	$0.73	$0.67	$0.79	$0.06	$0.00	$0.02	$0.43	$0.00	$1.81	$1.66	$1.95				
≥ 10,000	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.00	$0.01	$0.00	$0.03	$0.03	$0.03				
TOTAL	**$40.72**	**$25.26**	**$55.56**	**$37.27**	**$25.96**	**$50.68**	**$0.62**	**$2.91**	**$0.24**	**$2.64**	**$0.12**	**$84.52**	**$57.75**	**$112.77**	**$1.71**	**$86.23**	**$59.47**	**$114.48**

Notes: Detail may not add due to independent rounding. 90 percent confidence bounds reflects uncertainty in technology compliance forecast and unit treatment costs. Estimates are discounted to 2003, and given in 2003 dollars.

Sources Capital Costs: SW CWS, Exhibit J.2bb; SW NTNCWS, Exhibit J.2bf; GW CWS, Exhibit J.2bj; GW NTNCWS, Exhibit J.2bn.
O&M Costs: SW CWS, Exhibit J.2bc; SW NTNCWS, Exhibit J.2bg; GW CWS, Exhibit J.2bk; GW NTNCWS, Exhibit J.2bo.
Non-Treatment Costs: SW CWS, Exhibit J.2bd; SW NTNCWS, Exhibit J.2bh; GW CWS, Exhibit J.2bl; GW NTNCWS, Exhibit J.2bp.
State Costs; Appendix J, Exhibit J.2as

Exhibit 7.5b Total Annualized Costs for Stage 2 DBPR Rule Activities ($Millions/Year, 7 Percent Discount Rate)

System Size (Population Served)	System Costs: Capital Costs Mean Value	Capital Costs 90 Percent Confidence Bound Lower (5th %tile)	Capital Costs 90 Percent Confidence Bound Upper (95th %tile)	O&M Costs Mean Value	O&M Costs 90 Percent Confidence Bound Lower (5th %tile)	O&M Costs 90 Percent Confidence Bound Upper (95th %tile)	Non-Treatment Costs (Point Estimate) Implement-ation	IDSE	Monitoring Plans	Moni-toring	Operational Evaluations	Total System Costs Mean Value	Total System Costs 90 Percent Confidence Bound Lower (5th %tile)	Total System Costs 90 Percent Confidence Bound Upper (95th %tile)	State Costs	Total Costs of the Rule Mean Value	Total Costs of the Rule 90 Percent Confidence Bound Lower (5th %tile)	Total Costs of the Rule 90 Percent Confidence Bound Upper (95th %tile)
Surface Water CWSs																		
< 10,000	$5.06	$2.58	$7.68	$5.46	$2.82	$8.13	$0.15	$1.16	$0.06	-$0.06	$0.01	$11.84	$6.74	$17.14				
≥ 10,000	$25.76	$13.18	$37.45	$13.16	$7.66	$20.35	$0.11	$2.04	$0.04	-$0.90	$0.08	$40.29	$22.21	$59.18				
Surface Water NTNCWSs																		
< 10,000	$0.32	$0.16	$0.49	$0.51	$0.26	$0.76	$0.01	$0.00	$0.00	$0.01	$0.00	$0.85	$0.45	$1.27				
> 10,000	$0.05	$0.03	$0.08	$0.03	$0.01	$0.04	$0.00	$0.00	$0.00	$0.00	$0.00	$0.09	$0.05	$0.12				
Ground Water CWSs																		
< 10,000	$8.11	$6.71	$9.53	$5.57	$5.11	$6.02	$0.38	$0.36	$0.14	$0.85	$0.00	$15.40	$13.54	$17.27				
≥ 10,000	$5.42	$4.86	$5.98	$4.92	$4.62	$5.22	$0.06	$0.13	$0.02	$1.86	$0.00	$12.41	$11.55	$13.26				
Ground Water NTNCWSs																		
< 10,000	$0.62	$0.52	$0.72	$0.58	$0.54	$0.63	$0.07	$0.00	$0.03	$0.34	$0.00	$1.64	$1.50	$1.78				
≥ 10,000	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.00	$0.01	$0.00	$0.02	$0.02	$0.03				
TOTAL	**$45.35**	**$28.05**	**$61.93**	**$30.22**	**$21.04**	**$41.15**	**$0.78**	**$3.69**	**$0.29**	**$2.11**	**$0.10**	**$82.55**	**$56.06**	**$110.05**	**$1.70**	**$84.24**	**$57.76**	**$111.75**

Notes: Detail may not add due to independent rounding. 90 percent confidence bounds reflects uncertainty in technology compliance forecast and unit treatment costs. Estimates are discounted to 2003, and given in 2003 dollars.

Sources Capital Costs: SW CWS, Exhibit J.2br; SW NTNCWS, Exhibit J.2bv; GW CWS, Exhibit J.2bz; GW NTNCWS, Exhibit J.2cd.
O&M Costs: SW CWS, Exhibit J.2bs; SW NTNCWS, Exhibit J.2bw; GW CWS, Exhibit J.2ca; GW NTNCWS, Exhibit J.2ce.
Non-Treatment Costs: SW CWS, Exhibit J.2bt; SW NTNCWS, Exhibit J.2bx; GW CWS, Exhibit J.2cb; GW NTNCWS, Exhibit J.2cf.
State Costs: Appendix J, Exhibit J.2aw

7.2 Labor Rates and Laboratory Fees

Labor Rates

Labor costs to PWSs are estimated using hourly labor rates for technical and managerial labor categories. Labor rates representative of national averages, based on Bureau of Labor Statistics (BLS) figures as reported in *Labor Costs for National Drinking Water Rules* (USEPA 2003e), are used in all analyses. The technical and managerial wage rates vary with system size and include fringe benefits. Labor rates do not differ between surface and ground water systems.

Exhibit 7.6a shows the technical and managerial rates for each of the nine standard system size categories used in this EA. Exhibit 7.6b shows the technical and managerial rates according to the system size categories used to specify Stage 2 monitoring requirements. All rates have been adjusted to 2003 dollars using the Employment Cost Index (ECI) (BLS 2003).

To account for the composition of staff at PWSs of varying sizes, EPA uses only the technical rate for systems serving fewer than 3,300 people. For systems serving 3,300 or more people, EPA uses a ratio of 80 percent technical labor to 20 percent managerial labor to arrive at a weighted labor rate. The final labor rates used for the cost analysis are shown in the combined column (column C) in Exhibits 7.6a and b.

Exhibit 7.6a System Wage Rates by Standard Size Categories

System Size (Population Served)	Labor Rate (2003$/hr)		
	Technical	Managerial	Combined
	A	B	C
<100	$21.44	$44.36	$21.44
100-499	$23.09	$47.78	$23.09
500-999	$24.74	$51.20	$24.74
1,000-3,299	$24.74	$51.20	$24.74
3,300-9,999	$25.34	$51.20	$30.51
10,000-49,999	$26.05	$51.20	$31.08
50,000-99,999	$26.05	$51.20	$31.08
100,000-999,999	$31.26	$51.20	$35.25
1,000,000+	$31.26	$51.20	$35.25

Notes: EPA estimates that systems with populations greater than 3,300 use a combination of operators (technical) and engineers (managerial), with an 80/20 ratio between the two, respectively.
Source: Labor Costs for National Drinking Water Rules (USEPA, 2003s)

Exhibit 7.6b System Wage Rates by Monitoring Size Categories

System Size (Population Served)	Labor Rate (2003$/hr)		
	Technical	Managerial	Combined
	A	B	C
Surface Water and Mixed CWSs			
<500	$22.55	$46.65	$22.55
500-3,299	$24.74	$51.20	$24.74
3,300-9,999	$25.34	$51.20	$30.51
10,000-49,999	$26.05	$51.20	$31.08
50,000-249,999	$28.00	$51.20	$32.64
250,000-999,999	$31.26	$51.20	$35.25
1,000,000-4,999,999	$31.26	$51.20	$35.25
5M+	$31.26	$51.20	$35.25
Disinfecting Ground Water Only CWSs			
<500	$22.35	$46.25	$22.35
500-9,999	$24.86	$51.20	$24.86
10,000-99,999	$26.05	$51.20	$31.08
100,000-499,999	$31.26	$51.20	$35.25
500,000+	$31.26	$51.20	$35.25
Surface Water and Mixed NTNCWSs			
<500	$22.39	$38.84	$22.39
500-3,299	$24.74	$51.20	$24.74
3,300-9,999	$25.34	$51.20	$30.51
10,000-49,999	$26.05	$51.20	$31.08
50,000-249,999	$31.26	$51.20	$35.25
250,000-999,999	N/A	N/A	N/A
1,000,000-4,999,999	N/A	N/A	N/A
5M+	N/A	N/A	N/A
Disinfecting Ground Water Only NTNCWSs			
<500	$22.20	$45.94	$22.20
500-9,999	$24.76	$51.20	$24.76
10,000-99,999	$26.05	$51.20	$31.08
100,000-499,999	$31.26	$51.20	$35.25
500,000+	N/A	N/A	N/A

Notes: EPA estimates that systems with populations greater than 3,300 use a combination of operators (technical) and engineers (managerial), with an 80/20 ratio between the two, respectively.
Source: Labor Costs for National Drinking Water Rules (USEPA, 2003s)

EPA recognizes that there may be significant variation in labor rates across all PWSs. However, data are not currently available that would allow assignment of labor rates to specific PWSs based on characteristics such as size, classification, or geographical region. In the absence of such data and because analyses in this EA are performed on a national level, the data from *Labor Costs for National Drinking Water Rules* are used for all systems.

Labor costs attributable to States for administrative tasks are estimated based on an average annual full-time-equivalent (FTE) labor cost, including overhead and fringe benefits, of $65,255 (2001$). This rate was established based on data from the 2001 State Drinking Water Needs Analysis (ASDWA 2001). For use in the Stage 2 EA analyses, the $65,255 annual rate was updated to 2003 dollars ($70,132)

using the ECI (BLS 2003) and converted to an hourly basis (1 FTE = 2,080 hours) to establish a State rate of $33.60 per hour.

Laboratory Fees

A laboratory fee, expressed as a cost per sample, is associated with TTHM and HAA5 monitoring costs for IDSE and additional routine monitoring. Based on laboratory costs reported in the 1996 ICR, EPA estimated the laboratory fee at $200 per sample for all size categories. This estimate does not include shipping costs. For systems serving 10,000 people or more, a shipping cost of $10 was added to account for the fact that larger systems often have in-house laboratory facilities and can take advantage of bulk discounts. For systems serving fewer than 10,000 people, a shipping cost of $40 is added because very few small systems have in-house laboratory facilities and they have less opportunity to take advantage of bulk discounts. Laboratory fees are not expected to differ substantially between disinfecting ground water systems and surface water systems.

7.3 Non-Treatment Costs for Systems and States/Primacy Agencies

This section presents the estimated national costs for systems and States/Primacy Agencies to perform Stage 2 DBPR activities that are not related to treatment. These activities have been described in Chapter 1 and are described in detail in Appendix H. The following subsections provide a brief summary of each activity and key assumptions used to estimate costs for each:

7.3.1 Rule Implementation
7.3.2 Initial Distribution System Evaluations
7.3.3 Monitoring Plans
7.3.4 Additional Routine Monitoring
7.3.5 Operational Evaluations

Appendix H provides the methodology and calculations for all non-treatment-related costs. Note that cost calculations in Appendix H are performed using system inventory data broken out by system size categories that are different from the standard nine system size categories used elsewhere in this EA. EPA believes these alternate categories to be more appropriate for establishing the number of samples required per system. Section 7.3.6 summarizes the one-time and yearly costs for all non-treatment-related Stage 2 DBPR activities.

Monitoring requirements for the Stage 1 DBPR were dependent on the system type (NTNCWS or CWS), the source water type (surface or ground) and the number of plants per system. EPA has identified several potential issues when requirements are based on the number of plants per system. These include:

- The number of required sample sites may be either excessive or insufficient to represent TTHM and HAA5 occurrence throughout the system, particularly in situations where a small system uses multiple plants, or where a very large system uses a small number of plants.

- Plant-based sampling requirements for mixed systems (i.e., those receiving disinfected surface water and ground water in their distribution system) may be excessive, depending upon the system's characteristics.

- Plant-based monitoring requirements pose unique implementation issues for systems that use temporary supplies during the year.

An alternative population-based approach was included in the proposed Stage 2 DBPR, and many positive comments were received. For this reason and those listed above, a population-based monitoring approach was adopted for the final rule whereby IDSE and Stage 2 monitoring requirements are based only on system type, source water type, and retail population served.

7.3.1 Rule Implementation

Public Water Systems

All systems subject to the Stage 2 DBPR will incur one-time costs for staff to read the rule and become familiar with its provisions and to be trained on its requirements. The technical and managerial labor rates presented in Section 7.2 were used along with estimates of labor hours to generate implementation costs for all systems. The mix of labor rates used to estimate implementation costs varies by activity and system size as summarized in Appendix H.

States/Primacy Agencies

State/Primacy Agency implementation activities include:

- Public notification
- Regulation adoption and program development
- Training State/Primacy Agency staff
- Training PWS staff
- Technical assistance
- Updating the data management system

The number of FTEs required per activity was estimated by EPA based on previous experience with other rules. State/Primacy Agency activities include public notification (0.1 FTEs), regulation adoption and program implementation (0.50 FTEs), training State/Primacy Agency staff (0.25 FTEs), training PWS staff and technical assistance (1.00 FTE), and updating the management system (0.10 FTEs). The labor rates used to estimate State/Primacy Agency costs are presented in Section 7.2. The number of States and territories included the 50 States (or EPA regions where States do not have primacy), 6 territories, and 1 tribal government.

7.3.2 Initial Distribution System Evaluations

Public Water Systems

The purpose of the IDSE is to identify compliance monitoring sites that are representative of the highest TTHM and HAA5 levels in the distribution system. IDSEs can be performed by either (1) conducting standard monitoring or (2) completing an System Specific Study (SSS) that may include historical data or hydraulic modeling results. NTNCWSs serving fewer than 10,000 people are not subject to the IDSE requirements of the Stage 2 DBPR. A CWS or NTNCWS does not have to perform the IDSE if: (1) all Stage 1 DBPR compliance samples are less than or equal to 40 μg/L for TTHM and 30 μg/L for HAA5, or (2) the system serves fewer than 500 people and qualifies for the very small system waiver.

Systems performing an IDSE will incur costs for evaluating their distribution systems to identify sampling sites, preparing an IDSE monitoring plan, sampling, and reporting results. Systems electing to complete an SSS may not incur sampling costs; however, they will still incur labor costs for preparing an IDSE study plan and preparing the report. Also, some systems that do not perform the IDSE may have more sampling sites required under the Stage 2 DBPR than under the Stage 1 DBPR and, thus, will incur a small labor cost for selecting new Stage 2 sites. A detailed description of the process that EPA used to estimate the total national IDSE costs, as well as detailed calculation tables, are presented in Appendix H.

States/Primacy Agencies

States/Primacy Agencies also will incur costs as a result of the IDSEs. The activities they will conduct include analyzing PWS IDSE reports, determining which systems cannot receive a very small system waiver, consulting with PWSs, and IDSE recordkeeping. The estimates of burden and costs depend on the IDSE option (standard monitoring plan or SSS) and system size. Total costs for States/Primacy Agencies for the IDSE are estimated to be $2.2 million.

7.3.3 Monitoring Plans

Public Water Systems

All systems are required to prepare a monitoring plan for routine Stage 2 DBPR monitoring. Most systems will have to base the new monitoring plan on the IDSE results. Some systems, such as those receiving very small system waivers and NTNCWSs serving fewer than 10,000 people, will only need to update existing Stage 1 monitoring plans.

As described in Section 7.1.2, some ground water systems may choose to add disinfection to correct a significant deficiency under the GWR. Because the GWR is expected to be promulgated at the same time or just after the Stage 2 DBPR is promulgated, EPA expects new systems adding disinfection to meet GWR requirements to simultaneously achieve compliance with Stage 2 MCLs. Therefore, as discussed in Chapter 3 of this EA, these systems are not included in the treatment baseline. The IDSE will likely not apply to these systems because they are expected to add disinfection after the IDSE requirement is complete. These systems will, however, need to prepare Stage 2 monitoring plans.

Estimates of labor hours for systems to complete the monitoring plans are in Appendix H.

States/Primacy Agencies

States/Primacy Agencies will also incur costs to review and approve monitoring plans submitted by systems. Estimates of burden and cost for monitoring plans are found in Appendix H. The estimated costs for State/Primacy Agency review and approval of monitoring plans is $926,016.

7.3.4 Additional Routine Monitoring

Public Water Systems

EPA has established a population-based monitoring approach for the Stage 2 DBPR, where monitoring requirements are no longer based on number of plants per system as under the Stage 1 DBPR. As a result, systems may have the same, fewer, or more monitoring sites for the Stage 2 DBPR compared to Stage 1, depending on number of plants and how the State/Primacy Agency determined their Stage 1 monitoring requirements. Some systems will have the same monitoring requirements under the Stage 2 DBPR as they did under the Stage 1 DBPR, and will, therefore, incur no additional costs for this activity. In other cases, incremental costs will be negative (that is, costs will be reduced) under the Stage 2 DBPR for systems that have fewer sites than the Stage 1 DBPR (see Exhibit H.8 in Appendix H). Systems with more monitoring sites under the Stage 2 DBPR than under the Stage 1 DBPR will incur costs. Estimates of numbers of systems that have additional monitoring sites and total costs for additional routine monitoring are provided in Appendix H.

As described in Section 7.1.2, some ground water systems may choose to add disinfection to correct a significant deficiency under the GWR. These are systems that do not disinfect currently that will need to install disinfection and monitor for DBPs for the first time. Because the GWR is expected to be promulgated at the same time or just after the Stage 2 DBPR is promulgated, EPA expects new systems adding disinfection to meet GWR requirements to simultaneously achieve compliance with Stage 2 MCLs. Therefore, these systems are not included in the treatment baseline. The IDSE will likely not apply to these systems because they are expected to add disinfection after the IDSE requirement is complete. Systems adding disinfection for the GWR, however, will need to monitor DBPs for the first time under Stage 2. The derivation of routine monitoring costs for systems that add disinfection to achieve compliance with the GWR is provided in Appendix H.

Costs for additional routine monitoring include laboratory analysis and labor for taking the sample.

States/Primacy Agencies

States/Primacy Agencies will incur costs related to review and evaluation of monitoring data submitted by systems. EPA estimates states will require 0.4 FTEs to track compliance data, update data management systems, and file records. These costs are estimated to total $1.6 million per year.

7.3.5 Operational Evaluations

Public Water Systems

To address excess DBP levels that may occasionally occur (but do not cause rule violations), the Stage 2 DBPR contains a provision for operational evaluations. An operational evaluation level is exceeded when a sample result when multiplied by two, added to the sum of the previous two quarters' samples, and divided by four would result in a concentration greater than 80 μg/L for TTHM or 60 μg/L for HAA5. The equation for calculating the concentration for an operational evaluation (C_{SE}) is:

$$C_{SE} = (Q_1 + Q_2 + 2*Q_3)/4$$

where Q_1 is the concentration of the of the DBP two quarters ago, Q_2 is the concentration of the DBP in the previous quarter, and Q_3 is the concentration of the DBP in the current quarter. If C_{SE} is greater than the maximum contaminant level (MCL) for the DBP measured, then the operational evaluation level is exceeded. For example, if a system had first-quarter and second-quarter results of 75 μg/L for TTHM and had a third-quarter result of 90 μg/L, then the calculation would yield:

$$(75\ \mu g/L + 75\ \mu g/L + 2*(90\ \mu g/L))/4 = 82.5\ \mu g/L,$$

meaning the operational evaluation level is exceeded.

If an operational evaluation level is exceeded, systems must conduct an "operational evaluation" to investigate and document the cause. Appendix H provides estimates of the number of systems expected to exceed an operational evaluation level and the associated costs.

States/Primacy Agencies

States will incur some costs to review operational evaluations submitted by systems. Appendix H estimates the time and costs that will be spent by States to review these operational evaluations. Costs for States/Primacy Agencies to review the operational evaluations are estimated to be $114,173 per year.

7.3.6 Results (One-Time and Yearly Costs)

Exhibit 7.7 summarizes the one-time system costs for implementation, IDSEs, and development of Stage 2 monitoring plans, along with the yearly costs for additional routine monitoring and operational evaluations. Note that IDSE costs make up the majority of the one-time costs. Total one-time system costs for implementation, IDSEs, and Stage 2 monitoring plans are approximately $74.6 million (including $12.3 million for implementation activities, $57.4 million for IDSE activities, and $4.9 million for monitoring

plans). Total annual system costs for additional routine monitoring and operational evaluations are approximately $4.4 million (including $4.2 million for additional routine monitoring, $0.2 million for operational evaluations). As shown in Exhibit 7.7, additional routine monitoring costs are positive for some systems and negative for others (because of the redefined monitoring requirements from a plant-based to a population-based approach). One-time and annual costs for States/Primacy Agencies are summarized in Appendix H, Exhibit H.21.

Exhibit 7.7 Summary of System Costs for Non-Treatment Related Stage 2 DBPR Rule Activities (One-Time and Yearly)

System Size (Population Served)	One Time-Costs ($)				Annual Costs ($)		
	Implementation	IDSE	Stage 2 Monitoring Plans	Total	Additional Routine Monitoring	Operational Evaluations	Total
	A	B	C	D=A+B+C	E	F	G=E+F
Surface Water and Mixed CWSs							
<100	$ 244,635	$ 447,582	$ 94,772	$ 786,989	$ (52,103)	$ 534	$ (51,568)
100-499	$ 498,740	$ 912,489	$ 193,212	$ 1,604,442	$ (106,222)	$ 1,089	$ (105,133)
500-999	$ 363,678	$ 3,140,721	$ 181,839	$ 3,686,237	$ (331,698)	$ 3,011	$ (328,686)
1,000-3,299	$ 640,272	$ 5,529,388	$ 320,136	$ 6,489,795	$ (583,969)	$ 5,301	$ (578,668)
3,300-9,999	$ 623,055	$ 8,379,826	$ 258,721	$ 9,261,602	$ 953,611	$ 20,870	$ 974,481
10,000-49,999	$ 1,212,306	$ 17,851,398	$ 461,867	$ 19,525,571	$ (2,477,619)	$ 98,959	$ (2,378,660)
50,000-99,999	$ 239,846	$ 6,426,075	$ 93,524	$ 6,759,446	$ 216,219	$ 39,199	$ 255,418
100,000-999,999	$ 212,143	$ 6,113,574	$ 93,984	$ 6,419,700	$ 276,429	$ 38,699	$ 315,128
1,000,000+	$ 15,227	$ 731,365	$ 11,566	$ 758,158	$ 36,517	$ 5,076	$ 41,593
National Totals	**$ 4,049,902**	**$ 49,532,418**	**$ 1,709,621**	**$ 55,291,940**	**$ (2,068,834)**	**$ 212,739**	**$ (1,856,095)**
100% Ground Water CWSs							
<100	$ 1,596,365	$ 221,266	$ 416,873	$ 2,234,503	$ 96,758	$ -	$ 96,758
100-499	$ 1,975,736	$ 273,849	$ 515,942	$ 2,765,527	$ 119,753	$ -	$ 119,753
500-999	$ 894,469	$ 1,931,945	$ 507,572	$ 3,333,986	$ 553,626	$ -	$ 553,626
1,000-3,299	$ 1,085,531	$ 2,344,617	$ 615,991	$ 4,046,139	$ 671,883	$ -	$ 671,883
3,300-9,999	$ 492,179	$ 1,063,047	$ 279,290	$ 1,834,515	$ 304,631	$ -	$ 304,631
10,000-49,999	$ 797,681	$ 1,642,671	$ 320,895	$ 2,761,247	$ 3,518,648	$ -	$ 3,518,648
50,000-99,999	$ 88,492	$ 182,233	$ 35,599	$ 306,325	$ 390,348	$ -	$ 390,348
100,000-999,999	$ 46,421	$ 166,938	$ 30,689	$ 244,048	$ (92,140)	$ -	$ (92,140)
1,000,000+	$ 2,180	$ 5,964	$ 1,868	$ 10,013	$ (25,261)	$ -	$ (25,261)
National Totals	**$ 6,979,054**	**$ 7,832,529**	**$ 2,724,718**	**$ 17,536,302**	**$ 5,538,247**	**$ -**	**$ 5,538,247**
Surface Water and Mixed NTNCWSs							
<100	$ 46,558	$ -	$ 10,346	$ 56,904	$ -	$ -	$ -
100-499	$ 63,891	$ -	$ 14,198	$ 78,089	$ -	$ -	$ -
500-999	$ 23,602	$ -	$ 5,245	$ 28,847	$ -	$ -	$ -
1,000-3,299	$ 20,707	$ -	$ 4,602	$ 25,309	$ -	$ -	$ -
3,300-9,999	$ 6,591	$ -	$ 1,216	$ 7,807	$ 25,473	$ -	$ 25,473
10,000-49,999	$ 3,263	$ 46,876	$ 1,303	$ 51,442	$ -	$ -	$ -
50,000-99,999	$ -	$ -	$ -	$ -	$ -	$ -	$ -
100,000-999,999	$ 740	$ 23,725	$ 313	$ 24,778	$ 3,860	$ -	$ 3,860
1,000,000+	$ -	$ -	$ -	$ -	$ -	$ -	$ -
National Totals	**$ 165,353**	**$ 70,601**	**$ 37,222**	**$ 273,176**	**$ 29,333**	**$ -**	**$ 29,333**
100% Ground Water NTNCWSs							
<100	$ 498,070	$ -	$ 184,987	$ 683,057	$ 175,519	$ -	$ 175,519
100-499	$ 425,353	$ -	$ 157,979	$ 583,331	$ 149,893	$ -	$ 149,893
500-999	$ 131,289	$ -	$ 51,924	$ 183,212	$ 253,333	$ -	$ 253,333
1,000-3,299	$ 55,048	$ -	$ 21,771	$ 76,819	$ 106,220	$ -	$ 106,220
3,300-9,999	$ 4,781	$ -	$ 1,891	$ 6,672	$ 9,226	$ -	$ 9,226
10,000-49,999	$ 2,082	$ 855	$ 1,143	$ 4,080	$ 15,822	$ -	$ 15,822
50,000-99,999	$ 189	$ 78	$ 104	$ 371	$ 1,438	$ -	$ 1,438
100,000-999,999	$ 215	$ -	$ 192	$ 406	$ 2,085	$ -	$ 2,085
1,000,000+	$ -	$ -	$ -	$ -	$ -	$ -	$ -
National Totals	**$ 1,117,027**	**$ 932**	**$ 419,990**	**$ 1,537,949**	**$ 713,536**	**$ -**	**$ 713,536**
Grand Total All Systems	**$ 12,311,336**	**$ 57,436,480**	**$ 4,891,552**	**$ 74,639,368**	**$ 4,212,282**	**$ 212,739**	**$ 4,425,021**

Notes: Detail may not add due to independent rounding.

Source: Appendix H, Exhibit H.16. Costs for Stage 2 monitoring plans and additional routine monitoring include those costs for systems that are projected to add disinfection to comply with the Ground Water Rule.

7.4 Technology Unit Costs

Available treatment technologies for reducing DBPs were identified during the Stage 2 Microbial-Disinfectants/Disinfection Byproducts (M-DBP) Federal Advisory Committees Act (FACA) deliberations (USEPA 2000n). They include alternative disinfectants such as ozone, ultraviolet light (UV), and chlorine dioxide, as well as DBP precursor removal treatment technologies such as microfiltration or ultrafiltration. Converting to chloramines for residual disinfection was also identified as a relatively inexpensive treatment technology that can limit DBP formation in many distribution systems.

Unit cost estimates for these treatment technologies are in units of dollars per plant for initial capital and yearly O&M activities. Household unit costs are in units of dollars per household per year. Derivation of unit costs for a wide range of plant sizes, represented by different design and average daily flow rates, are provided in the document, *Technologies and Costs for Control of Microbial Contaminants and Disinfection Byproducts* (USEPA 2003o). EPA uses mean design flow and average daily flow for each of the nine system size categories (shown in Exhibit 3.4) to estimate unit costs for each treatment technology for each system type, source water type, and size category.

Section 7.4.1 describes the treatment technologies and operating conditions that are used to predict national treatment costs of the Stage 2 DBPR. Section 7.4.2 discusses alternatives to treatment identified by EPA and others during the FACA process and explains why these processes are not included in the cost analysis for the Stage 2 DBPR. Section 7.4.3 discusses uncertainty in the unit costs and explains how the uncertainties were explicitly accounted for in the Stage 2 cost model.

7.4.1 Treatment Technologies Used to Estimate Costs

This section discusses the treatment technologies available for surface water plants first, followed by the treatment technologies used for ground water plants. A discussion of uncertainties in unit costs follows. A summary of unit treatment costs is presented at the end of the section. Appendix I supports the data in Section 7.4.1, showing the detailed derivation of unit costs over the entire range of expected plant flows.

Treatment Technologies for Surface Water Plants

Exhibit 7.8a lists the treatment technologies that are available to surface water plants for complying with Stage 1 DBPR and Stage 2 DBPR regulatory alternatives. The SWAT decision tree, as noted in Appendix A, includes both installation of treatment technologies and changes to operational practices. Although changes in operational practices may result in small increases in chemical costs or minor capital improvements, EPA assumes their costs are negligible as compared to the costs of the advanced treatment technologies (e.g., UV, ozone, granular activated carbon, microfiltration/ultra-filtration). Therefore, the predicted costs for the Stage 2 DBPR do not include costs for operational changes (Section 7.8 summarizes uncertainties in national cost estimates). The treatment technologies presented in the SWAT Decision Tree (Appendix A) that are not costed in this EA because they are assumed to incur negligible costs are:

- Adjusting disinfection dose

- Moving the point of chlorination

- Enhanced coagulation/enhanced softening (required for the Stage 1 DBPR)

- Turbo coagulation

Although EPA assumes that large surface water plants serving 100,000 people or more can select any of the treatment technologies presented in Exhibit 7.8a, small plants may not be able to use a particular treatment technology because of operational constraints or other reasons. Limitations on the use of treatment technologies by small systems, summarized in the second column in Exhibit 7.8a, were identified during the small surface water expert review process (see Appendix A for details).

The last column in Exhibit 7.8a identifies the design criteria and operating conditions for each treatment technology in this EA for which costs are calculated. To capture the range of costs, the Technology and Cost (T&C) document evaluated treatment technologies over a range of possible influent water qualities and operating conditions (USEPA 2003o). For the purposes of estimating the costs of the Stage 2 DBPR, the Technical Workgroup (TWG) selected water quality and operating parameters that would capture the typical circumstances under which plants may use the treatment technology. EPA does not propose that all systems would operate under these conditions, but they suffice to generate capital and O&M costs typical of the range of system types and sizes. While these assumptions simplify the true variety of operating conditions, EPA believes they capture reasonable estimates of national costs. The uncertainties associated with selecting these operational parameters and conditions are summarized in Section 7.8.

Appendix A presents additional information on how each treatment technology was modeled in SWAT, including log removal and disinfection credits for *Giardia* and viruses. Note that, for UV, the disinfection credit for viruses was 2.0 logs for all runs. The primary disinfectant (usually chlorine) dose was then modified to meet the remaining disinfection requirements.

Some advanced treatment technologies were considered in combination for surface water systems to meet the Stage 2 DBPR (as modeled in SWAT). When treatment technologies are a combination of two or more unit processes (e.g., Granular Activated Carbon—20-Minute Contact Time (GAC20) with Advanced Disinfectants such as Chlorine Dioxide or Ozone), the technology unit costs are assumed to be the sum of the costs for each unit process. For example, the cost for implementing GAC20 with an Advanced Disinfectant (e.g., Ozone) is equal to the sum of GAC20 and Ozone unit costs. This may over-estimate unit costs since some economies of scale are expected when two or more treatment technologies are installed at the same time.

Exhibit 7.8a Treatment Technologies for Surface Water Plants

Technology	Constraints	Design Criteria and Operating Conditions
Switching to chloramines (CLM) as a residual disinfectant	Can be used alone or in conjunction with all other treatment technologies in this exhibit	Ammonia dose = 0.55 mg/L (output from SWAT)
Chlorine dioxide (CLO2)	Assumed not practical for systems fewer than 100 people	EPA assumed that plants will not build a new contact basin for chlorine dioxide ClO_2 dose = 1.25 mg/L
Ultraviolet light disinfection (UV)[1]	None	Median water quality parameters— UV_{254} = 0.051 cm^{-1}, turbidity = 0.1 NTU, alkalinity = 60 mg/L as $CaCO_3$, hardness = 100 mg/L as $CaCO_3$ Dose = 40 mJ/cm^2
Ozone	Assumed not practical for systems serving fewer than 100 people	Design dose = 3.2 mg/L, contact time = 12 minutes[2]
Microfiltration / Ultrafiltration (MF/UF)	None	Median water quality parameters— Temperature=10°C, disposal to sewer
Granular activated carbon filtration, empty-bed contact time of 10 minutes (GAC10)	Assumed not practical for small systems serving fewer than 10,000 people	Reactivation frequency = 360 days[3] On-site regeneration
GAC10 + Advanced Disinfectants	Assumed not practical for small systems serving fewer than 10,000 people	Chlorine dioxide as the advanced disinfectant Reactivation frequency = 360 days[3] On-site regeneration
Granular activated carbon filtration, empty-bed contact time of 20 minutes (GAC20)	None	Reactivation frequency = 90 days[3] Onsite regeneration used for systems serving $\geq$ 10,000 Media replacement used for systems serving < 10,000
GAC20 + Advanced Disinfectants	None	Systems serving $\geq$ 10,000 (GAC20 + chlorine dioxide) Systems serving 100 - 9,999 (GAC20 + ozone) Systems serving < 100 (GAC20 + UV) Onsite media regeneration used for systems serving $\geq$ 10,000 Media replacement used for systems serving < 10,000
Membranes (MF/UF + nanofiltration [NF])	None	Median water quality parameters— MF/UF: 10°C, disposal to sewer NF: 10°C, ocean discharge

Notes:

1 Available for Stage 2 DBPR regulatory alternatives only; not considered available for the Stage 1 DBPR. UV was assumed to be used as a supplement to chlorine to achieve some of the required *Giardia* and virus inactivation, thereby reducing chlorine dosages.

2 Dose does not consider *Cryptosporidium* inactivation, and, therefore, may not represent what systems would do to meet Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) requirements. However, the higher dose is accounted for in the LT2ESWTR EA.

3 Median reactivation frequency generated by SWAT.

Source: T&C document (USEPA 2003o), FACA deliberations for Stage 2 treatment technologies (USEPA 2000n). SWAT Decision Tree (Appendix A), and Small Surface Water Delphi Groups (Appendix A).

Treatment Technologies for Ground Water Plants

Exhibit 7.8b lists the treatment technologies used to estimate costs of the Stage 1 DBPR and Stage 2 DBPR regulatory alternatives for ground water plants. Fewer treatment technologies are applicable to disinfecting ground water plants than to surface water plants. As noted in Appendix B, the ICR Ground Water Delphi process concluded that disinfecting ground water systems would choose primarily from four treatment technologies—conversion to chloramines, ozone, GAC20, and nanofiltration. Limitations on treatment technology use by small systems, as identified during the small ground water system expert review process, are provided in the second column.

Because UV was still very much an emerging treatment technology when the Ground Water Delphi process was conducted (Spring, 2000), UV was not considered as a treatment option for large ground water plants for either the Stage 1 or Stage 2 DBPRs. UV was, however, considered an available treatment technology for small ground water systems to meet Stage 2 DBPR requirements. The small-system expert reviewers assumed UV would be used instead of chlorine to achieve 4.0 logs of virus inactivation in all circumstances. Current UV validation techniques as outlined in the *UV Disinfection Guidance Manual* (USEPA 2003g) do not allow for validation of 4-log virus inactivation. Therefore it will be necessary to use two UV reactors in series, each achieving 2-log virus inactivation, to achieve the desired 4-log virus removal. A dose of 200 millijoules per centimeter square (mJ/cm^2) is assumed necessary to achieve 2-log virus inactivation, much higher than the UV dose of 40 mJ/cm^2 assumed in the T&C document for surface water systems (USEPA 2003o). Thus, the unit cost estimates shown in Exhibit 7.8b for UV ($/plant) for small ground water plants represent new estimates for two reactors in series with a higher dose of 200 mJ/cm^2. A recent study by Ballester and Malley (2004), however, suggests a possible synergistic effect when using UV together with chloramines. If this effect is verified, the assumptions here may be overstated and the costs will be conservatively high.

Exhibit 7.8b Treatment Technologies for Disinfecting Ground Water Plants

Treatment Technology	Constraints	Design Criteria and Operating Conditions
Switching to CLM as a Residual Disinfectant	This advanced treatment technology can be used alone or in conjunction with all of the following treatment technologies	Ammonia dose = 0.15 mg/L [1]
UV[2]	Was considered only for small systems with populations of fewer than 10,000 people. Requires two reactors in series.	Median water quality parameters— UV_{254} = 0.051 cm^{-1}, turbidity = 0.1 NTU, alkalinity = 60 mg/L as $CaCO_3$, hardness = 100 mg/L as $CaCO_3$ Dose = approximately 200 mJ/cm
Ozone	Assumed not practical for systems serving fewer than 100 people	Design dose = approximately 3.2 mg/L, contact time = 12 minutes
GAC20	None	Reactivation frequency = 240 days [3] On-site regeneration used for systems serving $\geq$ 10,000 Media replacement used for systems < 10,000
Nanofiltration	None	Median water quality parameters— Temperature=10°C, ocean discharge

Notes:
1 Dose based on decisions from the ICR Ground Water Delphi Group.
2 Available for Stage 2 DBPR regulatory alternatives only; not considered available for the Stage 1 DBPR.
3 Reactivation frequency based on decisions from the ICR Ground Water Delphi Group.

Source: T&C document (USEPA 2003o), FACA deliberations for Stage 2 treatment technologies (USEPA 2000n), and ICR and Small Ground Water Delphi Groups (Appendix B).

Unit Costs for the Stage 2 DBPR

Capital and O&M unit costs for each treatment technology are derived from the T&C document (USEPA 2003o). The T&C document contains between 16 and 20 point estimates of capital and O&M costs over the range of expected design and average flow rates. Appendix I displays these point estimates for the treatment technologies, design criteria, and operating conditions listed in Exhibits 7.8a and b. In previous T&C drafts, non-linear cost curves were generated for specific flow ranges based on a more limited set of point estimates. Because the number of point estimates for the unit costs was increased to better represent the full range of expected flows, EPA believes that direct straight-line interpolation between the point values is adequate for characterizing the changes in unit costs as flow increases or decreases. Along with the 16 to 20 point estimates, Appendix I graphically shows the relationship of unit cost and flow (i.e., the point estimates connected by straight lines).

Unit treatment costs for each system type and size category are estimated using (1) the capital and O&M cost data in Appendix I and (2) the mean design and average daily flow values presented in Exhibit 3.4. For example, the design flow for UV for surface water plants in CWSs serving between 10,000 and 49,999 people is estimated to be 5.324565 millions of gallons per day (MGD) (the value in Exhibit 3.4 is rounded to 5.325 MGD). Exhibit I.5 shows that the capital cost for UV surface water

plants is $361,819 for a design flow of 3.5 MGD and $543,582 for a design flow of 7.0 MGD. The cost for a 5.325 MGD plant can be calculated by linear interpolation as:

Unit Cost = $361,819 + ($543,582 - $361,819) * (5.324565 MGD - 3.5 MGD)/(7.0 MGD - 3.5 MGD)

Unit Cost = $456,572

(Note, detail may not exactly equal value in Exhibit 7.10a due to independent rounding).

Household unit treatment costs ($/HH/year) are estimated in order to provide a potential and approximate measure of the increase in water bills that is expected to result from the Stage 2 DBPR. Steps for deriving household unit costs are outlined below.

- Step 1: Capital costs of treatment are amortized over a 20 year period using the cost-of-capital rates summarized in Exhibit 7.9. These rates are derived from *Development of Cost of Capital Estimates for Public Water Systems, Final Report* (USEPA 2001e).[3] For each treatment technology, amortized capital costs are added to annual O&M costs to produce annual treatment costs in units of dollars per plant per year ($/plant/yr).

- Step 2: Results from step 1 ($/plant/yr) are converted to dollars per 1000 gallons per year ($/kgal/yr) using the following formula:

$$C_{HH} = C_P/(ADF*365*1000)$$

where:
C_{HH} = unit cost per household in $/kgal
C_P = unit cost per plant $/plant/yr
ADF = average daily flow in mgd

- Step 3: Estimated household usage rate (in units of 1,000 gallons per year, or kgal/yr) is used to convert results from step 2 ($/kgal/yr) to dollars per household per year ($/HH/yr) according to the formula:

$$C_{AHH} = C_{HH}*Q_{HH}$$

where:
C_{AHH} = annual household unit cost ($/HH/yr)
Q_{HH} = annual household usage rate (kgal/yr)

[3] Cost-of-capital estimates are used to account for interest payments that PWSs may incur and pass along to customers in the form of water bill increases. These rates may be different than social discount rates (3 and 7 percent) used elsewhere in the economic analysis. Social discount rates are more appropriate for estimating economic impacts on a national level. See EPA's *Guidelines for Preparing Economic Analyses* (USEPA 2000j) for a full discussion of the use of social discount rates in the evaluation of policy decisions.

Exhibit 7.9 summarizes the annual household usage rates used to estimate household costs in this chapter. These are from the Baseline Handbook, as derived from the 1995 CWSS[4]. EPA recognizes that there may be significant variation in household water usage between specific PWSs (table C.4.2.3 of the handbook presents confidence intervals around these estimates), but believes that mean usage rate values are adequate for characterizing household costs.

Exhibit 7.9 Household Cost Inputs

System Size (Population Served)	Mean Annual Water Usage per Household (kgal/year)	Public Cost of Capital Rate	Private Cost of Capital Rate
	A	B	C
<100	83	5.31%	6.22%
100-499	83	5.31%	6.22%
500-999	104	5.58%	6.22%
1,000-3,299	87	5.58%	6.22%
3,300-9,999	97	5.58%	6.22%
10,000-49,999	109	5.20%	5.66%
50,000-99,999	119	5.24%	6.27%
100,000-999,999	125	5.24%	6.27%
1,000,000+	125	5.24%	6.27%

Sources:
(A) Derived from the Third Edition of the Baseline Handbook (USEPA, 2001c) Table C.4.2.3, all systems . Rates for systems serving < 500 people revised based on further analysis by EPA.
(B) and (C) *Development of Cost of Capital Estimates for Public Water Systems, Final Report* (USEPA, 2001d).

As an example, consider the derivation of the household unit costs for UV for a CWS surface water system serving between 10,000 and 49,999 people. The capital cost is $456,572 as calculated above. The O&M cost from Exhibit 7.10b is $15,274/plant/year. In that size category 90.1 percent of households are served by public systems and 9.9 percent by private systems (see Exhibit 3.3). So the discount rate to be used for amortizing the capital is then:

$$i = .901*(0.052) + .099*(0.0566) = 0.0525$$

Amortizing the capital at a 5.25 percent discount rates gives:

$$C_{cap\text{-}ann} = \$456{,}572*0.0525*(1 + 0.0525)^{20}/((1 + 0.0525)^{20} - 1) = \$37{,}417.15/\text{plant/year}$$

$$C_p = \$37{,}417.15 + \$15{,}274.16 = \$52{,}691.31/\text{plant/year}$$

This is the result of step 1 listed above. Step 2 involves multiplying the cost by the average daily flow to obtain a unit cost per thousand gallons of water.

[4] Note that household usage rates for the affordability analysis in Chapter 8 are *median* values from 1995 CWSS data, whereas the values in Exhibit 7.13 are *mean* values.

C_{HH} = ($52,691.31/plant/year)/[(2.34Mgal/plant/d)*(365d/yr)*(1000kgal/Mgal)] = $0.06/kgal/yr.

Step 3 involves multiplying by the household usage rate, which from Exhibit 7.9 is 109 kgal/yr

C_{AHH} = $0.06/kgal/yr*109kgal/HH/yr = $6.72/HH

This is the value shown in Exhibit 7.10c.

Exhibits 7.10a-b and 7.11a-b summarize annual O&M costs ($/plant/year) and capital costs ($/plant) for surface and ground water treatment technologies, respectively. Note that unit costs are different for surface and ground water plants in each size category because they are based on different mean design and average daily flows per plant as shown in Exhibit 3.4. Costs are provided for each treatment technology and for each of the nine population size categories for plants in CWSs. Unit costs for NTNCWSs are not presented, but can be derived from the data in Appendix I using NTNCWS flows, as summarized in Exhibit 3.4.

Exhibits 7.10c and 7.11c summarize household unit treatment costs ($/HH/year) for surface and ground water treatment technologies, respectively. The household unit costs in Exhibits 7.10c and 7.11c represent only the household costs for installation and operation of the treatment technology and do not include costs for other items such as the IDSE or monitoring. A description of the process used to generate distributions of possible household treatment costs is provided in Section 7.5.3.

Exhibit 7.10a Capital Unit Costs ($/Plant) for CWS Surface Water Plants

System Size (Population Served)	Plant Design Flow (MGD)	CLM	CLO2	UV	Ozone	MF/UF	GAC10	GAC10+AD	GAC20	GAC20+AD	Membranes
<100	0.02	$29,104.44		$12,389.73		$195,605.59			$49,239.18	$49,239.18	$260,909.86
100-499	0.08	$29,104.44		$23,031.80		$373,422.89			$120,214.53	$120,214.53	$511,246.10
500-999	0.21	$33,047.01	$38,637.25	$45,188.94	$401,494.03	$668,228.42			$274,674.40	$319,863.34	$922,064.41
1,000-3,299	0.57	$40,954.40	$41,950.61	$87,869.72	$610,467.18	$1,032,468.83			$630,258.56	$1,240,725.74	$1,585,978.03
3,300-9,999	1.42	$83,772.20	$80,980.80	$318,958.94	$989,688.20	$2,002,992.32			$1,726,876.12	$2,716,564.32	$3,336,150.82
10,000-49,999	5.32	$83,772.20	$201,714.84	$457,719.08	$1,992,626.96	$5,831,476.20	$2,662,884.51	$2,864,599.35	$4,388,911.73	$4,590,626.57	$10,977,349.65
50,000-99,999	8.26	$85,666.74	$218,640.92	$645,428.85	$2,558,175.82	$8,469,691.08	$3,622,545.65	$3,841,186.57	$6,043,134.98	$6,261,775.90	$16,315,154.73
100,000-999,999	29.89	$172,356.04	$341,382.88	$2,142,573.70	$5,726,786.46	$26,059,504.89	$8,993,844.94	$9,335,227.82	$15,370,784.57	$15,712,167.45	$51,427,679.24
1,000,000+	200.95	$485,633.73	$877,596.16	$7,756,654.16	$25,393,578.52	$146,969,927.83	$36,851,865.10	$37,729,461.26	$64,692,915.84	$65,570,511.99	$271,760,784.19

Source: Design flows from Exhibit 3.4, and unit costs from Appendix I.

Exhibit 7.10b Annual O&M Unit Costs ($/Plant/Year) for CWS Surface Water Plants

System Size (Population Served)	Plant-Average Daily Flow (MGD)	CLM	CLO2	UV	Ozone	MF/UF	GAC10	GAC10+AD	GAC20	GAC20+AD	Membranes
<100	0.01	$1,366.97		$3,465.33		$6,788.93			$19,849.99	$19,849.99	$14,964.21
100-499	0.03	$1,486.13	$14,200.27	$4,567.48	$55,555.11	$10,560.66			$47,768.56	$61,968.83	$25,798.47
500-999	0.08	$2,786.70	$16,491.53	$5,906.07	$58,860.42	$25,696.45			$59,595.71	$65,501.78	$62,334.66
1,000-3,299	0.22	$3,075.12	$17,767.16	$8,060.73	$61,074.17	$40,850.24			$120,988.58	$182,062.75	$110,067.20
3,300-9,999	0.59	$6,367.05	$20,288.25	$10,462.98	$65,448.37	$90,783.00			$188,170.95	$253,619.32	$256,285.82
10,000-49,999	2.34	$9,532.26	$23,993.48	$15,274.16	$88,075.83	$258,314.24	$103,214.63	$127,208.11	$292,402.22	$316,395.70	$817,602.69
50,000-99,999	3.80	$11,365.79	$27,157.89	$17,309.16	$103,776.82	$401,754.12	$138,118.16	$165,276.06	$385,208.70	$412,366.60	$1,291,782.17
100,000-999,999	14.61	$20,636.42	$48,315.25	$32,774.25	$216,130.20	$1,337,846.76	$337,930.01	$386,245.26	$1,074,985.73	$1,123,300.98	$4,500,839.35
1,000,000+	107.80	$73,080.99	$197,514.28	$170,152.92	$1,241,600.91	$8,908,719.65	$1,767,266.63	$1,964,780.90	$6,091,016.57	$6,288,530.85	$30,384,366.43

Source: Average daily flows from Exhibit 3.4, and unit costs from Appendix I.

Exhibit 7.10c Household Unit Treatment Costs ($/Household/Year) for CWS Surface Water Plants

System Size (Population Served)	Mean Annual Water Usage per HH (kgal)	CLM	CLO2	UV	Ozone	MF/UF	GAC10	GAC10+AD	GAC20	GAC20+AD	Membranes
<100	83	$139.50		$163.48		$851.00			$869.14	$869.14	$1,348.43
100-499	83	$32.32	$116.11	$53.30	$454.26	$345.06			$473.88	$589.99	$565.14
500-999	104	$20.10	$70.95	$34.99	$333.82	$296.45			$297.68	$332.68	$505.44
1,000-3,299	87	$6.99	$22.76	$16.56	$120.46	$137.12			$186.18	$306.64	$261.11
3,300-9,999	97	$6.09	$12.29	$16.97	$67.58	$117.89			$151.41	$218.99	$243.95
10,000-49,999	109	$2.09	$5.17	$6.73	$32.07	$93.93	$41.01	$46.18	$83.20	$88.37	$219.10
50,000-99,999	119	$1.58	$3.88	$6.07	$27.07	$94.61	$37.58	$41.46	$75.95	$79.84	$226.64
100,000-999,999	125	$0.82	$1.80	$4.93	$16.18	$81.94	$25.38	$27.17	$55.03	$56.83	$205.32
1,000,000+	125	$0.36	$0.86	$2.58	$10.62	$66.95	$15.31	$16.16	$36.36	$37.22	$167.99

Source: Mean water usage per household derived from the Third Edition of the Baseline Handbook (USEPA, 2001c)

Exhibit 7.11a Capital Cost ($/Plant/Year) for CWS Disinfecting Ground Water Plants

System Size (Population Served)	Plant Design Flow (MGD)	CLM	UV	Ozone	GAC20	NF
<100	0.02	$29,104.44	$47,108.15	$0.00	$51,560.52	$67,676.53
100-499	0.06	$29,104.44	$70,701.54	$0.00	$102,166.90	$119,226.85
500-999	0.16	$30,298.78	$126,977.04	$370,630.22	$220,628.98	$209,226.96
1,000-3,299	0.38	$39,102.18	$252,548.67	$507,022.28	$457,866.77	$379,952.47
3,300-9,999	0.89	$49,613.33	$724,535.96	$761,428.90	$1,064,410.99	$828,831.05
10,000-49,999	1.64	$83,772.20		$1,081,364.49	$1,671,400.95	$1,598,457.82
50,000-99,999	4.12	$83,772.20		$1,730,048.55	$3,239,129.48	$3,994,609.23
100,000-999,999	7.68	$84,799.17		$2,466,239.92	$5,162,317.80	$7,341,646.08
1,000,000+	41.35	$98,772.20		$7,443,344.25	$18,067,167.43	$33,373,795.86

Source: Design flows from Exhibit 3.4, and unit costs from Appendix I.

Exhibit 7.11b Annual O&M Costs ($/Plant/Year) for CWS Disinfecting Ground Water Plants

System Size (Population Served)	Plant-Average Daily Flow (MGD)	CLM	UV	Ozone	GAC20	NF
<100	0.01	$1,361.57	$7,162.14	$0.00	$10,760.70	$7,835.50
100-499	0.02	$1,414.02	$9,562.28	$0.00	$19,848.70	$11,411.69
500-999	0.05	$1,470.58	$12,780.87	$55,839.34	$33,800.85	$27,593.43
1,000-3,299	0.13	$2,958.23	$17,170.99	$59,990.54	$54,578.39	$48,144.08
3,300-9,999	0.34	$4,184.39	$20,428.68	$62,469.10	$97,058.06	$109,460.54
10,000-49,999	0.72	$6,186.52		$66,975.28	$108,465.68	$193,835.38
50,000-99,999	2.01	$7,788.54		$84,465.80	$157,248.60	$484,005.34
100,000-999,999	4.26	$9,383.04		$108,576.27	$239,037.74	$992,000.90
1,000,000+	27.22	$19,308.42		$350,166.93	$965,369.32	$5,723,540.30

Source: Average daily flows from Exhibit 3.4, and unit costs from Appendix I.

Exhibit 7.11c Household Unit Treatment Costs ($/Household/Year) for CWS Disinfecting Ground Water Plants

System Size (Population Served)	Mean Annual Water Usage per HH (kgal)	CLM	UV	Ozone	GAC20	NF
<100	83	$177.77	$512.49	$0.00	$693.37	$625.03
100-499	83	$51.26	$204.56	$0.00	$374.38	$283.38
500-999	104	$22.99	$133.73	$495.03	$297.85	$257.26
1,000-3,299	87	$11.40	$70.14	$187.08	$169.68	$145.98
3,300-9,999	97	$6.53	$63.74	$98.87	$145.77	$139.86
10,000-49,999	109	$5.45		$65.00	$102.54	$135.66
50,000-99,999	119	$2.39		$37.03	$69.19	$132.32
100,000-999,999	125	$1.32		$25.16	$53.61	$128.64
1,000,000+	125	$0.34		$12.08	$30.76	$106.41

Source: Mean water usage per household derived from the Third Edition of the Baseline Handbook (USEPA, 2001c)

7.4.2 Alternatives to Treatment

During the FACA process, the M-DBP TWG identified many ways systems could reduce the residence time of the water in their distribution systems, thereby reducing TTHM and HAA5 concentrations. These included:

- Flushing more frequently, or looping sections of the distribution system to eliminate dead ends.
- Modifying portions of the distribution system with problematic DBP levels.
- Optimizing storage to minimize retention time in the distribution system.

The costs for these activities could range from close to zero (e.g., changing tank operations without making capital improvements) to more substantial costs for reconfiguring storage facilities or looping distribution system networks. The benefits from distribution system activities that reduce DBP concentrations also vary widely and are dependent on system-specific conditions. Therefore, these activities were not evaluated in this EA (see Section 7.7 for a discussion of unquantifiable costs).

Other alternatives to treatment that could reduce TTHM and HAA5 levels in the distribution system include connecting to a nearby water system or identifying another water source that has lower DBP precursor levels. While the latter may not be feasible for some remote systems, EPA estimates that more than 22 percent of all small systems are located within metropolitan regions where distances between neighboring utilities will not present a prohibitive barrier. To estimate this percentage, EPA used the April 2000 Safe Drinking Water Information System (SDWIS) database to compare the ZIP codes for CWSs that serve 100 or fewer people and medium and large CWSs. EPA then determined that out of the 446 surface water CWSs that serve 100 or fewer people, 98 (22 percent) have ZIP codes that are identical to those for medium and large CWSs (however, size of the ZIP code zone was not considered). Consolidation with another water system may represent the least-cost alternative for many small systems.

7.4.3 Uncertainty in Unit Costs

In developing the unit costs used in this EA, the design criteria for the compliance treatment technologies were selected to represent typical, or average, conditions for the universe of systems. As a result, there is uncertainty in these unit cost estimates, as they are based on designs and quotes assuming average conditions, rather than on an detailed aggregation of State, regional, or local estimates based on actual field conditions. To model the uncertainty around unit costs in this EA, the national average unit cost factors are characterized as triangular distributions with minimum and maximum values set at the following percentages relative to the best estimate:

- Capital costs: ± 30%
- O&M costs: ± 15%

These percentages were developed by EPA based on input from engineering professionals and represent recommendations from the National Drinking Water Advisory Council (NDWAC) (2001) in their review of the national cost estimation methodology for the Arsenic Rule. EPA believes that the uncertainties in capital and O&M costs for a given treatment technology are independent of one another and that uncertainties across all treatment technologies are independent.

7.5 The Stage 2 DBPR Cost Model

The cost model combines compliance forecasts, as described in Chapter 5, with the technology unit costs, as described in Section 7.4, to obtain national treatment costs. The model accounts for uncertainty in the national costs in several ways, as explained in Section 7.5.1. Once the treatment costs and the uncertainty surrounding them are determined, they are combined with the non-treatment costs from Section 7.3. The costs are then projected over time and discounted to obtain present value and annualized costs for the rule as described in Section 7.6.2. Lastly, household costs are determined as described in Section 7.6.3. A detailed list of all cost model files and flow charts is in Appendix K.

7.5.1 Probability Analysis to Estimate Nominal Treatment Costs

Inputs to Incorporate Uncertainty in National Costs

EPA recognizes that there is uncertainty in the inputs used to determine the national costs of this rule. Ideally, the model would quantify each uncertainty. Data regarding the quantitative impact of each element of uncertainty, however, are not available. EPA has developed an approach to quantifying the more significant areas of uncertainty that potentially have a large influence on national costs:

- Uncertainty in potential impact of the IDSE on the compliance forecast for large and medium surface water systems, discussed in Chapter 5.
- Uncertainty in methods used to develop the compliance forecast (i.e., SWAT and the ICR Matrix Method), as discussed in Chapter 5 and Appendix A.
- Uncertainty in average unit costs (capital and O&M), as discussed in Section 7.4.3.

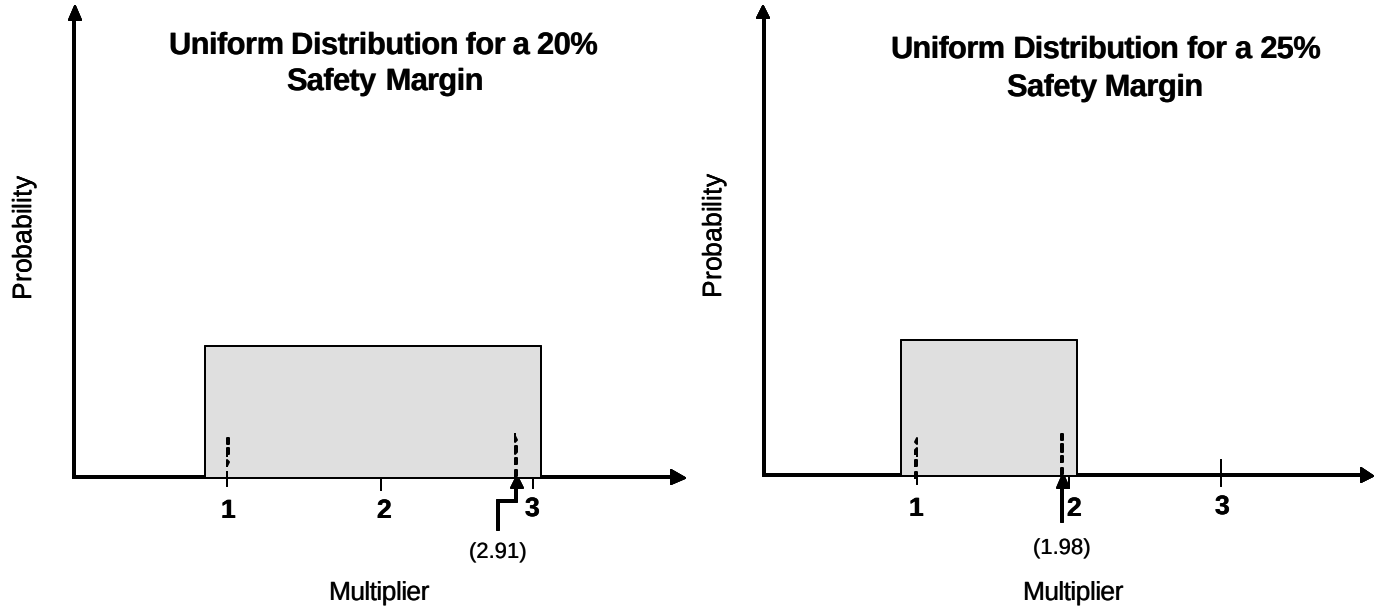
As described in Chapter 5, it is possible that systems may measure higher DBP levels at Stage 2 compliance monitoring sites than were measured under the ICR. EPA believes that the 20 percent safety margin on compliance (used throughout the primary cost analysis) already accounts for the potential impacts of the IDSE for small surface water systems, ground water systems, and chloramine systems. The Agency believes, however, that the 20 percent safety margin is not sufficient to account for the potential impacts of the IDSE on all large and medium surface water systems because spatial variability of DBP levels and distribution system complexity are greatest in these systems. Based on the analysis of spatial variability in DBP distribution system data and other factors, EPA developed an approach to quantify the potential impacts of the IDSE by preparing an alternative compliance forecast using a 25 percent safety margin (see Section 5.3.4 for details). Because a 20 percent safety margin may already account for the IDSE for some large a medium surface water systems, results based on both a 20 and 25 percent safety margin are used in the cost model.

Since the proposal, EPA developed an second method, called the ICR Matrix Method, to estimate the percent of plants making treatment technology changes to meet the Stage 2 DBPR. The percent of plants making treatment technology changes from Stage 1 to Stage 2 are different for the ICR Matrix Method and SWAT. Because both SWAT and the ICR Matrix Method have associated uncertainty, results from both are used to generate the compliance forecast for surface water systems.

The ICR Matrix Method does not predict the specific treatment technologies that plants will install. Thus, results from the ICR matrix method are incorporated by comparing the predicted percent of plants making treatment technology changes with SWAT results to create a ICR Matrix Method-to-SWAT multiplier. EPA generated a uniform distribution with 1.0 as the 5^{th} percentile value and the ICR Matrix Method-to-SWAT multiplier for plants making treatment technology changes as the 95^{th} percentile value. Two separate distributions were used for large and medium surface water systems, one for the 20 percent safety margin and one for the 25 percent safety margin. Exhibit 7.12 provides a graphical depiction of the two uniform distributions for the Preferred Alternative.

Uncertainty in technology unit costs is described in Section 7.4.3. In summary, EPA developed triangular distributions for both capital (± 30 percent) and O&M costs (±15 percent) to incorporate the uncertainty in unit treatment costs.

Exhibit 7.12 Uniform Distributions for Incorporating the ICR Matrix Method-to-SWAT Multiplier into the Compliance Forecasts for Surface Water Systems



Probability Analysis in the Cost Model

The cost model incorporates uncertainty using a Monte Carlo simulation. The model follows four basic steps, the first three of which are consistent with the probability analysis to generate the compliance forecast as described in Section 5.3.6:

- Step 1: For large and medium surface water systems, the model randomly selects the predicted treatment technology selection delta for either the 20 or 25 percent safety margin runs. Each safety margin has an equal (50 percent) chance of being selected. For small surface water systems and all ground water systems, the treatment technology selection delta for the 20 percent safety margin is always selected.

- Step 2: For large, medium, and small surface water systems, the model randomly selects the ICR-to-SWAT multiplier from the appropriate uniform distribution from Exhibit 5.7 for the safety margin selected in Step 1.

- Step 3: For large, medium, and small surface water systems, the model multiplies the result from Step 2 by the treatment technology selection delta results identified in Step 1 to calculate the percent and number of plants making treatment technology changes from Stage 1 to Stage 2. For ground water systems, the treatment technology selection delta for a 20 percent safety margin is always used to calculate the percent of plants changing from Stage 1 to Stage 2.

- Step 4: The model randomly selects a number from 0.7 to 1.3 (± 30%) to represent uncertainty in national capital costs for all technologies. Then it randomly selects a

number from 0.85 to 1.15 (± 15%) to represent uncertainty in national O&M costs for all technologies. The model multiplies the treatment technology selection delta (step 3) by the technology unit costs and the two uncertainty factors to estimate national treatment costs (O&M)

The process is repeated 10,000 times to produce a distribution of plants making treatment technology changes from Stage 1 to Stage 2 (results from Step 3, same as reported in Chapter 5) and national treatment costs (results from Step 4). For more detail on this simulation, see the flow charts and file description in Appendix K.

7.5.2 Projections and Discounting to Produce Annualized Costs

There are two kinds of nominal cost estimates for both treatment and non-treatment activities: (1) one-time costs that occur near the beginning of the rule implementation period, and (2) yearly costs that systems and States/Primacy Agencies will incur after systems have made necessary changes to treatment and/or monitoring to comply with the Stage 2 DBPR. For the purposes of this EA, one-time and yearly costs were projected over a 25-year time period to coincide with the estimated life span of capital equipment and a time lag of 5 to 10 years for treatment technology installation after rule promulgation. The projected schedules for all rule activities are summarized in Appendix D.

As described previously in this chapter and in the discussion of benefits in Chapter 6, it is common practice to adjust benefits and costs to a present value[5] using a social discount rate so that they can be compared to one another. This process takes into account the time preference that society places on expenditures and allows comparison of cost and benefit streams that are variable over a given time period.[6] Similar to calculating the present value of benefits (see Section 6.5), the present value of costs for any future period can be calculated using the following equation:

$$PV = V(t) / (1 + R)^t$$

Where: t = The number of years from the reference period
R = Social discount rate
V(t) = The cost occurring t years from the reference period

There is much discussion among economists of the proper social discount rate to use for policy analysis. For Stage 2 DBPR cost analyses, present value calculations are made using two social discount rates thought to best represent current policy evaluation methodologies, 3 and 7 percent. Historically, the use of 3 percent is based on rates of return on relatively risk-free investments, as described in the *Guidelines for Preparing Economic Analyses* (USEPA 2000j). The rate of 7 percent is a recommendation of the Office of Management and Budget (OMB) as an estimate of "before-tax rate of return to incremental private investment" (USEPA 1996b). For any future cost, the higher the discount

[5] For purposes of analyses in this EA, all present value figures are presented at a year 2003 price level. Present value calculations are performed to the expected year rule implementation (2005).

[6] See EPA's *Guidelines for Preparing Economic Analyses* (USEPA 2000j) for a full discussion of the use of social discount rates in the evaluation of policy decisions.

rate, the lower the present value. Specifically, a future cost (or stream of costs) evaluated at a 7 percent social discount rate will always result in a *lower* total present value cost than the same future cost evaluated at a 3 percent rate.

To allow evaluation of alternatives on an annual basis, their total present value costs are annualized using the same social discount rates (3 and 7 percent) over 25 years. When applying social discount rates to annualize costs, the higher the discount rate, the higher the annualized cost. Thus, the magnitudes of the discount rates influence costs in the opposite direction (i.e., a present value cost annualized at a 7 percent rate will always result in *higher* values than the same present value cost annualized at a 3 percent rate). The final relationship between annualized costs at 3 and 7 percent is dependent on the time frame for annualization, as well as when the costs are incurred (as set forth in the Rule Activity Schedule in Appendix D). Given a long enough time frame, the 7 percent annualized value will eventually be greater than the 3 percent annualized value.

In summary, the methodology for projecting and discounting costs is as follows:

- Project all nominal costs (treatment, non-treatment, and State) over a 25-year time horizon based on the rule implementation schedule in Appendix D.

- Calculate total present value costs using social discount rates. The same rates were used as for the benefits calculation: 3 and 7 percent (see Section 6.5.3).

- Annualize the costs over 25 years using the same social discount rates.

Values derived using this methodology are presented in subsequent sections of Chapter 7. Detailed spreadsheets of all cost calculations are provided in Appendix J.

7.5.3 Methodology for Estimating Household Costs

EPA assumes that generally systems will pass some or all of the costs of a new regulation onto their customers in the form of rate increases. As noted in Section 7.4.1, household costs, which are in units of *dollars per household per year ($/HH/yr)*, are estimated in this chapter to provide a measure of potential increases in water bills as a result of the Stage 2 DBPR, if all costs are passed onto consumers.

A distribution of possible household costs is developed for each system type and population size category. The distribution reflects that some households are served by systems that will incur only non-treatment costs (e.g., implementation, IDSE, monitoring plans, additional routine monitoring, and operational evaluation costs) as a result of the Stage 2 DBPR, while others are served by systems that incur treatment costs as well. Treatment activities can range from converting to chloramines, which has a relatively low cost, to installing membranes, which has a relatively high cost.

Data inputs specific to household cost calculations are shown in Exhibit 7.9, and a description of the household cost methodology is provided below. Section 7.4.1 provides a detailed description of the derivation of household unit treatment costs, and Exhibits 7.10c and 7.11c present household unit

treatment costs for surface and ground water treatment technologies. Appendix K provides a detailed list of files and flow charts for the Stage 2 DBPR household cost model.

- Step 1: The average number of households served per plant is calculated by dividing the total households served (Exhibit 3.5) by the total number of plants (Exhibit 3.2) in each system size category.

- Step 2: The number of households incurring different types of costs is based on the number of plants incurring costs, as derived in Appendix H and Section 3.5, respectively. The percent of systems performing non-treatment related rule activities is derived in Appendix H and summarized in Exhibit 7.2. EPA assumes that the percent of systems performing these activities is equivalent to the percent of plants performing activities. The number of plants making treatment technology changes to meet Stage 2 is shown in Exhibits 5.14a and 5.14c[7]. The number of plants incurring costs is multiplied by the average number of households served per plant to estimate the total number of households incurring different types of costs.

- Step 3: For each type of cost (treatment and non-treatment), a household unit cost is computed using the method described in Section 7.4.

- Step 4: The annual household unit costs ($/HH/yr) are combined with the number of households incurring each type of cost (results from step 2) to generate distributions of possible household treatment costs. The different types of costs are combined assuming that treatment and non-treatment costs are independent of one another. This might not always be the case, but EPA believes it is a realistic approximation.

7.6 Results

This section presents the results of the cost model described in the preceding sections. Section 7.6.1 shows the number of plants performing various rule activities. Section 7.6.2 displays the one-time capital and non-treatment costs as calculated by the model. Section 7.6.3 displays the results after the cost projections and discounting are performed. Section 7.6.4 displays the household cost distributions.

7.6.1 Number of Plants Making Treatment Technology Changes

The number of plants making treatment technology changes is determined from the compliance forecasts as described in Chapter 5. The model produces a distribution of the number of plants making treatment technology changes to represent uncertainty in the compliance forecast for surface water systems. As shown in Exhibit 7.3, the mean estimated number of plants making treatment technology changes is 2,338 plants.

[7]Only plants in CWSs are used to generate HH cost distributions. NTNCWSs do not typically provide water to households.

7.6.2 One-Time Costs

To estimate the total national costs of treatment, the plant unit costs (capital and O&M in $/plant as summarized in Exhibits 7.10 and 7.11) are multiplied by the Stage 2 DBPR treatment technology selection deltas (Exhibits 5.14a-d). The calculations are performed for surface and ground water plants and CWS and NTNCWS systems separately. These costs are summed across treatment technologies and size categories to estimate the total treatment costs for the Stage 2 DBPR.

Exhibit 7.13 summarizes the estimated initial capital investment and yearly O&M costs. This exhibit is broken out by system type, source water type, and system size category. Appendix J and Exhibits J.1b through J.1d provide similar cost information (total initial capital and yearly O&M costs) for the Stage 2 DBPR regulatory alternatives.

7.6.3 Total Annual Costs

Appendix J contains results from each step of the cost projection and discounting process described in Section 7.6.2 for each regulatory alternative. For the Preferred Alternative, Exhibits J.2a through J.2ar show the nominal costs projected over the rule schedule, and Exhibits J.2as through J.2cf show the present value of each cost calculated to the expected year of rule implementation (2005). The annualization step is shown at the bottom of the present value exhibits.

Exhibits 7.14a and 7.14b present the stream of present value costs and the total annualized costs for the Stage 2 DBPR Preferred Alternative at 3 and 7 percent discount rates, respectively. These tables are equivalent to Exhibits J.2as and J.2aw in Appendix J.

Exhibit 7.13 Total Initial Capital Costs ($Millions) and Yearly O&M Costs ($Millions/Year)

Preferred Alternative

Source	System Classification	System Size (population served)	Capital Costs				O&M Costs			
			Mean Value	Median Value	90 Percent Confidence Bound Lower (5th %tile)	90 Percent Confidence Bound Upper (95th %tile)	Mean Value	Median Value	90 Percent Confidence Bound Lower (5th %tile)	90 Percent Confidence Bound Upper (95th %tile)
Surface Water	CWSs	<100	$ 1.20	$ 1.18	$ 0.60	$ 1.89	$ 0.22	$ 0.22	$ 0.11	$ 0.32
		100-499	$ 3.59	$ 3.54	$ 1.81	$ 5.58	$ 0.90	$ 0.90	$ 0.47	$ 1.34
		500-999	$ 4.24	$ 4.16	$ 2.13	$ 6.63	$ 0.67	$ 0.67	$ 0.35	$ 1.00
		1,000-3,299	$ 26.79	$ 26.71	$ 13.65	$ 40.68	$ 3.69	$ 3.70	$ 1.91	$ 5.49
		3,300-9,999	$ 68.36	$ 68.00	$ 35.07	$ 103.50	$ 5.85	$ 5.87	$ 3.03	$ 8.69
		10,000-49,999	$ 124.13	$ 124.48	$ 64.58	$ 179.49	$ 6.63	$ 6.60	$ 3.85	$ 9.77
		50,000-99,999	$ 73.91	$ 74.31	$ 38.44	$ 106.75	$ 3.74	$ 3.70	$ 2.18	$ 5.58
		100,000-999,999	$ 201.75	$ 202.92	$ 101.21	$ 294.49	$ 8.96	$ 8.69	$ 5.24	$ 14.10
		1,000,000+	$ 94.35	$ 94.25	$ 48.67	$ 137.67	$ 5.39	$ 5.14	$ 3.12	$ 8.71
		All Sizes	$ 598.31	$ 599.55	$ 306.16	$ 876.67	$ 36.04	$ 35.49	$ 20.24	$ 55.02
	NTNCWSs	<100	$ 0.74	$ 0.73	$ 0.37	$ 1.16	$ 0.13	$ 0.13	$ 0.07	$ 0.20
		100-499	$ 1.45	$ 1.44	$ 0.74	$ 2.25	$ 0.37	$ 0.37	$ 0.19	$ 0.55
		500-999	$ 0.94	$ 0.93	$ 0.47	$ 1.46	$ 0.15	$ 0.15	$ 0.08	$ 0.22
		1,000-3,299	$ 2.08	$ 2.07	$ 1.06	$ 3.15	$ 0.29	$ 0.29	$ 0.15	$ 0.43
		3,300-9,999	$ 1.41	$ 1.41	$ 0.73	$ 2.14	$ 0.12	$ 0.12	$ 0.06	$ 0.18
		10,000-49,999	$ 0.60	$ 0.60	$ 0.31	$ 0.86	$ 0.03	$ 0.03	$ 0.02	$ 0.04
		50,000-99,999	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
		100,000-999,999	$ 0.45	$ 0.45	$ 0.23	$ 0.65	$ 0.02	$ 0.02	$ 0.01	$ 0.03
		1,000,000+	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
		All Sizes	$ 7.67	$ 7.63	$ 3.91	$ 11.69	$ 1.10	$ 1.10	$ 0.57	$ 1.65
	Subtotal		**$ 605.99**	**$ 607.18**	**$ 310.07**	**$ 888.36**	**$ 37.14**	**$ 36.59**	**$ 20.82**	**$ 56.66**
Ground Water	CWSs	<100	$ 8.35	$ 8.34	$ 7.19	$ 9.54	$ 0.93	$ 0.93	$ 0.87	$ 1.00
		100-499	$ 33.25	$ 33.24	$ 28.08	$ 38.45	$ 3.50	$ 3.50	$ 3.23	$ 3.78
		500-999	$ 20.22	$ 20.22	$ 17.03	$ 23.38	$ 1.88	$ 1.88	$ 1.73	$ 2.02
		1,000-3,299	$ 39.43	$ 39.41	$ 32.34	$ 46.55	$ 2.83	$ 2.83	$ 2.58	$ 3.08
		3,300-9,999	$ 65.93	$ 65.88	$ 53.54	$ 78.38	$ 2.40	$ 2.40	$ 2.20	$ 2.60
		10,000-49,999	$ 59.09	$ 59.08	$ 53.39	$ 64.79	$ 5.03	$ 5.03	$ 4.76	$ 5.30
		50,000-99,999	$ 14.96	$ 14.96	$ 13.38	$ 16.53	$ 1.28	$ 1.28	$ 1.20	$ 1.36
		100,000-999,999	$ 29.70	$ 29.71	$ 26.43	$ 32.95	$ 2.83	$ 2.83	$ 2.64	$ 3.02
		1,000,000+	$ 3.38	$ 3.38	$ 2.97	$ 3.79	$ 0.43	$ 0.43	$ 0.40	$ 0.46
		All Sizes	$ 274.30	$ 274.22	$ 234.36	$ 314.36	$ 21.11	$ 21.11	$ 19.60	$ 22.63
	NTNCWSs	<100	$ 3.18	$ 3.17	$ 2.73	$ 3.62	$ 0.35	$ 0.35	$ 0.33	$ 0.38
		100-499	$ 5.04	$ 5.05	$ 4.26	$ 5.82	$ 0.53	$ 0.53	$ 0.48	$ 0.57
		500-999	$ 2.48	$ 2.48	$ 2.08	$ 2.87	$ 0.22	$ 0.22	$ 0.20	$ 0.24
		1,000-3,299	$ 1.61	$ 1.61	$ 1.32	$ 1.90	$ 0.10	$ 0.10	$ 0.09	$ 0.10
		3,300-9,999	$ 0.46	$ 0.46	$ 0.38	$ 0.55	$ 0.01	$ 0.01	$ 0.01	$ 0.01
		10,000-49,999	$ 0.10	$ 0.10	$ 0.09	$ 0.11	$ 0.01	$ 0.01	$ 0.01	$ 0.01
		50,000-99,999	$ 0.02	$ 0.02	$ 0.02	$ 0.02	$ 0.00	$ 0.00	$ 0.00	$ 0.00
		100,000-999,999	$ 0.03	$ 0.03	$ 0.03	$ 0.03	$ 0.00	$ 0.00	$ 0.00	$ 0.00
		1,000,000+	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
		All Sizes	$ 12.92	$ 12.92	$ 10.88	$ 14.93	$ 1.23	$ 1.23	$ 1.13	$ 1.32
	Subtotal		**$ 287.21**	**$ 287.14**	**$ 245.24**	**$ 329.30**	**$ 22.34**	**$ 22.34**	**$ 20.73**	**$ 23.95**
Total			**$ 893.20**	**$ 894.32**	**$ 555.31**	**$ 1,217.66**	**$ 59.48**	**$ 58.93**	**$ 41.55**	**$ 80.61**

Notes: All values in millions of year 2003 dollars.
Detail may not add exactly to totals due to independent rounding.

Source: This exhibit is identical to Exhibit J.1a

Exhibit 7.14a Total Annualized Costs at 3 Percent Social Discount Rate ($Millions)

Preferred Alternative

	Surface Water CWS			Surface Water NTNCWS			Disinfecting Ground Water CWS			Disinfecting Ground Water NTNCWS			Primacy Agencies	Total		
		90 Percent Confidence Bound			90 Percent Confidence Bound			90 Percent Confidence Bound			90 Percent Confidence Bound				90 Percent Confidence Bound	
	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Point Estimate	Mean Value	Lower (5th %tile)	Upper (95th %tile)
2005	$ 0.6	$ 0.6	$ 0.6	$ 0.0	$ 0.0	$ 0.0	$ 0.1	$ 0.1	$ 0.1	$ 0.0	$ 0.0	$ 0.0	$ 3.7	$ 4.4	$ 4.4	$ 4.4
2006	$ 9.0	$ 9.0	$ 9.0	$ 0.1	$ 0.1	$ 0.1	$ 3.2	$ 3.2	$ 3.2	$ 0.5	$ 0.5	$ 0.5	$ 3.6	$ 16.4	$ 16.4	$ 16.4
2007	$ 20.1	$ 20.1	$ 20.1	$ 0.0	$ 0.0	$ 0.0	$ 1.0	$ 1.0	$ 1.0	$ 0.0	$ 0.0	$ 0.0	$ 0.1	$ 21.3	$ 21.3	$ 21.3
2008	$ 74.6	$ 46.3	$ 100.9	$ 0.1	$ 0.1	$ 0.1	$ 13.0	$ 12.2	$ 13.7	$ 0.0	$ 0.0	$ 0.0	$ 1.8	$ 89.5	$ 60.4	$ 116.6
2009	$ 85.2	$ 44.4	$ 124.2	$ 0.7	$ 0.4	$ 1.1	$ 31.3	$ 27.4	$ 35.1	$ 1.7	$ 1.5	$ 1.9	$ 0.7	$ 119.6	$ 74.5	$ 163.0
2010	$ 104.9	$ 54.4	$ 154.1	$ 1.4	$ 0.7	$ 2.1	$ 48.7	$ 42.0	$ 55.4	$ 2.4	$ 2.1	$ 2.8	$ -	$ 157.4	$ 99.2	$ 214.3
2011	$ 107.3	$ 55.8	$ 158.1	$ 1.5	$ 0.8	$ 2.2	$ 49.3	$ 42.6	$ 56.1	$ 2.3	$ 2.0	$ 2.7	$ 1.3	$ 161.8	$ 102.5	$ 220.4
2012	$ 108.9	$ 56.4	$ 161.0	$ 1.6	$ 0.8	$ 2.4	$ 53.3	$ 46.6	$ 60.1	$ 2.7	$ 2.4	$ 3.1	$ 1.3	$ 167.9	$ 107.5	$ 228.0
2013	$ 60.6	$ 31.7	$ 91.4	$ 1.7	$ 0.9	$ 2.5	$ 50.9	$ 44.8	$ 57.0	$ 3.1	$ 2.7	$ 3.4	$ 1.3	$ 117.5	$ 81.3	$ 155.6
2014	$ 39.9	$ 21.1	$ 60.9	$ 1.3	$ 0.7	$ 1.9	$ 34.5	$ 31.0	$ 38.0	$ 2.3	$ 2.0	$ 2.5	$ 1.2	$ 79.1	$ 56.0	$ 104.5
2015	$ 24.0	$ 12.9	$ 37.3	$ 0.8	$ 0.4	$ 1.2	$ 18.8	$ 17.7	$ 19.8	$ 1.4	$ 1.3	$ 1.4	$ 1.2	$ 46.1	$ 33.5	$ 60.9
2016	$ 23.3	$ 12.5	$ 36.2	$ 0.8	$ 0.4	$ 1.1	$ 18.2	$ 17.2	$ 19.2	$ 1.3	$ 1.3	$ 1.4	$ 1.2	$ 44.8	$ 32.5	$ 59.1
2017	$ 22.6	$ 12.2	$ 35.1	$ 0.7	$ 0.4	$ 1.1	$ 17.7	$ 16.7	$ 18.7	$ 1.3	$ 1.2	$ 1.4	$ 1.1	$ 43.5	$ 31.6	$ 57.4
2018	$ 21.9	$ 11.8	$ 34.1	$ 0.7	$ 0.4	$ 1.1	$ 17.2	$ 16.2	$ 18.1	$ 1.3	$ 1.2	$ 1.3	$ 1.1	$ 42.2	$ 30.7	$ 55.7
2019	$ 21.3	$ 11.5	$ 33.1	$ 0.7	$ 0.4	$ 1.0	$ 16.7	$ 15.7	$ 17.6	$ 1.2	$ 1.2	$ 1.3	$ 1.1	$ 41.0	$ 29.8	$ 54.1
2020	$ 20.7	$ 11.1	$ 32.2	$ 0.7	$ 0.4	$ 1.0	$ 16.2	$ 15.3	$ 17.1	$ 1.2	$ 1.1	$ 1.2	$ 1.0	$ 39.8	$ 28.9	$ 52.5
2021	$ 20.1	$ 10.8	$ 31.2	$ 0.7	$ 0.4	$ 1.0	$ 15.7	$ 14.8	$ 16.6	$ 1.1	$ 1.1	$ 1.2	$ 1.0	$ 38.6	$ 28.1	$ 51.0
2022	$ 19.5	$ 10.5	$ 30.3	$ 0.6	$ 0.3	$ 1.0	$ 15.3	$ 14.4	$ 16.1	$ 1.1	$ 1.1	$ 1.2	$ 1.0	$ 37.5	$ 27.3	$ 49.5
2023	$ 18.9	$ 10.2	$ 29.4	$ 0.6	$ 0.3	$ 0.9	$ 14.8	$ 14.0	$ 15.6	$ 1.1	$ 1.0	$ 1.1	$ 0.9	$ 36.4	$ 26.5	$ 48.1
2024	$ 18.4	$ 9.9	$ 28.6	$ 0.6	$ 0.3	$ 0.9	$ 14.4	$ 13.6	$ 15.2	$ 1.1	$ 1.0	$ 1.1	$ 0.9	$ 35.3	$ 25.7	$ 46.7
2025	$ 17.8	$ 9.6	$ 27.7	$ 0.6	$ 0.3	$ 0.9	$ 14.0	$ 13.2	$ 14.7	$ 1.0	$ 1.0	$ 1.1	$ 0.9	$ 34.3	$ 24.9	$ 45.3
2026	$ 17.3	$ 9.3	$ 26.9	$ 0.6	$ 0.3	$ 0.8	$ 13.6	$ 12.8	$ 14.3	$ 1.0	$ 0.9	$ 1.0	$ 0.9	$ 33.3	$ 24.2	$ 44.0
2027	$ 16.8	$ 9.0	$ 26.2	$ 0.6	$ 0.3	$ 0.8	$ 13.2	$ 12.4	$ 13.9	$ 1.0	$ 0.9	$ 1.0	$ 0.8	$ 32.3	$ 23.5	$ 42.7
2028	$ 16.3	$ 8.8	$ 25.4	$ 0.5	$ 0.3	$ 0.8	$ 12.8	$ 12.0	$ 13.5	$ 0.9	$ 0.9	$ 1.0	$ 0.8	$ 31.4	$ 22.8	$ 41.5
2029	$ 15.9	$ 8.5	$ 24.7	$ 0.5	$ 0.3	$ 0.8	$ 12.4	$ 11.7	$ 13.1	$ 0.9	$ 0.9	$ 0.9	$ 0.8	$ 30.5	$ 22.2	$ 40.3
Total	**$ 905.8**	**$ 498.3**	**$ 1,338.7**	**$ 18.1**	**$ 9.6**	**$ 27.0**	**$ 515.9**	**$ 468.4**	**$ 563.5**	**$ 31.9**	**$ 29.3**	**$ 34.5**	**$ 29.8**	**$ 1,501.6**	**$ 1,035.5**	**$ 1,993.5**
Ann.	**$ 52.0**	**$ 28.6**	**$ 76.9**	**$ 1.0**	**$ 0.6**	**$ 1.5**	**$ 29.6**	**$ 26.9**	**$ 32.4**	**$ 1.8**	**$ 1.7**	**$ 2.0**	**$ 1.7**	**$ 86.2**	**$ 59.5**	**$ 114.5**

Notes: Present values in millions of 2003 dollars. Estimates are discounted to 2005.
Detail may not add exactly to totals due to independent rounding.
Ann = value of total annualized at discount rate.

Source: This exhibit is identical to Exhibit J.2as, which is derived from Exhibits J.2a through rr.

Exhibit 7.14b Total Annualized Costs at 7 Percent Social Discount Rate ($Millions)

Preferred Alternative

	Surface Water CWS			Surface Water NTNCWS			Disinfecting Ground Water CWS			Disinfecting Ground Water NTNCWS			Primacy Agencies	Total		
		90 Percent Confidence Bound			90 Percent Confidence Bound			90 Percent Confidence Bound			90 Percent Confidence Bound				90 Percent Confidence Bound	
	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Point Estimate	Mean Value	Lower (5th %tile)	Upper (95th %tile)
2005	$ 0.6	$ 0.6	$ 0.6	$ 0.0	$ 0.0	$ 0.0	$ 0.1	$ 0.1	$ 0.1	$ 0.0	$ 0.0	$ 0.0	$ 3.4	$ 4.1	$ 4.1	$ 4.1
2006	$ 8.0	$ 8.0	$ 8.0	$ 0.1	$ 0.1	$ 0.1	$ 2.9	$ 2.9	$ 2.9	$ 0.5	$ 0.5	$ 0.5	$ 3.2	$ 14.6	$ 14.6	$ 14.6
2007	$ 17.3	$ 17.3	$ 17.3	$ 0.0	$ 0.0	$ 0.0	$ 0.8	$ 0.8	$ 0.8	$ 0.0	$ 0.0	$ 0.0	$ 0.1	$ 18.3	$ 18.3	$ 18.3
2008	$ 61.6	$ 38.3	$ 83.4	$ 0.1	$ 0.1	$ 0.1	$ 10.7	$ 10.1	$ 11.4	$ 0.0	$ 0.0	$ 0.0	$ 1.5	$ 73.9	$ 49.9	$ 96.4
2009	$ 67.8	$ 35.3	$ 98.8	$ 0.6	$ 0.3	$ 0.9	$ 24.9	$ 21.8	$ 27.9	$ 1.4	$ 1.2	$ 1.5	$ 0.6	$ 95.2	$ 59.2	$ 129.7
2010	$ 80.3	$ 41.6	$ 118.0	$ 1.1	$ 0.5	$ 1.6	$ 37.3	$ 32.2	$ 42.4	$ 1.9	$ 1.6	$ 2.1	$ -	$ 120.6	$ 76.0	$ 164.1
2011	$ 79.1	$ 41.1	$ 116.5	$ 1.1	$ 0.6	$ 1.7	$ 36.4	$ 31.4	$ 41.4	$ 1.7	$ 1.5	$ 2.0	$ 1.0	$ 119.3	$ 75.6	$ 162.5
2012	$ 77.3	$ 40.0	$ 114.3	$ 1.1	$ 0.6	$ 1.7	$ 37.9	$ 33.1	$ 42.7	$ 1.9	$ 1.7	$ 2.2	$ 0.9	$ 119.1	$ 76.3	$ 161.8
2013	$ 41.4	$ 21.7	$ 62.4	$ 1.1	$ 0.6	$ 1.7	$ 34.8	$ 30.6	$ 39.0	$ 2.1	$ 1.9	$ 2.4	$ 0.9	$ 80.3	$ 55.6	$ 106.3
2014	$ 26.2	$ 13.9	$ 40.0	$ 0.8	$ 0.4	$ 1.2	$ 22.7	$ 20.4	$ 25.0	$ 1.5	$ 1.3	$ 1.6	$ 0.8	$ 52.0	$ 36.8	$ 68.7
2015	$ 15.2	$ 8.2	$ 23.6	$ 0.5	$ 0.3	$ 0.7	$ 11.9	$ 11.2	$ 12.5	$ 0.9	$ 0.8	$ 0.9	$ 0.8	$ 29.2	$ 21.2	$ 38.6
2016	$ 14.2	$ 7.6	$ 22.1	$ 0.5	$ 0.2	$ 0.7	$ 11.1	$ 10.5	$ 11.7	$ 0.8	$ 0.8	$ 0.9	$ 0.7	$ 27.3	$ 19.8	$ 36.0
2017	$ 13.3	$ 7.1	$ 20.6	$ 0.4	$ 0.2	$ 0.6	$ 10.4	$ 9.8	$ 11.0	$ 0.8	$ 0.7	$ 0.8	$ 0.7	$ 25.5	$ 18.5	$ 33.7
2018	$ 12.4	$ 6.7	$ 19.3	$ 0.4	$ 0.2	$ 0.6	$ 9.7	$ 9.1	$ 10.2	$ 0.7	$ 0.7	$ 0.7	$ 0.6	$ 23.8	$ 17.3	$ 31.5
2019	$ 11.6	$ 6.2	$ 18.0	$ 0.4	$ 0.2	$ 0.6	$ 9.1	$ 8.5	$ 9.6	$ 0.7	$ 0.6	$ 0.7	$ 0.6	$ 22.3	$ 16.2	$ 29.4
2020	$ 10.8	$ 5.8	$ 16.8	$ 0.4	$ 0.2	$ 0.5	$ 8.5	$ 8.0	$ 8.9	$ 0.6	$ 0.6	$ 0.6	$ 0.5	$ 20.8	$ 15.1	$ 27.5
2021	$ 10.1	$ 5.4	$ 15.7	$ 0.3	$ 0.2	$ 0.5	$ 7.9	$ 7.5	$ 8.4	$ 0.6	$ 0.5	$ 0.6	$ 0.5	$ 19.4	$ 14.1	$ 25.7
2022	$ 9.5	$ 5.1	$ 14.7	$ 0.3	$ 0.2	$ 0.5	$ 7.4	$ 7.0	$ 7.8	$ 0.5	$ 0.5	$ 0.6	$ 0.5	$ 18.2	$ 13.2	$ 24.0
2023	$ 8.8	$ 4.8	$ 13.7	$ 0.3	$ 0.2	$ 0.4	$ 6.9	$ 6.5	$ 7.3	$ 0.5	$ 0.5	$ 0.5	$ 0.4	$ 17.0	$ 12.3	$ 22.4
2024	$ 8.3	$ 4.4	$ 12.8	$ 0.3	$ 0.1	$ 0.4	$ 6.5	$ 6.1	$ 6.8	$ 0.5	$ 0.4	$ 0.5	$ 0.4	$ 15.9	$ 11.5	$ 21.0
2025	$ 7.7	$ 4.2	$ 12.0	$ 0.3	$ 0.1	$ 0.4	$ 6.0	$ 5.7	$ 6.4	$ 0.4	$ 0.4	$ 0.5	$ 0.4	$ 14.8	$ 10.8	$ 19.6
2026	$ 7.2	$ 3.9	$ 11.2	$ 0.2	$ 0.1	$ 0.4	$ 5.6	$ 5.3	$ 6.0	$ 0.4	$ 0.4	$ 0.4	$ 0.4	$ 13.9	$ 10.1	$ 18.3
2027	$ 6.7	$ 3.6	$ 10.5	$ 0.2	$ 0.1	$ 0.3	$ 5.3	$ 5.0	$ 5.6	$ 0.4	$ 0.4	$ 0.4	$ 0.3	$ 13.0	$ 9.4	$ 17.1
2028	$ 6.3	$ 3.4	$ 9.8	$ 0.2	$ 0.1	$ 0.3	$ 4.9	$ 4.6	$ 5.2	$ 0.4	$ 0.3	$ 0.4	$ 0.3	$ 12.1	$ 8.8	$ 16.0
2029	$ 5.9	$ 3.2	$ 9.2	$ 0.2	$ 0.1	$ 0.3	$ 4.6	$ 4.3	$ 4.9	$ 0.3	$ 0.3	$ 0.4	$ 0.3	$ 11.3	$ 8.2	$ 15.0
Total	**$ 607.5**	**$ 337.3**	**$ 889.4**	**$ 11.0**	**$ 5.8**	**$ 16.3**	**$ 324.1**	**$ 292.4**	**$ 355.8**	**$ 19.4**	**$ 17.7**	**$ 21.1**	**$ 19.8**	**$ 981.7**	**$ 673.1**	**$ 1,302.3**
Ann.	**$ 52.1**	**$ 28.9**	**$ 76.3**	**$ 0.9**	**$ 0.5**	**$ 1.4**	**$ 27.8**	**$ 25.1**	**$ 30.5**	**$ 1.7**	**$ 1.5**	**$ 1.8**	**$ 1.7**	**$ 84.2**	**$ 57.8**	**$ 111.7**

Notes: Present values in millions of 2003 dollars. Estimates are discounted to 2005.
Detail may not add exactly to totals due to independent rounding.
Ann = value of total annualized at discount rate.

Source: This exhibit is identical to Exhibit J.2aw, which is derived from Exhibits J.2a through rr.

7.6.4 Household Cost Results

Exhibit 7.15 presents the mean, median, 90th percentile, and 95th percentile of expected rate increases, along with the percent of households that are expected to face an increase of $1 or less per month ($12 or less per year) or $10 or less each month ($120 or less per year). Data are provided for all systems subject to the rule and for only the subset of systems making treatment technology changes. Note that household cost increases in Exhibit 7.15 include costs for non-treatment-related rule activities (implementation, IDSE, additional routine monitoring, and operational evaluations).

Exhibits 7.16a and b show the cumulative distribution of household cost increases for all surface water and ground water systems, and Exhibits 7.17a and b shows the distribution of household cost increases for only those systems making treatment technology changes. Additionally, Exhibit 7.17c shows the cumulative distributions in systems making treatment technology changes for the five small system size categories.

As shown in Exhibit 7.15, the mean, median, and 90th percentile household costs increase for all systems (including those that do not make treatment technology changes) are $0.66, $0.03, and $0.39, respectively. The mean, median, and 90th percentile household cost increases for systems that install new treatment technologies are $5.38, $0.80 and $10.04, respectively. Note that the number of households affected by plants installing treatment could be greater than shown in Exhibit 7.15 because an entire system would most likely incur costs even if only some of the plants for that system make treatment technology changes (this would result in lower household costs, however). It should also be noted that these are very conservative estimates that assume that all costs are passed on to consumers, cheaper compliance alternatives are not used, and systems do not receive any financial assistance.

EPA estimates that, as a whole, households subject to the Stage 2 DBPR face minimal increases in their annual costs. Approximately 86 percent of the households potentially subject to the rule are served by systems serving at least 10,000 people; these systems experience the lowest increases in costs due to significant economies of scale. Households served by small systems that make treatment technology changes will face the greatest increases in annual costs. Exhibit 7.17c provides additional detail regarding the distribution of household costs for small systems.

Although cost model results predict that a few very small systems will experience large household cost increases as a result of adding advanced treatment technology for the Stage 2 DBPR, these predictions are probably not realistic because small systems have other alternatives available to them besides making treatment technology changes. For example, some of these systems currently may be operated on a part-time basis; therefore, they may be able to modify the current operational schedule or use excess capacity to avoid installing a costly treatment technology to comply with the Stage 2 DBPR. The system also may identify another water source that has lower TTHM and HAA5 precursor levels. Systems that can identify such an alternate water source may not have to treat that water as intensely as their current source, resulting in lower treatment costs. Systems may elect to connect to a neighboring water system. While this may not be feasible for some remote systems, EPA estimates that more than 22 percent of all small water systems are located within metropolitan regions (USEPA 2003t) where distances between neighboring systems will not present a prohibitive barrier.

Exhibit 7.15 Annual Household Cost Increases

	Total Number of Households Served	Mean Annual Household Cost Increase	Median Annual Household Cost Increase	90th Percentile Annual Household Cost Increase	95th Percentile Annual Household Cost Increase	Percentage of Annual Household Cost Increase < $12	Percentage of Annual Household Cost Increase < $120
All Systems	101,553,868	$ 0.66	$ 0.03	$ 0.39	$ 1.26	99%	100%
All Small Systems	14,261,241	$ 2.26	$ 0.10	$ 0.79	$ 2.69	97%	99%
SW < 10,000	3,251,893	$ 4.95	$ 0.79	$ 2.69	$ 13.80	95%	99%
SW > 10,000	62,137,350	$ 0.50	$ 0.02	$ 0.35	$ 1.84	99%	100%
GW < 10,000	11,009,348	$ 1.47	$ 0.02	$ 0.39	$ 0.99	98%	100%
GW > 10,000	25,155,277	$ 0.14	$ 0.01	$ 0.03	$ 0.11	100%	100%
Households Served by Plants Adding Treatment							
	Total Number of Households Served	Mean Annual Household Cost Increase	Median Annual Household Cost Increase	90th Percentile Annual Household Cost Increase	95th Percentile Annual Household Cost Increase	Percentage of Household Cost Increase < $12	Percentage of Household Cost Increase < $120
All Systems	11,062,385	$ 5.38	$ 0.80	$ 10.04	$ 21.43	92%	99%
All Small Systems	619,628	$ 45.76	$ 17.09	$ 168.85	$ 190.19	39%	88%
SW < 10,000	314,083	$ 43.06	$ 13.79	$ 173.53	$ 177.93	47%	85%
SW ≥ 10,000	9,933,196	$ 2.83	$ 0.80	$ 6.98	$ 11.31	96%	100%
GW < 10,000	305,545	$ 48.55	$ 16.65	$ 106.39	$ 196.50	31%	92%
GW ≥ 10,000	509,562	$ 5.98	$ 1.37	$ 26.83	$ 33.87	79%	100%

Notes: Detail may not add to total due to independent rounding. Number of households served by systems adding treatment will be higher than households served by plants adding treatment because an entire system will incur costs even if only some of the plants for that system add treatment (this would result in lower household costs, however).

Source: Results represent the sum of treatment and non-treatment costs. Household costs for treatment are derived from household unit costs in Exhibits 7.10c and 7.11c combined with technology selection deltas, shown in Chapter 5. Household costs for non-treatment-related rule activites are derived from mean costs for each system size category for implementation, IDSE, monitoring plans, additional routine monitoring, and significant excursion (as derived in Appendix H). See section 7.5.3 for additional information on the derivation of household costs.

Exhibit 7.16a Household Cost Distributions, All Surface Water Systems Subject to the Rule

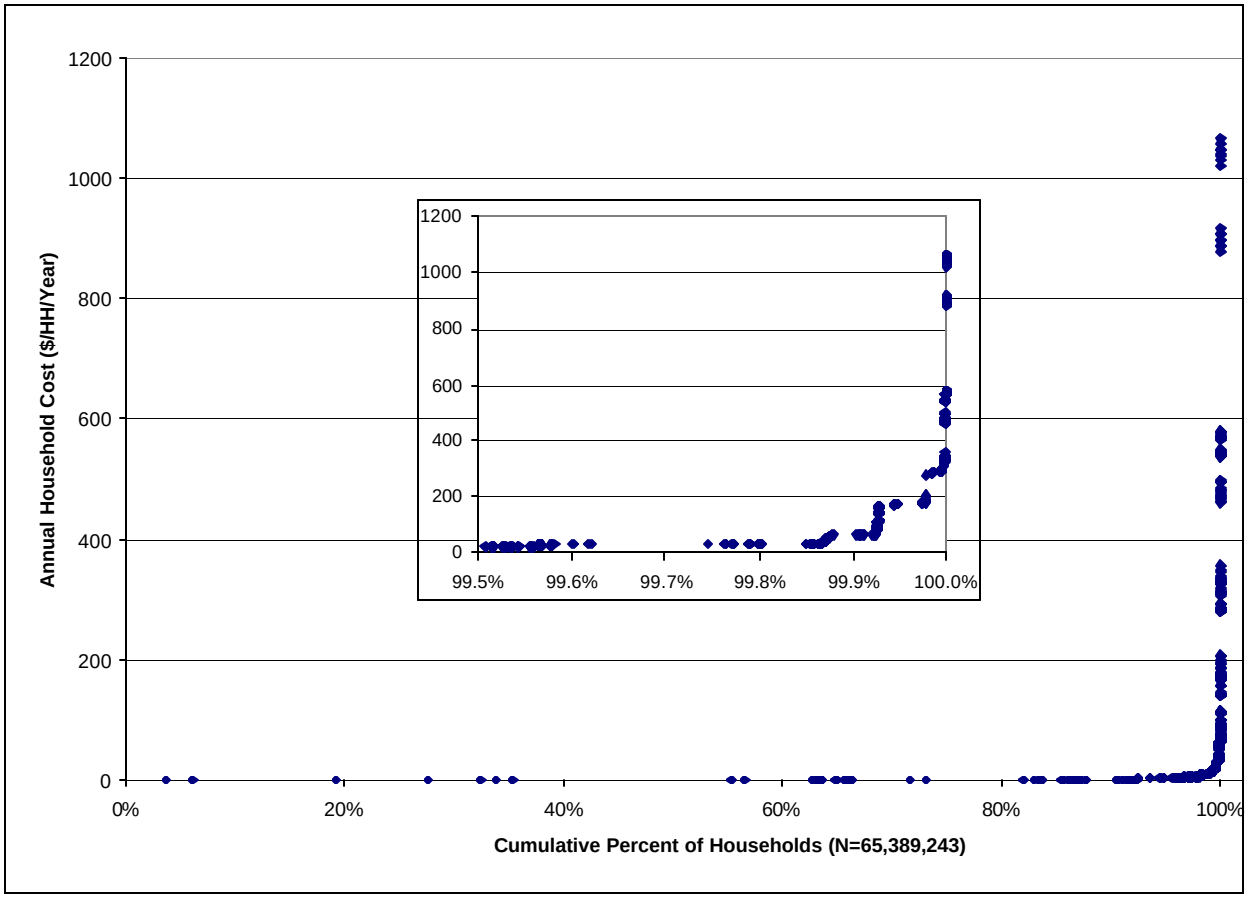


Exhibit 7.16b Household Cost Distributions, All Ground Water Systems Subject to the Rule

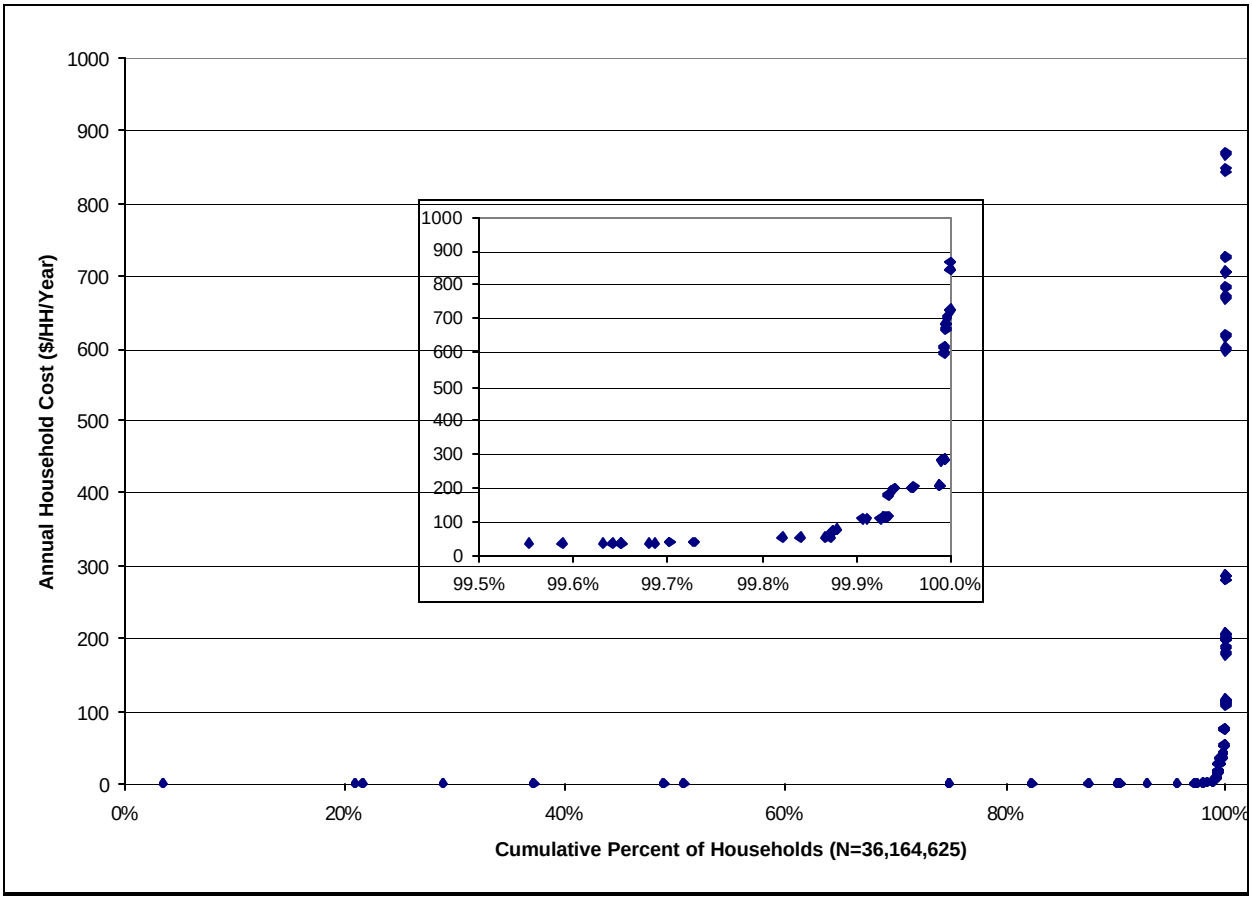


Exhibit 7.17a Household Cost Distributions, Surface Water Systems Making Treatment Technology Changes

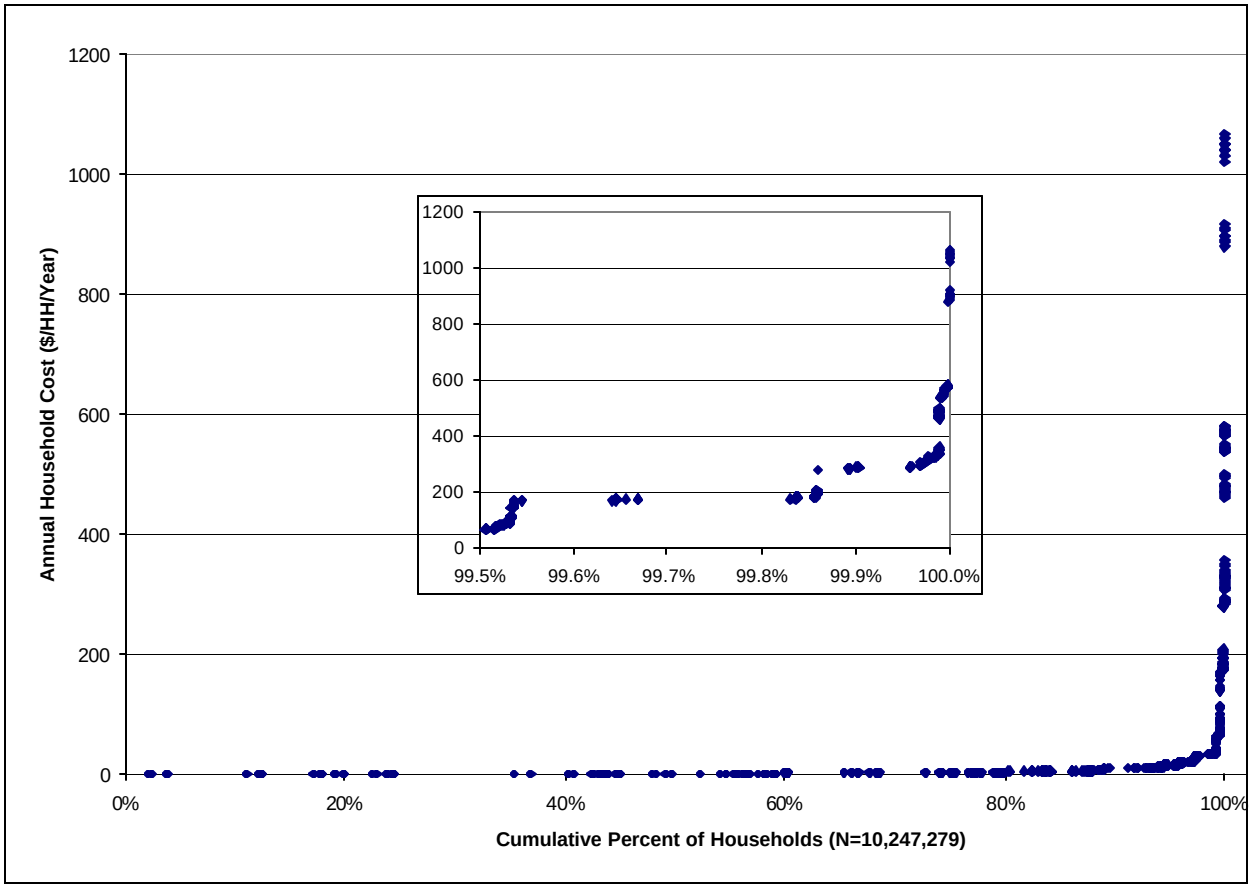


Exhibit 7.17b Household Cost Distributions, Ground Water Systems Making Treatment Technology Changes

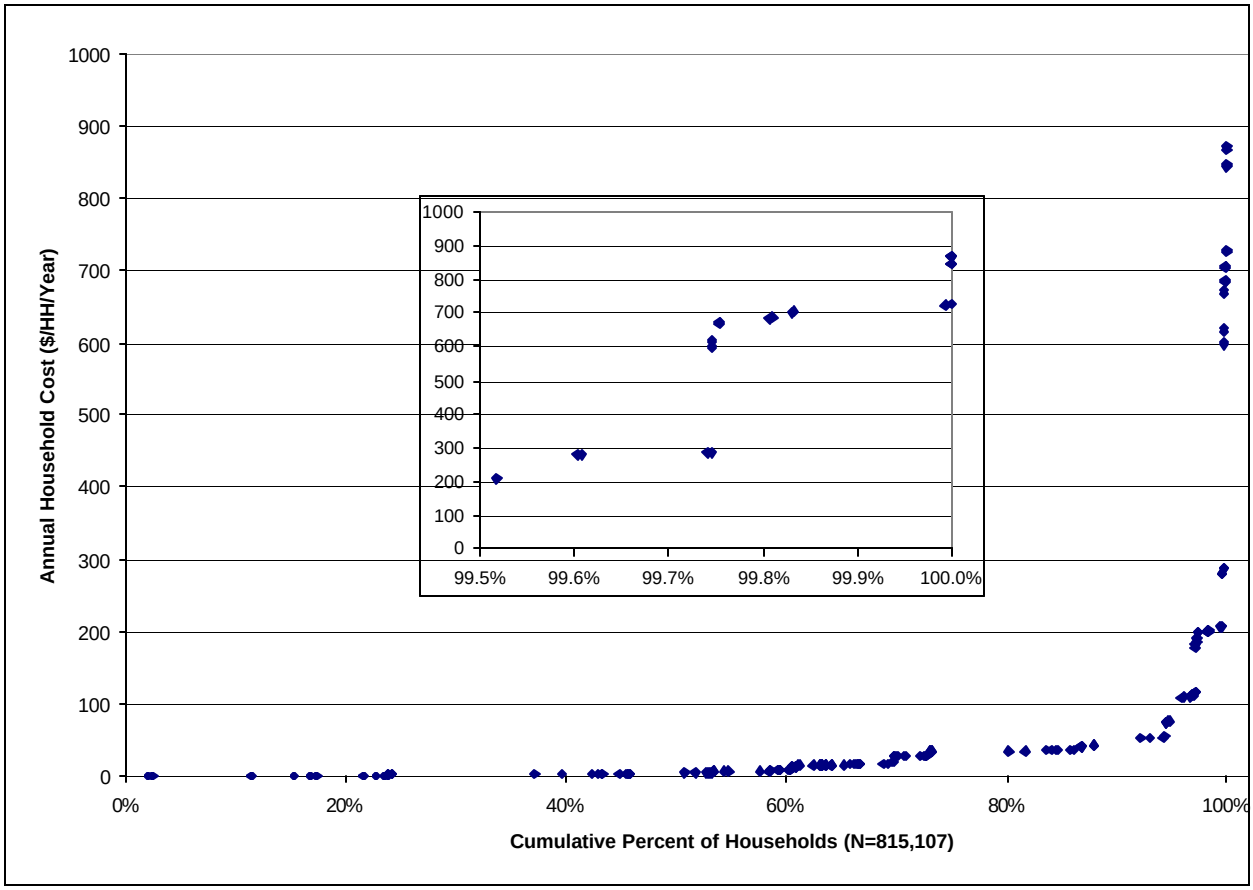
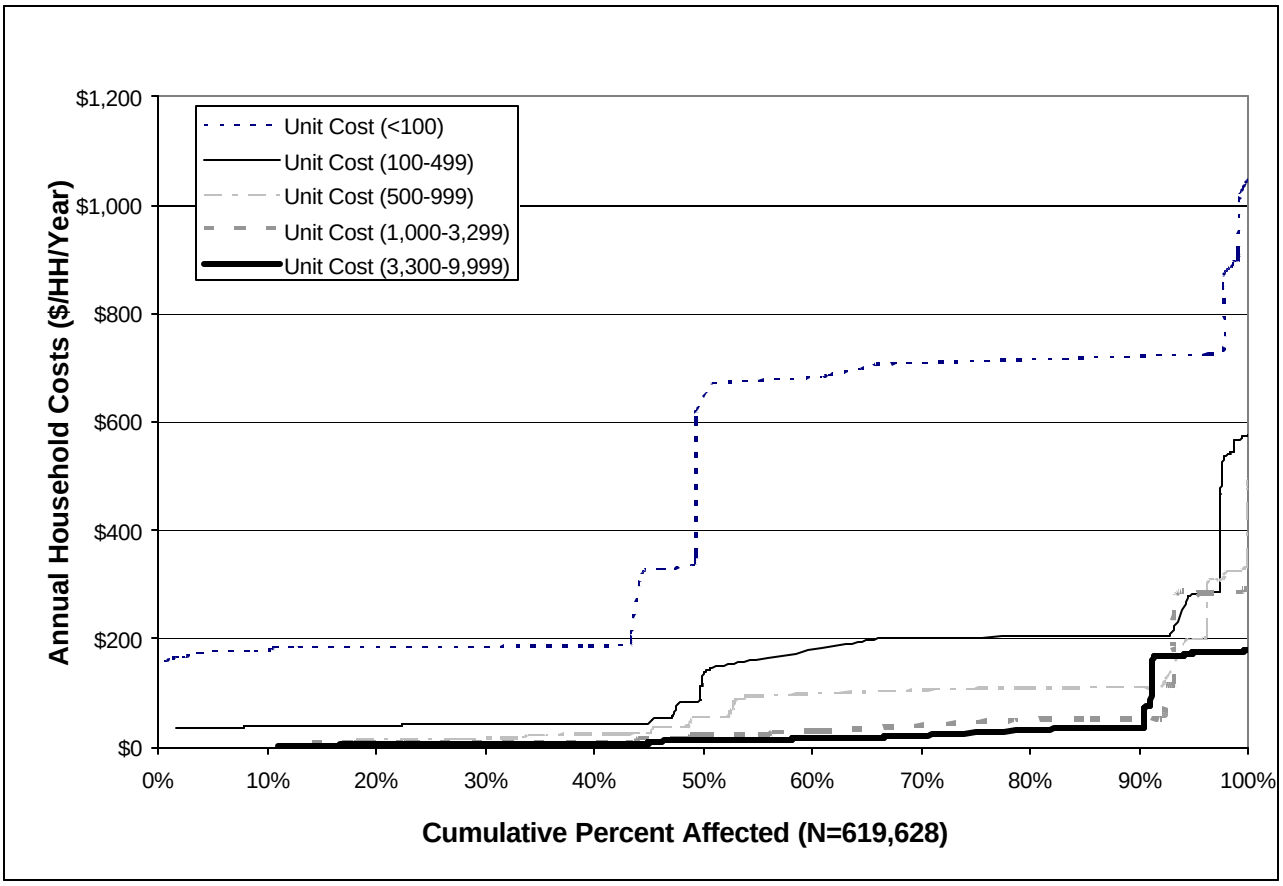


Exhibit 7.17c Household Cost Distributions, Small Systems Making Treatment Technology Changes (Surface and Ground)



7.7 Non-Quantified Costs

All significant costs that EPA has identified have been quantified. In some instances, EPA did not include a potential cost element because its effects are relatively minor and difficult to estimate. For example, it may be less costly for a small system to merge with neighboring systems than to add advanced treatment. Such changes have both costs (legal fees and connecting infrastructure) and benefits (economies of scale). Likewise, procuring a new source of water would have costs for new infrastructure, but could result in lower treatment costs. Operational costs such as changing storage tank operation were also not considered as alternatives to treatment. These might be options for systems with a single problem area with a long residence time. In the absence of detailed information needed to evaluate situations such as these, EPA has included a discussion of possible effects where appropriate. In general, however, the expected net effect of such situations is lower costs to PWSs. Thus, the EA tends to present conservatively high estimates of costs in relation to non-quantified costs.

7.8 Uncertainty Analysis

Many factors contribute to uncertainty in national cost estimates. Uncertainty in baseline data inputs, such as the total number of disinfecting plants and their typical average and design flow rates, are described in detail in Section 3.8. Other cost model inputs such as labor rates and laboratory fees also contain uncertainties. In these cases, EPA has evaluated available data and estimated a cost input value to represent the average of all water systems nationally. EPA recognizes that there is uncertainty in this average, and variability in the characteristics of individual systems. The influence of these uncertainties on national cost estimates is expected to be minor.

Key areas of uncertainty and their potential effects on the estimate of national costs are presented in Exhibit 7.18. EPA believes that uncertainty in the compliance forecast has a potentially large influence on cost (and benefit) estimates in this EA. Thus, the Agency has attempted to quantify the uncertainty by developing alternative approaches (see Chapter 5). These alternative approaches are used to represent a range of possible results and are incorporated into the cost model using Monte Carlo simulation techniques. Although the resulting mean costs and confidence intervals may not capture the full range of possibilities, EPA believes this approach helps inform the reader of the likely magnitude of the impact of the uncertainties.

In addition to quantifying some uncertainties in the compliance forecasts, EPA has explicitly accounted for uncertainty in estimated treatment technology unit costs. Treatment costs are modeled using a triangular distribution of ± 30 percent for Capital, and ± 15 percent for O&M costs to recognize uncertainty in the assumptions used to produce the national average unit costs.

Exhibit 7.18 Cost Uncertainty Summary

Uncertainty	Section With Full Discussion of Uncertainty	Effect on Estimate of National Costs		
		Underestimate	Overestimate	Unknown Impact
Uncertainty in the industry baseline (SDWIS and 1995 CWSS data)	3.4			X
Uncertainty in observed data and predictive tools used to characterize DBP occurrence and advanced treatment technology use for the pre-Stage 1 baseline	3			X
Uncertainty in predictive tools used to develop the compliance forecast for surface water systems (SWAT and ICR Matrix Method)	Chapter 5, Appendix A	Quantified in primary analysis (addresses potential overestimate or underestimate)		
Uncertainty in ground water and small surface water compliance forecast methodologies	Appendices A and B			X
Uncertainty in the potential impact of the IDSE on the compliance forecast for large and medium surface water systems	Chapter 5	Quantified in primary analysis (addresses potential underestimate)		
Treatment costs do not include costs for minor operational changes predicted by SWAT	7.4.1	X		
Median operational and water quality parameters considered for treatment technology unit costs	7.4.1			X
Economies of scale for combination treatment technologies not considered	7.4.1		X	
Possible UV-chloramine synergy not taken into account	7.4.1		X	
Potential low-cost alternatives to treatment not considered	7.4.2		X	
Uncertainties in unit costs	7.4.3	Quantified in primary analysis (addresses potential overestimate or underestimate)		

7.9 Comparison of Regulatory Alternatives

During the development of the Stage 2 DBPR, many regulatory alternatives were considered. Of these alternatives, four (including the Preferred Alternative analyzed in this chapter) were chosen for further, in-depth analysis. Chapter 4 provides a description of each alternative. Chapter 5 present compliance forecasts for the Preferred Alternative, and Appendix C presents the compliance forecasts for the other three alternatives, including the treatment technology selection deltas.

The same process used for developing costs for the Preferred Alternative was used to develop costs for the other alternatives. Unit costs (Exhibits 7.10 and 7.11) were multiplied by the treatment technology selection deltas presented in Appendix C, and results were summed for all treatment technologies. Exhibit 7.19 presents the summary of annualized costs for each alternative (detailed costs for each alternative are presented in Appendix J). While the total annualized costs in Exhibit 7.19 include costs for non-treatment-related rule activities (implementation, IDSE, monitoring plans, additional routine monitoring, and operational evaluations), any increase in cost for the regulatory alternatives is fully attributable to treatment costs.

Exhibit 7.19 Total Annualized Cost for the Stage 2 DBPR Regulatory Alternatives ($Millions)

Rule Alternative	Total Annualized Cost ($Millions)	
	3 Percent Discount Rate Mean Estimate	7 Percent Discount Rate Mean Estimate
Preferred	$ 86.2	$ 84.2
Alt. 1	$ 276.9	$ 265.5
Alt. 2	$ 444.1	$ 431.2
Alt. 3	$ 661.2	$ 644.3

Source: Appendix J.
For the Preferred Alternative, see Exhibit J.2as for 3% and J.2aw for 7%.
For Alternative 1, see Exhibit J.3i for 3% and J.3m for 7%.
For Alternative 2, see Exhibit J.4i for 3% and J.4m for 7%.
For Alternative 3, see Exhibit J.5i for 3% and J.5m for 7%.

8. Economic Impact Analysis

8.1 Introduction

As part of the rulemaking process, the Environmental Protection Agency (EPA) is required to address the potential direct and indirect burdens that the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR) may place on certain types of governments, businesses, and populations. This chapter presents the analyses EPA has performed in accordance with the following 12 Federal requirements:

1) The Regulatory Flexibility Act (RFA) of 1980, as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996.
2) An analysis of small system affordability to determine variance treatment technologies in accordance with Section 1415(e)(1) of the 1996 Safe Drinking Water Act (SDWA) Amendments.
3) Feasible treatment technologies available to all systems as required by Section 1412(b)(4)(E) of the 1996 SDWA Amendments.
4) A Technical, Financial, and Managerial Capacity Assessment as required by Section 1420(d)(3) of the 1996 SDWA Amendments.
5) The Paperwork Reduction Act (A separate Information Collection Request document contains the complete analysis).
6) The Unfunded Mandates Reform Act (UMRA) of 1995.
7) Executive Order 13175 (Consultation and Coordination with Indian Tribal Governments).
8) Impacts on sensitive subpopulations as required by Section 1412(b)(3)(c)(i) of the 1996 SDWA Amendments.
9) Executive Order 13045 (Protection of Children from Environmental Health Risks and Safety Risks).
10) Executive Order 12898 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations).
11) Executive Order 13132 (Federalism).
12) Executive Order 13211 (Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use).

Many of the requirements and executive orders listed above call for an explanation of why the rule is necessary, the statutory authority for the rule, and the primary objectives that the rule is intended to achieve (refer to Chapter 2 for more information regarding the objectives of the rule). More specifically, they are designed to assess the financial and health effects of the rule on sensitive, low-income, and Tribal populations as well as on small systems. The chapter also examines how much additional capacity systems will need to meet Stage 2 DBPR requirements and whether there are existing, feasible treatment technologies and treatment techniques available to meet rule requirements.

8.2 Regulatory Flexibility Act and Small Business Regulatory Enforcement Fairness Act

The Regulatory Flexibility Act (RFA) generally requires an agency to prepare a regulatory flexibility analysis for any rule subject to notice and comment rulemaking requirements under the

Administrative Procedure Act or other statute, unless the Agency certifies that the rule will not have a significant economic impact on a substantial number of small entities (5 U.S.C. 603(a)). Small entities include small businesses, small organizations, and small governmental jurisdictions.

8.2.1 Determining Significant Impacts on Small Entities

EPA conducted a screening analysis to determine if the Stage 2 DBPR would have a significant economic impact on a substantial number of small entities. In this analysis, EPA evaluated the potential economic impact of the rule on small entities by comparing annualized compliance cost as a percentage of annual revenues[1] for different small-entity classifications. Chapter 3 of this Economic Analysis (EA) provides data on the small entities potentially subject to the Stage 2 DBPR, and Chapter 7 discusses changes systems would need to make, as well as the likely costs.[2] Using information from these two chapters, along with additional information from the Safe Drinking Water Information System (SDWIS), the Community Water System Survey (CWSS), and the U.S. Census, EPA conducted a quantitative analysis of small-system impacts resulting from the rule.

Defining Small Entities Affected by the Rule

The RFA provides default definitions for each type of small entity. Small entities are defined as: (1) a small business as defined by the Small Business Administration (SBA) regulations at 13 CFR 121.201; (2) a small governmental jurisdiction that is a government of a city, county, town, school district or special district with a population of less than 50,000; or (3) a small organization that is any "not-for-profit enterprise which is independently owned and operated and is not dominant in its field." However, the RFA authorizes an agency to adopt alternative definitions that "are appropriate to the activities of the Agency after proposing the alternative definition(s) in the *Federal Register* and taking comment" (5 U.S.C. §601(3)-(5)) for each category of small entity. In addition, to establish an alternative small business definition, agencies must consult with the SBA's Chief Council for Advocacy.

The RFA references the definition of "small business" found in the Small Business Act, which authorizes the SBA to define "small business" further by regulation. The SBA defines small businesses by category using the North American Industry Classification System (NAICS). The NAICS code for public water supplies (PWSs) is 22131 (Water Supply and Irrigation Systems), and State agencies that include drinking water programs are classified as 92411 (Administration of Air and Water Resource and Solid Waste Management Programs) or 923120 (Administration of Public Health Programs). Ancillary systems (i.e., those that supplement the function of other establishments like factories, power plants, mobile home parks, etc.) cannot be categorized in a single NAICS code. For ancillary systems, the NAICS code is that of the primary establishment or industry. Examples of small businesses include small, privately owned PWSs and for-profit businesses where provision of water may be ancillary, such as

[1] Revenue information was used whenever available. When it was not available, different measures, such as sales or annual operating expenditures, were used.

[2] System information in this chapter is from the system baseline presented in Chapter 3 (Exhibit 3.2). For discussions of plants making treatment technology changes, refer to the Stage 2 DBPR treatment plants baseline (Exhibit 3.2). Systems conducting rule activities are presented in Exhibit 7.2, and plants adding treatment are presented in Exhibit 7.3.

mobile home parks or day-care centers. Examples of small organizations include churches, schools, and homeowner associations.

The Stage 2 DBPR applies to all community water systems (CWSs) and nontransient noncommunity water systems (NTNCWSs) that add a disinfectant other than ultraviolet light (UV) or that deliver water that has been treated with a disinfectant other than UV. A small CWS can be a business, government, or organization, since all entity types may supply water to the same population year round. A NTNCWS can be a business (other than a water utility) or an organization, since both types of entities may regularly supply water to at least 25 of the same people at least 6 months per year, but not year round. Although the SBA and the RFA provide clear definitions for small businesses, organizations, and governmental jurisdictions, small entities are not necessarily small water systems. The size of the entity has no relation to the number of people it serves as a water supply. Furthermore, data are not collected on businesses, organizations, and governmental jurisdictions in terms of the number of water customers they serve. Therefore, EPA chose to use an alternative definition for small entities.

For purposes of assessing the impacts of the Stage 2 DBPR on small entities, EPA considered small entities to be PWSs serving 10,000 or fewer people, which is the cut-off level Congress specified in the 1996 Amendments to SDWA for small system flexibility provisions. Because this definition does not correspond to the RFA's definitions for small businesses, governments, and nonprofit organizations, EPA requested comment on an alternative definition of a small entity in the preamble to the proposed Consumer Confidence Report (CCR) regulation (63 FR 7620 February 13, 1998). In the preamble to the final CCR regulation (63 FR 44511 August 19, 1998), EPA stated its intent to establish this alternative definition for regulatory flexibility assessments under the RFA for all drinking water regulations and has, therefore, used it for the Stage 2 DBPR.

Obtaining Data on the Number of Small Entities and Their Revenues or Expenditures

EPA obtained data on the number of small entities in each category, which are presented in Column A of Exhibit 8.1. The numbers of entities and their distribution among categories are derived from EPA's Baseline Handbook (USEPA 2001c) and the 1995 CWSS (USEPA 1997c), respectively. Approximately 43.0 percent of small entities are owned by governments, 37.3 percent are owned by businesses and ancillary systems, and 19.7 percent are owned by organizations.

EPA also estimated the annual revenues or expenditures of small entities, presented in Column B of Exhibit 8.1. PWS inventories, managed by EPA and other organizations, have traditionally been categorized by size and by the characteristics of the population served (i.e., CWSs, NTNCWSs, and transient noncommunity water systems (TNCWSs)) rather than by NAICS code. Revenues by NAICS code are not readily applicable to EPA's categorization of systems. Therefore, alternative methods for determining revenue were developed, as discussed below.

The estimated revenues for small entities in Exhibit 8.1 are from the Bureau of the Census (U.S. Department of Commerce 1992), the SDWIS, and additional data on independent privately owned CWSs, special districts, and authorities from the 1995 CWSS (USEPA 1997c). Column A of Exhibit 8.1 shows the numbers of entities classified as small businesses, governments, and organizations, obtained using information from the Third Edition of the Baseline Handbook (USEPA 2001c). These numbers were used to determine the weighted averages of estimated revenue. Column C shows the estimated revenues.

Small-government entities include municipal, county, state, federal, military, and special district systems. Data on all revenue for townships and municipalities were obtained from the *1992 Census of Governments* (U.S. Department of Commerce 1992) and converted to 2003 dollars by applying a conversion factor calculated from the national income and product account tables of the U.S. Bureau of Economic Analysis.[3] Specifically, the price deflators for 1992 and 2003 were obtained from Chain-Type Price Indexes for State and Local Governments (U.S. Department of Commerce BEA 2004a). The average revenue for all small governments with PWSs was calculated at $2,649,186.

Small-business entities in Exhibit 8.1 include both CWSs and NTNCWSs, such as privately owned CWSs, mobile home parks, country clubs, hotels, manufacturers, hospitals, and other establishments. For this analysis, all hospitals and day care centers are assumed to be businesses, as are 50 percent of systems classified as "other."[4] Estimated average revenue for the small businesses affected by the Stage 2 DBPR is $2,555,888.

Small organizations include primarily nonprofit NTNCWS such as schools and homeowner associations. The revenue estimates for small nonprofit organizations serving 500 or more people are actually higher than those for small businesses because the total number of such systems is small, and a large proportion of these organizations are schools and colleges with large budgets. This category also includes 50 percent of systems classified as "other." The average estimated revenue for small organizations affected by the Stage 2 DBPR is $4,750,838.

EPA also calculated the average estimated revenue for all small entities. This estimate is weighted to account for the number of small entities in each category (government, business, and organization) affected by the Stage 2 DBPR. This overall average is $2,981,331.

Measuring Significant Impacts

To evaluate the impact that a small entity is expected to incur as a result of the rule, this analysis calculates the entity's annualized compliance cost as a percentage of sales (for privately owned entities) or the entity's annualized compliance cost as a percentage of annual governmental revenue or expenditures (for publicly owned entities). The Interim Guidance for EPA Rulewriters for the RFA as amended by the SBREFA (March 1999) suggests using 1 percent as a threshold for determining significance, although additional factors may be considered. If compliance costs are less than 1 percent of sales or revenues for fewer than 1,000 entities, which represent less than 20 percent of all affected small entities, then in most cases there is no significant impact. In addition, the guidance suggests that if fewer than 100 entities experience economic impacts of 3 percent of their revenues or greater, then in most cases there is no significant impact.

Exhibit 8.1 presents the data that EPA used for the screening analysis. The numbers of entities expected to incur costs of more than 1 and 3 percent of their revenues are presented in Columns D and F, respectively. The numbers of entities experiencing impacts of more than 1 and 3 percent of their

[3]Methodology recommended by Bruce E. Baker, State and Local Governments, Government Division, U.S. Bureau of Economic Analysis.

[4]The "other" category contains systems that do not yet have a specific function identified.

revenues were compared to the total number of entities in each size category to calculate percentages, shown in Columns E and G.

Exhibit 8.1 Annualized Compliance Cost as a Percentage of Revenues for All Small Entities

Small Systems by Source of Water and Type of Entity	Number of Small Systems	Percent of Small Systems	Average Annual Estimated Revenues[1] per System ($)	Systems Experiencing Costs of ≥1% of their Revenues[2,3]		Systems Experiencing Costs of ≥3% of their Revenues[2,4]	
				Number of Systems	Percent of Systems	Number of Systems	Percent of Systems
	A	B	C	D=A*E	E	F=A*G	G
Primarily Surface Water and GWUDI Systems							
Small Governments	1,827	43%	$2,649,186	45	2.46%	20	1.10%
Small Businesses	1,584	37%	$2,555,888	39	2.47%	18	1.14%
Small Organizations	838	20%	$4,750,838	17	2.02%	6	0.72%
All Small Entities Using Primarily Surface Water or GWUDI	**4,250**	**100%**	**$2,981,331**	**101**	**2.38%**	**44**	**1.04%**
Primarily Ground Water Systems							
Small Governments	14,865	43%	$2,649,186	97	0.65%	18	0.12%
Small Businesses	12,888	37%	$2,555,888	153	1.19%	18	0.14%
Small Organizations	6,817	20%	$4,750,838	25	0.37%	8	0.12%
All Small Entities Using Primarily Ground Water	**34,570**	**100%**	**$2,981,331**	**276**	**0.80%**	**45**	**0.13%**

Note: Detail may not add due to independent rounding.

[1] Revenue information was used whenever available. When it was not available, other measures such as sales or annual operating expenditures were used. Data were not available to differentiate revenue for small entities by system sizes or by source water type. The revenue estimates reflect ground water as well as surface water systems.

[2] Compliance costs were compared to average annual revenue to determine whether 20 percent of small entities would incur costs exceeding 1 percent of their average annual revenues. Thresholds to determine whether a rule has a significant impact on a substantial number of small entities are taken from the Interim Guidance for EPA Rulewriters for the RFA as amended by the SBREFA (March 1999).

[3] Compliance costs incurred by each entity were compared to 1 percent of average annual revenues to determine whether 1,000 or more entities will experience an impact of 1 percent or greater of average annual revenues.

[4] Compliance costs incurred by each entity were compared to 3 percent of average annual revenues to determine whether 100 or more entities will experience an impact of 3 percent or greater of average annual revenues.

Sources:

(A) Number of disinfecting CWSs and NTNCWSs serving fewer than 10,000 people from the system baseline in Exhibit 3.2 (Column V), multiplied by 43%, 37.3%, and 19.7% to obtain number of small government, small businesses, and small organizations, respectively.

(B) Percent of small governments, businesses, and organizations derived from the 1995 CWSS (USEPA 1997c).

(C) Small Governments: Revenues from 1992 Census of Governments, GC92(4)-4: Finances of Municipal and Township Governments, U.S. Dept. of Commerce, Bureau of the Census; price deflators from Table 8.11, Chain-Type Quantity and Price Indexes for Government. All other price adjustments were calculated using the Consumer Price Index.

(E, G) Derived from the Stage 2 DBPR Cost Model (USEPA 2005i).

To consider whether 1,000 or more entities will experience an impact of 1 percent or greater of average annual revenues, EPA compared compliance costs incurred by each entity to 1 percent of average annual revenue. EPA estimated that a total of 101 small entities using surface water or ground water under the influence of surface water (GWUDI) and 276 small entities using ground water, representing 2.38 and 0.80 percent of all small entities affected by the Stage 2 DBPR, respectively, will experience an impact of 1 percent or greater of average annual revenues. This is less than the criteria of 1,000 entities used to determine significant impact.

Using a similar methodology, EPA also considered whether 100 or more entities will experience an impact of 3 percent or greater of average annual revenues. The Agency determined that 44 small entities using surface water or GWUDI and 45 small entities using ground water, representing 1.04 and 0.13 percent of all small entities subject to the Stage 2 DBPR, respectively, will experience an impact of 3 percent or greater of average annual revenues. This is less than the criterion of 100 entities used to determine significant impact.

Based on the large number of small entities, the nature of the economics for community water systems, and the information presented in Exhibits 8.1, EPA is certifying that the Stage 2 DBPR will not lead to significant economic impacts for a substantial number of small entities. CWSs have many resources available to them that other industries do not have. For example, financial assistance to small systems may be available from programs administered by EPA or other Federal agencies, as described in sections 8.2.2 and 8.3.3.

Because EPA is certifying that the Stage 2 DBPR will not lead to significant economic impacts for a substantial number of small entities, EPA is not required by the RFA, as amended by SBREFA, to conduct a final regulatory flexibility analysis (FRFA). Nevertheless, EPA has tried to reduce the impact of this rule on small systems.

8.2.3 Summary of the SBREFA Process

The RFA, as amended by SBREFA, and Section 203 of UMRA require EPA to provide small governments with an opportunity for timely and meaningful participation in the regulatory development process. EPA provided stakeholders, including small governments, with several opportunities to provide input on the Stage 2 DBPR. For example, EPA conducted three conference calls in Washington, DC to solicit feedback and information from the Small Entity Representatives (SERs) on Stage 2 DBPR impacts on small systems. SERs included small-system operators, local government officials, and small nonprofit organizations.

During the first call, held on January 28, 2000, EPA presented an overview of SDWA, as amended in 1996, and SBREFA. Issues and schedules for the Stage 2 DBPR rules were also discussed. The second call was held on February 25, 2000. EPA presented the stakeholders with an overview of the EPA regulatory development process and background on the development of the Stage 2 Microbial-Disinfectants/Disinfection Byproduct (M-DBP) Rules, particularly regarding health risks, issues and options identified by the Federal Advisory Committees Act (FACA) Committee, and DBP and microbial occurrence in small systems. The third meeting was held on April 7, 2000. EPA presented SERs with a cost estimate and an impact analysis for selected regulatory options. In addition, EPA presented SERs with schedules for the FACA and SBREFA processes.

These three conference calls generated a wide range of information, issues, and technical input from SERs. In general, the SERs were concerned about the impact of these proposed rules on small water systems (because of their small staff and limited budgets), small systems' ability to acquire the technical and financial capability to implement requirements, maintaining the flexibility to tailor requirements to their needs, and other limitations of small systems. The Agency used the feedback received during these meetings in developing the Stage 2 DBPR. EPA also mailed a draft version of the rule's preamble to the attendees of these meetings.

The Agency convened a Small Business Advocacy Review (SBAR) Panel to obtain advice and recommendations of representatives of the regulated small entities, including those of small local governments, in accordance with Section 609(b) of the RFA. The small entity stakeholders received background on the need for the rule and the possible components of the rule to assist them with their deliberations. EPA convened the SBAR Panel after completing the consultation meetings with SERs on the Stage 2 DBPR. Eight of the small entities were governments. SER's concerns were provided to the SBAR Panel when the Panel convened on April 25, 2000.

8.3 Small-System Affordability *[EPA will revise the affordability analysis once the revised affordability criteria become available.]*

Section 1415(e)(1) of SDWA allows States/Primacy Agencies to grant variances to small water systems (i.e., those serving fewer than 10,000 people) in lieu of complying with a maximum contaminant level (MCL) if EPA determines that no nationally affordable compliance treatment technologies exist for that combination of system size and water quality. These variances may be granted only when EPA has identified a variance treatment technology under Section 1412(b)(15) for the contaminant, system size, and source water quality in question. 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 treatment technologies, three showings must be made.

1) EPA must determine, on a national level, that there are no compliance treatment technologies that are available and affordable for the given combination of system size and source water quality.

2) If there is no nationally affordable compliance treatment technology, EPA must identify a variance treatment technology that may not reach the MCL, but that will achieve the maximum contaminant reduction affordable. This treatment technology must be listed as a small-system variance treatment technology by EPA for small systems to be able to rely on it for regulatory purposes.

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

The State/Primacy Agency must then make a determination for each system as to whether the system can afford to meet the MCL based on affordability criteria developed by the State/Primacy Agency. If the State/Primacy Agency 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 adequately protects human health.

The 1996 SDWA Amendments identify three categories of small PWSs that need to be addressed: (1) those serving a population of 3,301 to 10,000; (2) those serving a population of 501 to 3,300; and (3) those serving a population of 25 to 500. SDWA requires EPA to make determinations of available compliance treatment technologies and, if needed, variance treatment technologies for each size category. A compliance treatment technology is a technology that is affordable and that achieves compliance with the MCL and/or treatment technique. Compliance treatment technologies can include point-of-entry (POE) or point-of-use (POU) treatment units. Variance treatment technologies are specified only for those system size/source water quality combinations for which there are no listed compliance treatment technologies.

The following sections show how small system affordability was evaluated for the Stage 2 DBPR. The analysis is consistent with the methodology used in the document *National-Level Affordability Criteria Under the 1996 Amendments to the Safe Drinking Water Act* (USEPA 1998c) and the *Variance Technology Findings for Contaminants Regulated Before 1996* (USEPA 1998d). Because EPA determined that affordable compliance treatment technologies are available for all small systems for the Stage 2 DBPR, EPA did not identify any variance treatment technologies.

8.3.1 Affordability Threshold

[Place holder for explanation of the new threshold value]

8.3.2 Affordable Compliance Treatment Technologies

Section 1412(b)(4)(E)(ii) of SDWA, as amended in 1996, requires EPA to list treatment technologies that achieve compliance with MCLs established under the Act that are affordable and applicable to typical small drinking water systems. Owners and operators may choose any treatment technology or technique that best suits their conditions, as long as the MCL is met.

This section presents household costs ($ per household per year) for various treatment technologies. The methodology for generating household cost estimates is explained in detail in section 7.6.4. In general, the analysis in this section followed the methodology in section 7.6.4; however, some *inputs* for household cost calculations in this section are different and, in some cases, are conservatively high compared to data used to generate household cost distributions in Chapter 7. A conservatively high estimate of household costs is used to more accurately represent the high-end variability in household costs. This allows affordability of the Stage 2 DBPR to be more confidently assessed across the range of all affected small systems.

The size categories specified in SDWA for affordable treatment technology determinations are different than the nine standard size categories used in the majority of this EA, and subsequently, mean design and average daily flows for each category are different. The values for design and average flows (shown in Exhibit 8.2) are derived from the 1995 CWSS (USEPA 1997c).

Exhibit 8.2 Affordability Analysis Inputs

System Size (Population Served)	Flows (mgd)		Median HH Consumption Rates (kgal/yr)	HH Consumption Rate Used for Costing
	Median Average Daily Flow	Design Flow		
	a	b	c	d = 1.15*c
25-500	0.022	0.142	60	69
501-3,300	0.126	0.464	65	75
3,301-10,000	0.544	1.431	70	81

Sources:
A, B, and C: 1995 CWSS (USEPA 1997c).
D: Consumption rates were adjusted upward by 15 percent to account for distribution system leaks.

For each treatment technology, unit treatment costs ($ per 1,000 gallons) are estimated using the flow rates shown in Exhibit 8.2 and the technology unit costs in Appendix I (see Exhibit I.27 for details on the derivation of unit treatment costs). As suggested in *Variance Technology Findings for Contaminants Regulated Before 1996* (USEPA 1998d), capital costs were annualized using a 7 percent discount rate rather than the cost-of-capital rates used to generate the distribution of household costs in Chapter 7. The unit treatment costs ($ per 1,000 gallons) were multiplied by annual household consumption rates to determine the annual household cost increase ($ per household) for each treatment technology. Annual consumption rates are shown in Exhibit 8.2 and represent median yearly consumption derived from the 1995 CWSS (USEPA 1997c). (Note that *mean* yearly household consumption are shown in Exhibit 7.9 and are used for the household cost estimates in Chapter 7.) The values shown in Exhibit 8.2 were adjusted upward by 15 percent to account for water lost in the distribution system due to leaks, as suggested in *Variance Technology Findings for Contaminants Regulated Before 1996* (USEPA 1998d).

Exhibits 8.3a and 8.3b show the compliance treatment technologies for the Stage 2 DBPR for surface water and ground water systems along with their mean annual household costs for each of the three size categories. Exhibit 8.3c presents annual household cost increases for all households served by plants installing treatment to comply with the Stage 2 DBPR for systems serving 0 to 500, 501 to 3,300 and 3,301 to 10,000 people[5]. The mean, median, 90th percentile, and 95th percentile values are shown as well as the available expenditure margin and the number of households and plants that will experience annual cost increases above the available expenditure margin.

For a $300 affordability threshold, ozone, microfiltration/ultrafiltration (MF/UF), granular activated carbon—20-Minute Contact Time (GAC20), GAC20 with advanced oxidants, and integrated membranes are above the threshold in the 0 to 500 category. 143 plants are expected to install these treatment technologies, mostly GAC20 with advanced oxidants. The 500 to 3,300 category has GAC20 with

[5]Although the size categories specified by SDWA for the affordability analysis do not specifically include systems serving fewer than 25 people (per SDWA), these systems are included in all other analyses in this EA and are accounted for in Exhibit 8.4c. Thus, the estimate of the number of systems and households experiencing cost increases in Exhibit 8.4c is conservatively high.

advanced disinfectants and integrated membranes above the affordability threshold. One plant in this size category is predicted to install GAC20 with advanced oxidants. In the 3,300 to 10,000 category no treatment technologies are above the affordability threshold.

If the affordability threshold is lowered to $200 per household, MF/UF and GAC20 are over the threshold in the 500 to 3,300 category in addition to those already over the $300 threshold. Integrated membranes and GAC20 with advanced oxidants become over the threshold in the 3,300 to 10,000 category. Lowering the threshold to $200 per household would result in an additional 50 plants being over the affordability threshold for a total of 193 plants.

EPA believes, however, that the number of plants in small systems predicted to add advanced treatment technologies (including GAC20) is overstated for two reasons: 1) distribution system modifications are not considered in the compliance forecast, and 2) Stage 2 DBPR requirements for small systems are similar to Stage 1 DBPR requirements and might not trigger compliance violations.

Very few households will experience cost increases above the available expenditure margin as a result of adding advanced treatment technology to comply with the Stage 2 DBPR. However, these predictions are probably not realistic because small systems have other alternatives available to them besides adding treatment, such as operating on a part-time basis, identifying an alternative water source, and connecting to a neighboring water system. Refer to Chapter 7 for a more detailed discussion of household cost increases.

Exhibit 8.3a Affordable Compliance Treatment Technologies and Household Unit Treatment Costs ($/HH/Year) for Surface Water Systems

Compliance Technologies	System Size (Population Served)		
	0-500	501-3,300	3,301-10,000
Chloramines (0.15 mg/L)	$ 37.19	$ 11.19	$ 5.86
Chlorine Dioxide (1.25 mg/L) [1]	$ 69.27	$ 34.63	$ 11.69
UV (40mJ/cm2)	$ 50.69	$ 24.36	$ 17.03
Ozone (0.5-log dose) [1]	$ 738.88	$ 186.19	$ 70.92
MF/UF [1]	$ 331.67	$ 207.09	$ 135.53
GAC20 (EBCT=20 min, 90 day regeneration) [1]	$ 366.30	$ 248.18	$ 157.21
GAC20 + Advanced Disinfectants	$ 416.99	$ 434.38	$ 228.13
Integrated Membranes[1]	$ 515.64	$ 375.03	$ 281.00

Exhibit 8.3b Affordable Compliance Treatment Technologies and Household Unit Treatment Costs ($/HH/Year) for Ground Water Systems

Compliance Technologies	System Size (Population Served)		
	0-500	501-3,300	3,301-10,000
Chloramines (0.15 mg/L)	$ 37.09	$ 11.03	$ 5.69
UV (200mJ/cm2)	$ 139.22	$ 78.59	$ 57.79
Ozone (0.5-log dose) [1]	$ 738.88	$ 186.19	$ 70.92
GAC20 (EBCT=20 min, 240 day regeneration) [1]	$ 235.65	$ 188.89	$ 112.08
Nanofiltration [1]	$ 183.97	$ 167.95	$ 145.47

[1] Zero percent of plants were predicted to select this treatment technology.

Source: Exhibit I.27.

Exhibit 8.3c Distribution of Household Unit Treatment Costs for Plants Adding Treatment

Systems Size (population served)	Number of Households Served by Plants Adding Treatment (Percent of all Households Subject to the Stage 2 DBPR)	Mean Annual Household Cost Increase	Median Annual Household Cost Increase	90th Percentile Annual Household Cost Increase	95th Percentile Annual Household Cost Increase	Available Expenditure Margin ($/hh/yr)	Number of Households with Annual Cost Increases Greater then the Available Expenditure Margin	Number of Surface WaterPlants with Annual Cost Increases Greater than the Available Expenditure Margin	Number of Groundwater Plants with Annual Cost Increases Greater than the Available Expenditure Margin	Total Number of Plants with Annual Cost Increases Greater than the Available Expenditure Margin
	A	B	C	D	E	F	G	H	I	J = H + I
0 - 500	72860 (6%)	$69.18	$36.35	$63.87	$346.62	$300	6,171	41	102	143
501 - 3,300	323975 (6%)	$32.21	$10.37	$44.62	$203.80	$300	211	1	0	1
3,301 - 10,000	509330 (7%)	$27.72	$5.31	$107.48	$197.00	$300	0	0	0	0

Systems Size (population served)	Number of Households Served by Plants Adding Treatment (Percent of all Households Subject to the Stage 2 DBPR)	Mean Annual Household Cost Increase	Median Annual Household Cost Increase	90th Percentile Annual Household Cost Increase	95th Percentile Annual Household Cost Increase	Available Expenditure Margin ($/hh/yr)	Number of Households with Annual Cost Increases Greater then the Available Expenditure Margin	Number of Surface WaterPlants with Annual Cost Increases Greater than the Available Expenditure Margin	Number of Groundwater Plants with Annual Cost Increases Greater than the Available Expenditure Margin	Total Number of Plants with Annual Cost Increases Greater than the Available Expenditure Margin
	A	B	C	D	E	F	G	H	I	J = H + I
0 - 500	72860 (6%)	$69.18	$36.35	$63.87	$346.62	$200	6,171	41	102	143
501 - 3,300	323975 (6%)	$32.21	$10.37	$44.62	$203.80	$200	15,959	36	0	36
3,301 - 10,000	509330 (7%)	$27.72	$5.31	$107.48	$197.00	$200	2,321	15	0	15

Notes: Household unit costs represent treatment costs only, as presented in Exhibits 8.3a and 8.3b.

Source: Household unit costs in Exhibits 8.3a and 8.3b combined with treatment technology selection deltas in Exhibits 5.11 and 5.14.

Low- or even no-cost alternatives that would reduce total trihalomethanes (TTHM) and haloacetic acid (HAA5) levels in the distribution system by reducing average residence time include flushing distribution mains more frequently, eliminating loops and dead ends, and optimizing storage to minimize retention time. These were not considered in the Stage 2 DBPR compliance forecast (see section 7.4.2 for a more detailed discussion of alternatives to treatment). These activities could be used to help systems meet compliance less expensively than using GAC20.

Under the Stage 1 DBPR, surface and ground water systems serving fewer than 500 people must have one site for TTHM and HAA5 monitoring. Under the Stage 2 DBPR, systems have to add a site if their highest TTHM and HAA5 concentrations are at different locations. EPA estimates that approximately 3/4 of systems serving fewer than 100 people will have one site representing both their highest TTHM and HAA5 concentrations for the Stage 2 DBPR. Systems with one site for Stage 1 and one site for the Stage 2 DBPR would produce the same measure of compliance whether calculated using a running annual average (RAA) (Stage 1 compliance) or a locational running annual average (LRAA) (Stage 2 compliance).

In addition, it is anticipated that systems currently predicted by EPA to select GAC20 may be able to use less expensive treatment technologies by the time the Stage 2 DBPR is implemented. This is because the compliance decision tree (summarized in Chapter 3 and described in detail in Appendices A and B) represents current limitations on the use of inexpensive treatment technologies (e.g., chloramines and UV) taking into account operational and constructability constraints. These limitations may not exist by the time the rule is implemented due to advances in treatment and innovations by manufacturers.

8.3.3 Funding Options for Disadvantaged Systems

EPA believes that there is another mechanism in SDWA to address cost impacts on small systems that serve primarily low-income households. Systems that meet criteria established by the State/Primacy Agency could be classified as disadvantaged communities under §1452(d) of SDWA. They can receive additional subsidies through the DWSRF, including forgiveness of principal. Under DWSRF, States/Primacy Agencies must provide a minimum of 15 percent of the available funds for infrastructure loans to systems serving fewer than 10,000 or fewer people. Two percent of the State's/Primacy Agency's grant is set-aside funding that can only be used to provide technical assistance to small systems. In addition, up to 14 percent of the State's/Primacy Agency's grant may be used to provide technical, managerial, and financial assistance to all system sizes. For small systems that are disadvantaged, as defined by the State/Primacy Agency, up to 30 percent of a State's/Primacy Agency's DWSRF may be used for increased loan subsidies. This assistance can take the form of lower interest rates, principal forgiveness, or negative interest rate loans. The State may also extend repayment terms of loans for disadvantaged communities to up to 30 years.

Small systems will be encouraged to discuss their infrastructure needs for complying with the Stage 2 DBPR with their State/Primacy Agency to determine their eligibility for DWSRF loans, and, if eligible, to ask for assistance in applying for the loans.

In addition to the DWSRF, money is available from the Department of Agriculture's Rural Utility Service (RUS) and Housing and Urban Development's Community Development Block Grant (CDBG) Program. RUS provides loans, guaranteed loans, and grants to improve, repair, or construct water supply and distribution systems in rural areas and towns with a population of up to 10,000 people. In fiscal year

2003, RUS had over $1.5 billion of available funds for water and environmental programs. Also, three sources of funding exist under the CDBG program to finance building and improvements of public faculties such as water systems. These include: 1) direct grants to communities with populations over 200,000; 2) direct grants to States/Primacy Agencies, which in turn are awarded to smaller communities, rural areas, and coloñas in Arizona, California, New Mexico, and Texas; and 3) direct grants to U.S. territories and trusts. The CDBG budget for the formula program for fiscal year 2003 totaled over $4.4 billion.

8.4 Feasible Treatment Technologies for All Systems

In accordance with Section 1412(b)(4)(E) of the 1996 SDWA Amendments, EPA examined whether there were existing, feasible treatment technologies and treatment techniques available that would allow systems to meet the Stage 2 DBPR requirements. EPA examined alternatives for best available technologies (BATs) using two methods: Information Collection Rule (ICR) treatment studies and Surface Water Analytical Tool (SWAT) predictions. A discussion of the evaluation is provided in sections 8.4.1 and 8.4.2. Results from these two evaluations show that all systems can meet the TTHM and HAA5 LRAA MCLs (80 micrograms per liter (µg/L) and 60 µg/L, respectively) using one of the three following treatment technologies:

1) GAC adsorbers with at least 10 minutes of empty-bed contact time and an annual average reactivation/replacement frequency no greater than 120 days, plus enhanced coagulation or enhanced softening.

2) Nanofiltration using a membrane with a molecular weight cutoff of 1000 Daltons or less.

3) GAC adsorbers with at least 20 minutes of empty-bed contact time and an annual average reactivation/replacement frequency no greater than 240 days.

Section 8.4.3 discusses BATs specifically for consecutive systems.

8.4.1 ICR Treatment Studies

The ICR treatment studies were designed to evaluate the technical feasibility of using GAC and nanofiltration to remove DBP precursors prior to the addition of chlorine-based disinfectants (USEPA 2000o, Hooper and Allgeier 2002). EPA used TOC levels in the source or finished water to determine whether the ICR treatment study requirement applied to plants. Specifically, surface water plants with annual average source water TOC concentrations greater than 4 milligrams per liter (mg/L) and ground water plants with annual average finished water TOC concentrations greater than 2 mg/L were required to conduct treatment studies. Thus, the plants required to conduct treatment studies generally had waters with organic DBP precursor levels that were significantly higher than the national means of 3.2 mg/L and 1.5 mg/L for ICR surface and ground water plants, respectively (USEPA 2005l).

Plants that used GAC typically evaluated performance at two empty-bed contact times, 10 and 20 minutes, and over a range of operational times to evaluate the unsteady nature of TOC removal by GAC. This allowed GAC performance to be assessed with respect to empty-bed contact time, as well as reactivation/replacement frequency. Plants that conducted membrane treatment studies evaluated one or

two nanofiltration membranes with molecular weight cutoffs less than 1,000 Daltons. Regardless of the treatment technology evaluated, all treatment studies evaluated post-treatment DBP formation under distribution system conditions representative of the full-scale plant at the average residence time, using free chlorine as the primary and residual disinfectant.

The results of the ICR treatment study suggest that GAC would be an appropriate treatment technology for surface water systems and some ground water systems with influent TOC concentrations below approximately 6 mg/L (USEPA 2005l). (The ICR and National Rural Water Association (NRWA) data indicate that over 90 percent of plants have average influent TOC levels below 6 mg/L.) Larger systems would likely realize an economic benefit from on-site reactivation, which could allow them to use smaller, 10-minute empty-bed contact time contactors with more frequent reactivation (i.e., 120 days or less). Most small utilities would not find it economically advantageous to install on-site carbon reactivation facilities, and thus would opt for larger, 20-minute empty-bed contact time contactors, with less frequent carbon replacement (i.e., 240 days or less). EPA recognizes that some small systems attempting to implement GAC20 may face GAC supply challenges.

Theoretically, there is a linear relationship between empty-bed contact time and reactivation interval. Assuming equivalent performance, a doubling of the empty-bed contact time would be expected to result in a doubling of the reactivation interval. If this is the case, the 10-minute empty-bed contact time contactor reactivated at 120 days should result in equivalent performance to a 20-minute empty-bed contact time contactor reactivated at 240 days. However, the ICR treatment study data demonstrated that the 20-minute contactors generally outperform the 10-minute contactors. On the other hand, larger systems will typically operate with a larger number of parallel contactors compared to small systems, resulting in improved performance. Thus, the benefit that small systems gain by using a larger empty-bed contact time will be offset by use of a smaller number of parallel contactors. Based on these considerations, the proposed reactivation/replacement interval for the 20-minute contactor is simply double the reactivation/replacement interval for a 10-minute contactor.

The ICR treatment study demonstrated that approximately 70 percent of the surface water plants that conducted GAC studies could meet the 80/60 µg/L TTHM/HAA5 MCLs with a 20 percent safety factor (i.e., 64 µg/L and 48 µg/L, respectively) using GAC with 10 minutes of empty-bed contact time and a 120-day reactivation frequency. It also showed that 78 percent of the plants could meet the MCLs using GAC with 20 minutes of empty-bed contact time and a 240-day reactivation frequency. As discussed previously, the treatment studies were conducted at plants having poorer source and finished water quality than the national average. Therefore, EPA believes that the percentages of plants in the GAC studies that could meet the MCLs with the BATs translate to much higher percentages of plants nationwide.

The ICR treatment study results also demonstrated that nanofiltration was the better DBP control treatment technology for ground water sources with high TOC concentrations (i.e., above approximately 6 mg/L). The results of the membrane treatment studies showed that all ground water plants could meet the 80/60 µg/L TTHM/HAA5 MCLs with a 20 percent safety factor (i.e., 64 µg/L and 48 µg/L, respectively) at the average distribution system residence time using nanofiltration (USEPA 2000o, Hooper and Allgeier 2002). Although nanofiltration is generally more expensive than GAC, it would be less expensive than GAC for high TOC ground waters that require minimal pretreatment. Also, nanofiltration is an accepted treatment technology for treatment of the high-TOC ground waters in areas of the country, such as Florida and parts of the southwest.

8.4.2 BAT Evaluation Using SWAT

The second method that EPA used to examine alternatives for BAT was SWAT, which was developed to compare alternative regulatory strategies as part of the Stage 1 and Stage 2 M-DBP Advisory Committee deliberations (McGuire 2001). EPA considered the following BAT options:

- Enhanced coagulation (EC)/softening with chlorine
- EC/softening with chlorine and no pre-disinfection
- EC and GAC10
- EC and GAC20
- EC and chloramines

EC/softening is required under the Stage 1 DBPR for conventional plants. In the model, GAC10 was defined as granular activated carbon with an empty-bed contact time of 10 minutes and a reactivation frequency of no more than 90 days. GAC20 was defined as granular activated carbon with an empty-bed contact time of 20 minutes and a reactivation or replacement frequency of no more than 90 days. EPA assumed that systems would be operating to achieve both the Stage 2 MCLs of 80 µg/L TTHM and 60 µg/L HAA5 as an LRAA and the Surface Water Treatment Rule (SWTR) removal and inactivation requirements of 3-log for *Giardia* and 4-log for viruses. EPA also evaluated the BAT options under the assumption that plants operate to achieve DBP levels 20 percent below the MCL (i.e., a 20 percent safety factor). These assumptions along with other inputs for the SWAT runs are consistent with those specified in Appendix A.

The compliance percentages forecasted by SWAT are indicated in Exhibit 8.4. EPA estimates that over 97 percent of large systems will be able to achieve the Stage 2 MCLs, regardless of post-disinfection choice, if they apply the BAT (i.e., EC and GAC10). As shown in the current Occurrence Document (USEPA 2005l), the source water quality (e.g., DBP precursor levels) in medium and small systems is comparable to or better than that for large systems. Using the large-system estimate as a proxy for medium and small systems, EPA believes it is conservative to assume that at least 90 percent of these systems will be able to achieve the Stage 2 MCLs if they were to apply one of the GAC BATs. EPA realizes that it may not be economically feasible for small systems to install and operate an on-site GAC reactivation facility. Thus, it is assumed that small systems may adopt GAC20 (with 240 days of empty-bed contact time) in a replacement mode over GAC10. Some small systems may find that another defined BAT, like nanofiltration, will be cheaper than the GAC20 in a replacement mode because their specific geographic locations may make routine GAC shipment expensive.

Exhibit 8.4 SWAT Model Predictions of Percent of Large Plants in Compliance with TTHM and HAA5 Stage 2 MCLs after Application of Specified Treatment Technologies

Treatment Technology	Compliance with 80/60 LRAA			Compliance with 64/48 LRAA (20% Safety Factor)		
	Residual Disinfectant		All Systems	Residual Disinfectant		All Systems
	Chlorine	Chloramine		Chlorine	Chloramine	
(EC)	73.5%	76.9%	74.8%	57.2%	65.4%	60.4%
EC (no pre-disinfection)	73.4%	88.0%	78.4%	44.1%	62.7%	50.5%
EC & GAC10	100%	97.1%	99.1%	100%	95.7%	98.6%
EC & GAC20	100%	100%	100%	100%	100%	100%
EC & All Chloramines	NA	83.9%	NA	NA	73.6%	NA

Source: McGuire (2001).

8.4.3 BATs for Consecutive Systems

EPA is also proposing a BAT for consecutive systems to meet the TTHM and HAA5 MCLs of 80 and 60 µg/L, respectively. Presumably, consecutive systems that may need to employ the BAT are receiving water from their wholesaler(s) that barely meets or does not meet the MCLs. Removal of TTHM and HAA5 is difficult after they have formed. EPA believes that the best compliance strategy for consecutive systems is to collaborate with wholesalers on the water quality they need. However, this is a private agreement over which EPA does not have jurisdiction. There are expected to be wholesalers treating water with whom consecutive systems cannot work out agreements to enable the consecutive systems to meet the MCLs.

EPA is specifying chloramination with management of hydraulic flow and storage to minimize residence time in the distribution system as a BAT for consecutive systems that serve at least 10,000 people. Chloramination has been used for residual disinfection for many years to minimize the formation of chlorination DBPs, including TTHM and HAA5 (USEPA 2005l). EPA estimates that over 50 percent of large subpart H systems serving at least 10,000 people use chloramination for Stage 1 DBPR. The BAT provision to manage hydraulic flow and minimize residence time in the distribution system is intended to facilitate the maintenance of the chloramine residual and minimize the likelihood of nitrification. If consecutive systems receive chlorinated water that is close to, but lower than, the MCLs, they should in most cases be able to use chloramination to stop the formation of TTHM and HAA5 in their distribution system and thereby meet the MCL. If consecutive systems are already receiving chloraminated water from the wholesaler that is meeting the MCLs, the consecutive system should also be able to meet the MCL. In either of these situations, distribution system flow maintenance is important for maintaining the chloramine residual.

For those consecutive systems serving fewer than 10,000 people, EPA is defining management of hydraulic flow and storage to minimize residence time in the distribution system as a BAT. Chloramines are not included as a BAT for consecutive systems serving fewer than 10,000 people due to concerns

about the ability of systems to properly control the process, given that many have no treatment capability or expertise. EPA is also concerned about such systems having operational difficulties such as distribution system nitrification.

EPA believes that the various BATs proposed for non-consecutive systems are not appropriate for consecutive systems because their efficacy in controlling DBPs is based on precursor removal. Consecutive systems face the unique challenge of receiving waters in which DBPs are already present if the wholesale systems has used a residual disinfectant, which BATs for non-consecutive systems do not effectively remove. GAC is not cost-effective for removing DBPs. Dioxin is a potent carcinogen and a byproduct of GAC regeneration when GAC has been used to adsorb DBPs. Nanofiltration can be moderately effective at removing TTHM and HAA5, but only with membranes that have a very low molecular weight cutoff and very high cost of operation. Therefore, EPA believes that GAC and nanofiltration are not appropriate BATs for consecutive systems.

8.5 Effect of Compliance with the Stage 2 DBPR on the Technical, Managerial, and Financial Capacity of Public Water Systems

Section 1420(d)(3) of SDWA, as amended, requires that, in promulgating a National Primary Drinking Water Regulation (NPDWR), the Administrator shall include an analysis of the likely effect of compliance with the regulation on the technical, managerial, and financial (TMF) capacity of PWSs. The following analysis fulfills this statutory obligation by identifying the incremental impact that the Stage 2 DBPR will have on the TMF of regulated water systems. Analyses presented in this document represent only the impact of new or revised requirements, as established by the Stage 2 DBPR; the impacts of previously established requirements on system capacity are not considered.

Overall water system capacity is defined in *Guidance on Implementing the Capacity Development Provisions of the Safe Drinking Water Act Amendments of 1996* (USEPA 1998e) as the ability to plan for, achieve, and maintain compliance with applicable drinking water standards. Capacity encompasses three components: technical, managerial, and financial. Technical capacity is the operational ability of a water system to meet SDWA requirements. Key issues of technical capacity include:

- Source water adequacy—Does the system have a reliable source of water with adequate quantity? Is the source generally of good quality and adequately protected?

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

- Technical knowledge and implementation—Are the system's operators certified? Do the operators have sufficient knowledge of applicable standards? Can the operators effectively implement this technical knowledge? Do the operators understand the system's technical and operational characteristics? Does the system have an effective Operations and Maintenance (O&M) program?

Managerial capacity is the ability of a water system's managers to make financial, operating, and staffing decisions that enable the system to achieve and maintain compliance with SDWA requirements. Key issues include:

- Ownership accountability—Are the owners clearly identified? Can they be held accountable for the system?

- Staffing and organization—Are the operators and managers 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 (i.e., to conduct implementation, IDSE, additional routine monitoring, and operational evaluation activities to meet the Stage 2 DBPR requirements)? 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. Key issues include:

- Revenue sufficiency—Do revenues cover costs?

- Creditworthiness—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?

8.5.1 Requirements of the Stage 2 DPBR

The Stage 2 DBPR establishes five new requirements that may affect the TMF capacity of affected PWSs:

1) Compliance with MCLs established for TTHM and HAA5: MCLs of 80µg/L and 60µg/L for TTHM and HAA5, respectively, measured as LRAAs at the monitoring sites identified as a result of the IDSEs required under the Stage 2 DBPR.

2) Conducting an IDSE to identify sample locations for Stage 2 compliance monitoring that represent distribution system sites with high TTHM and HAA5 levels.

3) Preparing a monitoring plan, based on information in the IDSE and consultation with the State/Primacy Agency, that details the sites and times for compliance sampling.

4) Additional routine monitoring for DBPs.

5) If the operational evaluation level is exceeded, systems must conduct an operational evaluation and submit a report to the State/Primacy Agency no later than 90 days after being notified of the analytical result that exceeded the operational evaluation level.

In addition, personnel from systems regulated under the Stage 2 DBPR will need to familiarize themselves with the rule and its requirements.

8.5.2 Systems Subject to the Stage 2 DBPR

The Stage 2 DBPR will apply to all CWSs and NTNCWSs that add a primary or residual disinfectant other than UV, or that deliver water that has been treated with a disinfectant other than UV. The Stage 2 DBPR may affect 42,032 CWSs and 6,260 NTNCWSs—48,293 systems in all. While most will not, some systems may require increased TMF capacity to comply with the new requirements, or will need to tailor their choices to match their capacities.

8.5.3 Impact of the Stage 2 DBPR on System Capacity

The estimates presented in Exhibits 8.5 and 8.6 represent the anticipated impact of the Stage 2 DBPR on small and large system capacity as a result of the measures that systems are expected to adopt to meet the requirements of the rule (e.g., selecting monitoring sites for the IDSE, installing/upgrading treatment, operator training, communication with regulators and the service community, etc.). The extent of the impact of a particular requirement on system capacity is estimated using a scale of 0-5, where 0 represents a requirement that is not anticipated to have any impact on system capacity, 1 represents a requirement that is expected to have a minimal impact on system capacity, and 5 represents a requirement that is anticipated to have a very significant impact on system capacity.

Criteria used to develop the scores and associated impacts are discussed further in section 8.5.5.

8.5.4 Rationale for Scores

The baseline assumed for the purposes of this analysis, which identifies the incremental impact of the Stage 2 DBPR on the TMF capacity of systems, is complete implementation of the Stage 1 DBPR, the Interim Enhanced Surface Water Treatment Rule (IESWTR), and the Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR). As a result, it is anticipated that many of the systems facing the most difficult DBP challenges will have made appropriate modifications to their treatment process (e.g., changed point of disinfection, installed membrane technologies, etc.) to achieve compliance with these rules, and, therefore, will not need to install additional treatment technology to achieve compliance with the Stage 2 DBPR. However, the revised methodology for measuring system compliance with the MCLs for TTHM and HAA5 (i.e., LRAA) will require systems to reduce peak levels in DBP concentrations within their distribution systems. Since an LRAA represents a more stringent testing standard than an RAA, it is likely that some systems that previously met requirements established by the Stage 1 DBPR will be required to make changes to their treatment processes to comply with the Stage 2 DBPR. The derivation of the scores assigned in Exhibits 8.5 and 8.6 and the rationale behind them is described in the next section.

Exhibit 8.5 Estimated Impact of the Stage 2 DBPR on Small System Capacity (0 = no impact, 1 = minimal impact, and 5 = very significant impact)

Requirement	Number of Systems/ Plants (Percent)	Technical Capacity			Managerial Capacity			Financial Capacity		
		Source Water Adequacy	Infrastructure Adequacy	Technical Knowledge & Implementation	Ownership Accountability	Staffing & Organization	Effective External Linkages	Revenue Sufficiency	Credit Worthiness	Fiscal Mgmt. & Controls
Familiarization with requirements of the rule	44,453 systems (100%)	0	0	1	0	1	0	0	0	0
Conducting IDSE monitoring	10,478 systems (24%)	0	0	2	1	0	2	3	0	1
Plants with major treatment technology changes	1,784 plants (4%)	2	4	4	2	2	3	5	5	3
Stage 2 monitoring plan[1]	46,992 systems (100%)	0	0	1	1	0	1	1	0	0
Additional routine monitoring[1]		0	0	1	0	0	0	3	0	0
Operational evaluations	97 systems (0.2%)	0	0	1	1	1	1	0	0	0

[1]Some systems are expected to take more samples and some are expected to take less from Stage 1 to Stage 2, depending on the number of plants in their systems. Overall, the Stage 2 DBPR results in an increase in the total number of compliance samples taken from the Stage 1 DBPR. Exhibit H.8a presents the change in total samples for different system size categories.

Notes: (1) To analyze the impact of these requirements on system capacity, the requirements believed to have the most and the least impact on affected systems (i.e., the installation of treatment to ensure compliance with the LRAA MCLs for TTHM and HAA5, and familiarization with the requirements of the rule, respectively), were analyzed first. These initial analyses were then used as the bases against which the relative impact of the remaining requirements were assessed. The impact estimates developed for each requirement were also compared to those developed for the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) to ensure cross-rule consistency and to enable cross-rule comparisons.

(2) The scores presented above represent the worst-case scenario; the requirements of this rule are expected to have less impact on the capacity of most systems affected by each requirement.

Source: Number and percent of small systems subject to each rule activity from Exhibit 7.2 (sum of surface water/GWUDI), and ground water CWSs and NTNCWSs serving fewer than 10,000 people). Number of small plants making treatment technology changes from Exhibit 7.3 (sum of surface water/GWUDI, and ground water CWSs and NTNCWSs serving fewer than 10,000 people). Impact on capacity is determined relative to previous regulations as a function of the cost and number of systems/plants that require additional capacity to comply with each requirement, as described in section 8.5.5.

Exhibit 8.6 Estimated Impact of the Stage 2 DBPR on Large System Capacity (0 = no impact, 1 = minimal impact, and 5 = very significant impact)

Requirement	Number of Systems/ Plants (Percent)	Technical Capacity			Managerial Capacity			Financial Capacity		
		Source Water Adequacy	Infrastructure Adequacy	Technical Knowledge & Implementation	Ownership Accountability	Staffing & Organization	Effective External Linkages	Revenue Sufficiency	Credit Worthiness	Fiscal Mgmt. & Controls
Familiarization with requirements of the rule	3,839 systems (100%)	0	0	1	0	1	0	0	0	0
Conducting IDSE monitoring	2,302 systems (60%)	0	0	2	1	0	1	1	0	0
Plants with major treatment technology changes	554 plants (6%)	2	3	3	2	2	2	4	4	3
Stage 2 monitoring plan[1]	3,853 systems (100%)	0	0	1	1	0	1	1	0	0
Additional routine monitoring[1]		0	0	0	0	0	0	1	0	0
Operational evaluations	327 systems (9%)	0	0	0	1	0	1	0	0	0

[1]Some systems are expected to take more samples and some are expected to take less from Stage 1 to Stage 2, depending on the number of plants in their systems. Overall, the Stage 2 DBPR results in an increase in the total number of compliance samples taken from the Stage 1 DBPR. Exhibit H.8a presents the change in total samples for different system size categories.

Notes: (1) To analyze the impact of these requirements on system capacity, the requirements believed to have the most and the least impact on affected systems (i.e., the installation of treatment to ensure compliance with the LRAA MCLs for TTHM and HAA5, and familiarization with the requirements of the rule, respectively), were analyzed first. These initial analyses were then used as the bases against which the relative impact of the remaining requirements were assessed. The impact estimates developed for each requirement were also compared to those developed for the LT2ESWTR to ensure cross-rule consistency and to enable cross-rule comparisons.
(2) The scores presented above represent the worst case scenario; the requirements of this rule are expected to have less impact on the capacity of most systems affected by each requirement.

Source: Number and percent of large systems subject to each rule activity from Exhibit 7.2 (sum of surface water/GWUDI, and ground water CWSs and NTNCWSs serving 10,000 or more people). Number of large plants making treatment technology changes from Exhibit 7.3 (sum of surface water/GWUDI, and ground water CWSs and NTNCWSs serving 10,000 or more people). Impact on capacity is determined relative to previous regulations as a function of the cost and number of systems/plants that require additional capacity to comply with each requirement, as described in section 8.5.5.

8.5.5 Derivation of Stage 2 DBPR Scores

EPA developed a 5-point scoring system to analyze the likely effect of compliance with an NPDWR on the technical, managerial, and financial capacity of PWSs. For each regulation, it is necessary to complete the following steps:

1) Determine the type and number of PWSs to which the regulation applies.

2) List all of the requirements of the regulation.

3) Determine the type and number of PWSs to which each requirement applies.

4) Evaluate the impact of each requirement on the capacity of affected PWSs.

The determination of the universe of affected systems and the evaluation of the capacity impact of individual requirements requires the use of the cost and technical information contained in SDWIS, EAs developed for other rules, information collection requests, and other supporting documentation for the rule. These data sources are also used to develop a qualitative description of the expected response of affected systems to each requirement.

The overall evaluation of the impact of a requirement on the affected systems, presented in Exhibits 8.5 and 8.6, is determined by the impact of each requirement on nine sub-categories of capacity—three sub-categories under each of the broader divisions of technical, managerial, and financial capacity. Within these sub-categories, a professional engineer with extensive water system experience reviewed the costs, number of systems affected, and complexity of each requirement. After estimating the technical, managerial, and financial impacts within each sub-category, the professional engineer assigned the scores using best professional judgment. Costs were considered cumulatively for each requirement for small and large systems. This score represents the additional capacity that systems will need to develop to comply with each requirement. Due to a lack of available information on operating budgets, this analysis does not include a quantitative component.

To ensure the ability to make cross-rule comparisons, to standardize the assignment of numerical scores, and to minimize the subjectivity of the scoring system, the professional engineer compared the Stage 2 DBPR requirements to requirements of regulations for which capacity impact analyses have already been conducted (e.g., Ground Water Rule, LT1ESWTR). Similar requirements are assigned similar impact scores.

These group assignments are reviewed by the EPA Rule Manager and other EPA staff cognizant of small system issues to ensure that they accurately represent the cumulative impact of the rule requirements on system capacity. Any disagreements over the assignments are discussed. The EPA Rule Manager and other EPA staff discuss the rationale for the disagreement and evaluate whether the assignments need to be adjusted. EPA adjusts the assignments only after review of the rule support documents and an analysis of the expected system response to the rule requirements.

8.5.5.1 Familiarization with the Stage 2 DBPR

The requirements established under the Stage 2 DBPR are straightforward (use of LRAA instead of RAA to determine compliance with the MCLs for DBPs) and are grounded in requirements previously established under the Stage 1 DBPR. As a result, EPA does not expect that small or large systems regulated under this rule will face more than a minimal challenge to their technical or managerial capacity as a result of efforts to familiarize themselves with the Stage 2 DBPR. Furthermore, familiarization with the rule will not impact the financial capacity of either large or small systems.

8.5.5.2 Conducting an Initial Distribution System Evaluation

The IDSE was incorporated into the Stage 2 DBPR to ensure that systems monitor for DBPs at the location where TTHM and HAA5 values are highest. IDSEs are required for most PWSs under the Stage 2 DBPR, but will not affect the capacity of all systems subject to the requirement to the same extent. Some systems will be able to meet this requirement without conducting extensive additional monitoring, through an IDSE waiver. An IDSE waiver may be granted to CWSs serving fewer than 500 people with Stage 1 DBPR sites that represent both the highest TTHM and HAA5 concentrations. Systems for which all Stage 1 DBPR TTHM and HAA5 levels are less than or equal to 40/30 µg/L, respectively, may qualify for the 40/30 certification and not perform the IDSE. NTNCWSs that serve fewer than 10,000 people are not subject to the IDSE requirement. It is expected that large surface water systems will typically be required to conduct the most monitoring for the IDSE, while small ground water systems will be required to conduct the least.

Before doing an IDSE, systems required to monitor for DBPs will need to select monitoring locations. Identifying appropriate sampling locations is expected to require a modest improvement in the technical and managerial capacity of many systems. This requirement will have a much smaller impact on the capacity of systems that do not have to monitor than on those that do. While the former may need to contact their regulatory agencies to obtain waivers for the IDSE requirement and to meet reporting requirements, they will not be required to conduct as many new technical analyses of their distribution system and its impact on finished water quality. Regardless of whether a system must conduct additional monitoring as part of an IDSE, this requirement will have an impact on ownership accountability, since all new or historic monitoring data must be logged and submitted to the appropriate regulatory agency.

It is expected that large surface water systems will typically be required to conduct the greatest amount of monitoring for the IDSE, while small ground water systems will be required to conduct the least. Lab analysis of samples for TTHM and HAA5 are expensive (estimated at $200 per sample plus $10 to $40 for shipping costs, depending on system size; see Chapter 7 for discussion of laboratory costs). While these costs are not typically prohibitive for large systems, they may represent a significant challenge to the financial capacity of small systems. Some of these systems will need to revisit their current budgeting practices and fee structures to meet these additional costs.

8.5.5.3 Compliance with MCLs for TTHM and HAA5

The impact of the revised DBP MCLs on the managerial capacity of systems is not anticipated to be as great as the technical and financial challenges. However, system managers will need to review the implications of the revised method for measuring compliance with the MCLs for TTHM and HAA5, and may need to hire more highly certified operators or provide additional training for existing operators to

ensure that system staff can safely and effectively operate all new elements of the system's treatment train at all times. In addition, systems will need to rely on, and improve upon, their communication with regulators, technical and financial assistance providers, and their service community.

Systems whose finished water does meet the MCLs for TTHM or HAA5 calculated using LRAAs will need to adjust, change, or enhance their treatment practices. The installation, operation, and maintenance of new treatment technologies will require a substantial enhancement of these systems' technical capacity, particularly for small systems. Specifically, source water adequacy may be reduced if marginal sources are no longer viable. The system may also need to improve its infrastructure, and system operators will require correspondingly greater technical expertise to operate new treatment processes.

Note, however, that based on the recommendations of the Small Surface Water System Delphi Group convened by the Agency, EPA assumed for the purposes of the capacity impact analysis that small surface water systems would not install treatment technologies that were beyond their technical or managerial capacity in order to meet the requirements of this rule. For example, very small systems (those serving fewer than 500 people) would not install chlorine dioxide treatment because it requires a system operator to be in the plant every day. Instead, EPA assumed these smallest systems would install UV or membrane technologies, which do not require a system operator to be present each day. While the operation and maintenance of membrane treatment elements may challenge the technical capacity of small system operators, UV treatment is easy to implement, does not require the same level of technical know-how, and is relatively low cost. As a result, only some of those small systems that must install treatment to meet the MCLs for TTHM and HAA5 are expected to experience the full impact detailed in Exhibit 8.5.

While some small systems that must install new treatment to meet the revised MCL requirement will face a substantial challenge to their capacity, it is expected that this requirement will not have as dramatic an impact on large systems for the reasons described below.

Management for both large and small systems will need to work closely with regulatory agencies to receive approval on proposed design/treatment modifications. Since larger systems tend to have more developed relationships with regulatory personnel, as well as more established means of communicating with their customers, the impact on the managerial capacity of small systems is expected to be greater than the impact on the managerial capacity of large systems. Further, large system operators tend to have a higher level of expertise than their small system counterparts. As a result, large system operators will not require as much training to adequately operate and maintain any new treatment that must be installed. This requirement will not pose as great of a technical or managerial challenge to large systems.

The impact of the Stage 2 DBPR on the financial capacity of regulated systems is closely tied to the rule's impact on the technical capacity of these systems. Systems that must install additional treatment processes or upgrade their current treatment processes will face high costs. These costs may pose particular difficulties for many of the affected systems since the majority are relatively small (i.e., serving fewer than 3,300 customers), and therefore typically have a smaller revenue base and fewer households over which they can distribute additional costs. In addition, large systems may take better advantage of economies of scale than smaller systems because they buy larger quantities of chemicals and equipment. However, it is anticipated that some systems may elect to develop an alternative source (e.g., one with lower levels of naturally-occurring organic material) or interconnect with a nearby system if treatment costs prove prohibitive.

To obtain funding from either public or private sources, systems will need to demonstrate sound financial accounting and budgeting practices, and the ability to repay their debts. As a result, many of the smallest systems that do not currently charge explicitly for water service (e.g., mobile home parks, camp grounds, etc.) may need to begin billing their customers. Those systems that already charge for water service will likely need to increase their rates (frequently requiring approval of the local public utilities commission or public services commission, board approval, or vote within the service boundary), and improve their recordkeeping procedures. Again, this poses less of a challenge to large systems that have established billing practices and have developed close relationships with public utilities commissions.

Therefore, on the basis of the TMF challenges posed by this requirement, it is anticipated that the implementation of the revised monitoring methodology will have a substantial impact on the capacity of the 1,784 small plants and 554 large plants that are expected to make treatment technology changes to reduce DBP concentrations to comply with this rule (see Exhibit 7.3). The other systems are expected to experience only minor TMF impacts.

8.5.5.4 Stage 2 Monitoring Plan

All systems are required to develop a Stage 2 DBPR monitoring plan that includes monitoring locations, monitoring dates, and compliance calculation procedures. It must also include any agreements (e.g., permits, contracts) with third parties to sample, analyze, or report compliance information. Most systems will have to base the new monitoring plan on the IDSE results and Stage 1 compliance monitoring locations. Some systems, such as those receiving very small system waivers and NTNCWSs serving fewer than 10,000 people, will only need to update existing monitoring plans. The Stage 2 DBPR monitoring plan will be similar to monitoring plans already in existence. Therefore the requirement is expected to have a minimal impact.

8.5.5.5 Additional Routine Monitoring

It is anticipated that the additional routine monitoring required for some systems will have a relatively limited impact on TMF capacity. These systems already have experience sampling for DBPs and only a small number of additional samples may be required. Some systems may take fewer samples under Stage 2 than Stage 1, and very small systems will take the same number of samples as they do under Stage 1. Nonetheless, it is important to consider that the monitoring costs may strain the financial capacity of some small systems, especially since the sampling costs are high for TTHM and HAA5. Additional routine monitoring is expected to have minimal impact on the capacity of large systems since costs will be spread across a large population base.

8.5.5.6 Operational Evaluations

The operational evaluation level is exceeded when a sample result (when multiplied by 2 and added to the previous two quarters and then divided by 4) results in a concentration greater than 80 μg/L for TTHM or 60 μg/L for HAA5. If a system has exceeded the operational evaluation level, it must conduct a operational evaluation and submit a report to the State/Primacy Agency no later than 90 days after being notified of the analytical result that exceeded the operational evaluation level. The evaluation involves an examination of system treatment and distribution operational practices, including storage tank operations, excess storage capacity, distribution system flushing, changes in sources or source water

quality, and treatment technology changes or problems that may contribute to TTHM and HAA5 formation and what steps could be considered to minimize future exceedances. Based on the conclusions of their evaluation, some systems may install additional treatment or modify their distribution system (e.g., improve tank mixing by adding a recirculation system). However, since such modifications are not required, they are not considered for the purposes of this analysis.

An operational evaluation will require system operators to have a thorough knowledge of the components of their treatment train and distribution system. Further, some system operators, particularly small system operators, may require additional training or input from State/Primacy Agency or local extension agents. This requirement may also have a small impact on the managerial capacity of some systems, since owners will be required to ensure that these evaluations are conducted. Note, however, that this requirement does not require systems to notify the public or provide an explanation in their CCRs—minimizing the need for them to further develop their public outreach efforts. Finally, given that an operational evaluation is expected to take only 2 to 16 hours (depending on system size), this requirement will probably not have any impact on the financial capacity of large or small systems. Large systems with more complex distribution networks are expected to spend more time per exceedance than smaller, simpler systems. The frequency of exceedances is also expected to decrease over time as systems begin identifying the causes and working with their States/Primacy Agencies to reduce future exceedances.

8.5.6 Summary

The Stage 2 DBPR may have a substantial impact on the capacity of the 1,784 plants in small systems and 554 plants in large systems that must make changes to their treatment process to meet the Stage 2 DBPR requirements. However, while the impact to these systems is potentially significant, only 3.5 percent of all plants regulated under the Stage 2 DBPR (1,784 of 60,220) will be affected by this requirement. Since individual systems may employ more than one plant, it is likely that fewer than 1,678 systems (3.5 percent of systems) will be affected by this requirement. The new IDSE and monitoring requirements are expected to have a small impact on the technical and managerial capacity of small systems, a moderate impact on the financial capacity of some small systems, and a much smaller impact on large systems. The capacity of systems that must conduct an operational evaluation will only be impacted in a minor way, while those systems that must only familiarize themselves with the rule (the large majority of systems) will not face any capacity impact as a result of the Stage 2 DBPR.

8.6 Paperwork Reduction Act

The information collected as a result of the Stage 2 DBPR allows the States/Primacy Agencies and EPA to determine appropriate requirements for specific systems and to evaluate compliance with the rule. The Paperwork Reduction Act requires EPA to estimate the burden of complying with the rule on PWSs, States, and territories. Burden means the total time, effort, and financial resources required to generate, maintain, retain, disclose, or provide information to or for a Federal agency. This burden includes the time needed to:

- Review instructions

- Develop, acquire, install, and utilize treatment technology and systems for the purposes of collecting, validating, and verifying information

- Process and maintain information, and disclose and provide 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
- Transmit or otherwise disclose the information

For the first 3 years following promulgation of the final rule, the major information requirements involve developing and submitting a monitoring plan, conducting the IDSE Standard Monitoring Program or the System Specific Study, and submitting the IDSE report. The information collection requirements are mandatory under Part 141, the NPDWRs, and the information collected is not confidential. This information will allow the systems to determine appropriate treatment requirements and will allow States/Primacy Agencies and EPA to evaluate systems' compliance with the rule. The calculation of Stage 2 DBPR burden and costs can be found in *Information Collection Request for the Stage 2 Disinfectants and Disinfection Byproducts Rule* (USEPA 2005l). Exhibit 8.7 provides a summary of the results of the Information Collection Request calculations.

Exhibit 8.7 Summary of Average Annual Burden Hours and Labor Costs

	Average Annual Burden (Hours)	Average Annual Labor Costs ($Millions)	Average Annual O&M Costs ($Millions)	Average Annual Capital Costs ($Millions)	Average Annual Costs ($Millions)
NTNCWSs	9,506	$0.2	$0.0	$0	$0.2
CWSs	134,148	$3.5	$9.1	$0	$12.6
States and Territories	78,922	$2.7	$0.0	$0	$2.7
Total	**222,576**	**$6.4**	**$9.1**	**$0.0**	**$15.5**

Note: Figures represent burden and cost for the 3-year Information Collection Request approval only. Detail may not add due to independent rounding.

Source: *Information Collection Request for the Stage 2 Disinfectants and Disinfection Byproducts Rule* (USEPA 2005l).

The estimate of annual average burden for Stage 2 DBPR for States/Primacy Agencies and systems is 222,576 hours. This estimate covers the first 3 years of the Stage 2 DBPR and includes implementation of a portion of the IDSE (small system reports are not due until the fifth year). The annual average aggregate cost estimate is $9.1 million for operation and maintenance as a purchase of service for lab work, and $6.4 million is associated with labor. EPA assumes systems affected by the Stage 2 DBPR have already purchased the basic equipment to record chlorine concentrations, disinfection efficacy, and other parameters to comply with the Stage 1 DBPR. Therefore, there are no capital start-

up costs associated with information collection under this rule. The annual burden per response is 4.35 hours, and the frequency for response (average responses per respondent) is 6.83 annually. Respondents include 57 States/Primacy Agencies and 22,434 PWSs. The estimated number of likely respondents is 7,497 per year (the product of burden hours per response, frequency, and respondents may not total the annual average burden hours due to rounding).

8.7 Unfunded Mandates Reform Act Analysis

8.7.1 UMRA Requirements and their Impact on the Stage 2 DBPR

The UMRA of 1995, Public Law 104-4, consists of four Titles and numerous sections. Sections 201 through 205 of Title II, entitled "Regulatory Accountability and Reform,"are relevant to the Stage 2 DBPR and are discussed in this section. Title II, Section 201 of the UMRA, requires 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 by State, local, and Tribal governments, in the aggregate, or by the private sector, of $100 million or more in any 1 year. Section 203 requires the Agency to establish a small government agency plan before establishing any regulatory requirements that may significantly or uniquely affect small governments.

Section 204 of the UMRA requires the Agency to develop an effective process to permit elected officers of State, local, and Tribal governments to provide meaningful and timely input in the development of regulatory proposals that contain significant Federal intergovernmental mandates. Finally, Section 205 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 before promulgating a rule for which a written statement is needed under Section 202. 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 with the final rule an explanation why that alternative was not adopted.

EPA has determined that this rule does not contain a Federal mandate that may result in expenditures of $100 million or more for State, local and Tribal governments, in the aggregate, or for the private sector in any one year, as shown in Exhibit 8.8.

Although, the Stage 2 DBPR is not subject to the requirements of Sections 202 and 205 of UMRA, and EPA prepared a written statement addressing the following items:

- The authorizing legislation
- Benefit-cost 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
- Estimates of future compliance costs and disproportionate budgetary effects
- Macroeconomic effects

- 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

- 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 Stage 2 DBPR is discussed in Chapter 2 and section 8.2.2. The remaining items are discussed below, but are also addressed in other chapters of this EA, such as Chapters 4 and 7.

Exhibit 8.8 Public and Private Costs for the Stage 2 DBPR (Annualized at 3 and 7 Percent, $Millions)

	3% Discount Rate	7% Discount Rate	Percent of 3% Grand Total Costs	Percent of 7% Grand Total Costs
Surface Water Systems Costs	$ 45.9	$ 45.9	53%	55%
Ground Water Systems Costs	$ 22.2	$ 20.9	26%	25%
State Costs	$ 1.7	$ 1.7	2%	2%
Tribal Costs	$ 0.4	$ 0.4	0%	0%
Total Public	**$ 70.2**	**$ 68.9**	**81%**	**82%**
Surface Water Systems Costs	$ 7.1	$ 7.1	8%	8%
Ground Water Systems Costs	$ 8.9	$ 8.3	10%	10%
Total Private	**$ 16.0**	**$ 15.4**	**19%**	**18%**
GRAND TOTAL	**$ 86.2**	**$ 84.2**	**100%**	**100%**

Note: Detail may not add due to independent rounding.

Source: Derived from Exhibit 7.5 (costs) and Exhibit 3.2 (public/private breakout).

8.7.2 Social Benefits and Costs

The social benefits are those that accrue primarily to the public through increased protection from cancer and reproductive and developmental effects. To assign a monetary value to the reductions in fatal and non-fatal cancer cases, EPA estimated the current and future annual cases of bladder cancer from all causes, the number of cases attributed to DBP occurrence and exposure, and the reduction in future cases corresponding to anticipated reductions in DBP occurrence and exposure due to the Stage 2 DBPR. Mortalities from cancer were valued using a value of statistical life estimate consistent with EPA's policy. EPA also used two alternate (but equally valid) estimates of willingness-to-pay to avoid non-fatal bladder cancer (one based on avoiding a case of curable lymphoma and the other based on avoiding a case of chronic bronchitis).

Chapter 6 presents the benefits analysis, which includes both qualitative and monetized benefits of the rule. Although EPA estimated the number of avoided incidence of fetal loss, it is only presented as an illustrative example. The potential nonquantifiable benefits may include reproductive health effects, developmental health effects, reduction in other cancers, and benefits from reduction of other DBPs, co-occurring contaminants, or emerging contaminants. In addition, certain non-health-related benefits may exist, such as perceptions of drinking water quality, ecological, and other unknown effects.

Measuring the social costs of the rule requires identifying affected entities by ownership (public or private), considering regulatory alternatives, calculating regulatory compliance costs, and estimating any disproportionate impacts. Chapter 7 of this document details the cost analysis performed for the Stage 2 DBPR. The likely compliance scenario is expected to result in total annualized costs of approximately 86.2 million using a 3-percent discount rate (or 84.2 million using a 7-percent discount rate). Exhibit 8.9 summarizes the annualized costs and benefits for each regulatory alternative.

Exhibit 8.9 Total Annualized Benefits and Costs of Regulatory Alternatives ($Millions, 2003$)

Regulatory Alternative	Mean Annualized Benefits, Lymphoma (3%)	Mean Annualized Benefits, Lymphoma (7%)	Mean Annualized Benefits, Bronchitis (3%)	Mean Annualized Benefits, Bronchitis (7%)	Mean Annualized Costs (3%)	Mean Annualized Costs (7%)
Preferred Alternative	$ 1,522.99	$ 1,239.67	$ 758.88	$ 617.26	$ 86.23	$ 84.24
Alternative A1	$ 1,368.16	$ 1,118.85	$ 681.67	$ 557.05	$ 276.86	$ 265.47
Alternative A2	$ 5,102.92	$ 4,174.14	$ 2,542.47	$ 2,078.19	$ 444.13	$ 431.21
Alternative A3	$ 7,005.46	$ 5,731.03	$ 3,490.38	$ 2,853.32	$ 661.22	$ 644.30

Source: Benefits from Appendix F. Costs from Appendix J: For the Preferred Alternative, see Exhibit J.2as for 3% and J.2aw for 7%. For Alternative 1, see Exhibit J.3i for 3% and J.3m for 7%. For Alternative 2, see Exhibit J.4i for 3% and J.4m for 7%. For Alternative 3, see Exhibit J.5i for 3% and J.5m for 7%.

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 primary enforcement responsibility for their drinking water programs through the Public Water Systems Supervision (PWSS) Grants Program. States may use these funds to develop primacy programs or to contract with other State agencies to assist in the development or implementation of their primacy programs. However, they may not use these funds to contract with regulated entities (i.e., water systems). States may use PWSS Grants to set up and administer a State program that includes such activities as public education, testing, training, technical assistance, development and administration of a remediation grant and loan or incentive program (excluding the actual grant or loan funds), or other regulatory or nonregulatory measures.

Additional funding is available from other programs administered by EPA or other Federal agencies. These include EPA's Drinking Water State Revolving Fund (DWSRF), the U.S. Department of Agriculture's Rural Utilities' Loan and Grant Program, and the Department of Housing and Urban Development's Community Development Block Grant (CDBG) Program. Refer to section 8.3.3 for a more detailed discussion on funding.

8.7.3 Disproportionate Budgetary Effects

UMRA is intended to reduce the burden on State, local, and Tribal governments of Federal mandates that are not accompanied by adequate Federal funding. Section 202 of UMRA requires an analysis of possible disproportionate budgetary effects of certain classes of rules, in which Stage 2 DBPR

falls.[6] Such an analysis is required if EPA determines that accurate estimates are reasonably feasible. The specific concern is disproportionate budgetary effects of the Stage 2 DBPR upon certain areas or industries:

- Any particular regions of the United States
- Any particular State, local, or Tribal government
- Urban or rural or other types of communities
- Any segment of the private sector

This EA has considered how best to interpret and comply with these requirements. The remainder of this section describes ways to consider these requirements, whether meaningful data can be provided, and whether accurate estimates are possible. The general conclusion for this section, however, is that there are little basis and insufficient data to make accurate estimates of budgetary impacts that differ among groups, governments, types of communities, or segments of the private sector.

Most of the following analyses begin with national data and then disaggregate those data, when possible, using other measures. Because the data and estimates are national in scope, parameters tend to be merely proportional extensions based on a characteristic, not "bottom-up" estimates of actual differences among types of systems, communities, or economic sectors. Thus, the analyses may not reveal true differences attributable to the impacts of the rule alternatives on various regions. Local conditions at each regulated entity will drive the actual cost impacts of the rule (e.g., areas with high levels of DBP precursors).

When considering disproportionate impacts, it is necessary to consider whom the Stage 2 DBPR affects. The rule, by definition, covers some communities and a segment of the private sector. Most CWSs and NTNCWSs that add a primary or residual disinfectant other than UV, or that deliver water than has been treated with a disinfectant other than UV, will incur some costs. In an economic sense, differences between communities and utilities do not disadvantage one group over the other because the systems are not in a national market that allows for direct competition for customers. In general, those systems are better considered local natural monopolies.

Regions

EPA determined that the Stage 2 DBPR may have disproportionate budgetary effects on certain geographic regions. Higher TOC levels in source water present special challenges to some areas of the country (for detailed analysis, see section 3.5.2 and Appendix B). Ground water systems in Florida, in particular, will be heavily impacted by the Stage 2 DBPR due to the high levels of TOC in their source water and the large number of ground water systems located in the State. Other areas with high levels of precursors, such as TOC or bromide, will also be adversely affected. However, those systems with high precursor and DBP levels are also the ones most likely to receive the greatest benefit from the rule.

[6] "...[T]he agency shall prepare a written statement containing. . . (3) estimates by the agency, if and to the extent that the agency determines that accurate estimates are reasonably feasible, of. . . (B) any disproportionate budgetary effects of the Federal mandate upon any particular regions of the nation or particular State, local, or Tribal government, urban or rural or other types of communities, or particular segments of the private sector..."

State, Local, or Tribal Governments

There is no expectation that there will be disproportionate budgetary effects upon State, local, or Tribal governments. Costs are expected to be proportional to the risk posed by DBPs, even if unevenly distributed among systems and perhaps types of systems. Furthermore, there are no accurate estimates to address the differing budgetary effects of the Stage 2 DBPR on State, local or Tribal governments.

There are few data available that bear on this issue. Exhibit 8.8 breaks out national-level costs for PWSs, Tribal costs, and State costs, but only allocates costs to these categories rather than revealing any disproportionate impacts on the budgets of these groups. Exhibits 8.10a and 8.10b imply that State impacts may be larger to the extent that States contain a greater proportion of small disinfecting systems (particularly Texas, Florida, and New York).

Exhibit 8.10a Number of Small Disinfecting Systems by State

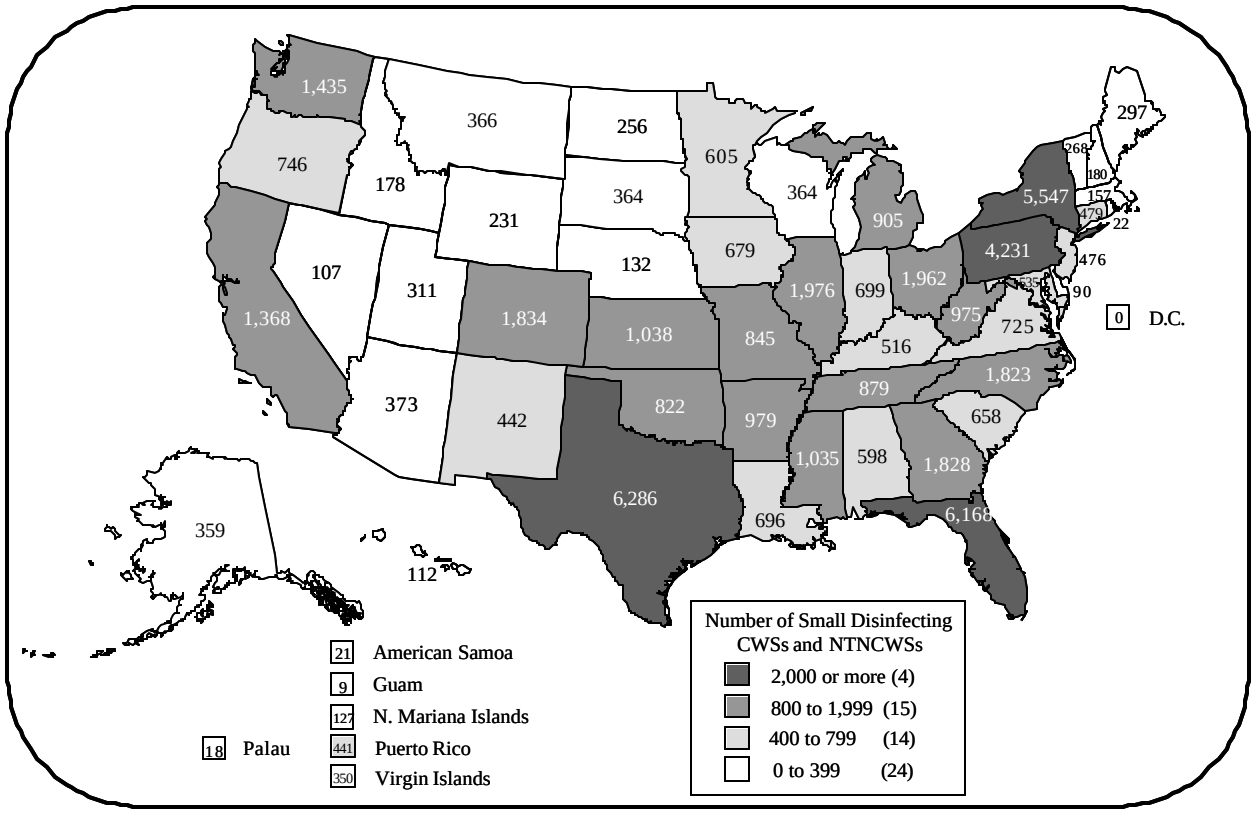
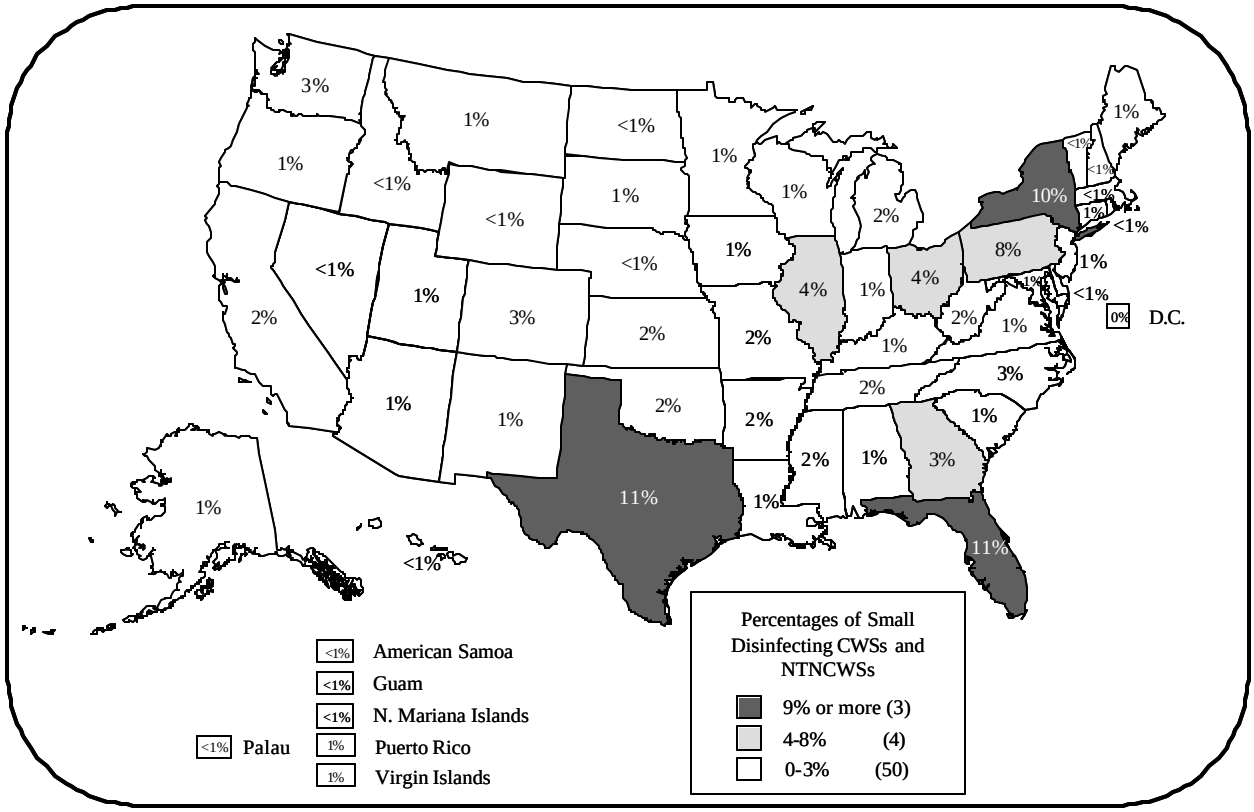


Exhibit 8.10b Percent of Small Disinfecting Systems by State



Source: Derived from SDWIS 4th Quarter Year 2003 Freeze data (USEPA 2003t). Percent of ground water systems disinfecting derived from *Ground Water Disinfection and Protective Practices in the U.S.* (USEPA 1996a).

Urban and Rural

In addition to the analyses summarized above, EPA assessed an additional area of potential disproportionate impact: the impacts on urban versus rural communities. The costs presented in Exhibit 8.11 demonstrate that there is no such disproportionate impact. For this analysis, small water systems (i.e., systems serving fewer than 10,000 people) were assumed to represent rural areas since they are generally located in more rural communities. Large water systems (i.e., systems serving at least 10,000 people) were assumed to represent urban areas since most urban areas are served by a few large systems. As seen by the figures in Exhibit 8.11a and 8.11b, the costs of the rule are similar for small and large systems. However, rural systems may lack the same economies of scale and technical, managerial, and financial capacity as urban systems, making it more challenging for them to meet rule requirements. These issues are discussed in greater detail in section 8.5.

Exhibit 8.11a Total Annualized Cost of Compliance for CWSs (3 and 7 Percent Discount Rates) ($Millions)

Source Water Category	Total Annual Cost to Systems Serving < 10,000 People ($ Millions)		Total Annual Cost to Systems Serving ≥ 10,000 People ($ Millions)	
	3 Percent	7 Percent	3 Percent	7 Percent
Surface Water Systems	$ 12.5	$ 11.8	$ 39.5	$ 40.3
Ground Water Systems	$ 15.9	$ 15.1	$ 13.4	$ 12.4
Tribal Systems	$ 0.3	$ 0.3	$ 0.0	$ 0.0
Total	$ 28.7	$ 27.2	$ 52.9	$ 52.7

Exhibit 8.11b Annualized Cost of Compliance for NTNCWSs (3 and 7 Percent Discount Rates) ($Millions)

Source Water Category	Total Annual Cost to Systems Serving < 10,000 People ($ Millions)		Total Annual Cost to Systems Serving ≥ 10,000 People ($ Millions)	
	3 Percent	7 Percent	3 Percent	7 Percent
Surface Water Systems	$ 1.0	$ 0.8	$ 0.1	$ 0.1
Ground Water Systems	$ 1.8	$ 1.6	$ 0.0	$ 0.0
Tribal Systems	$ 0.1	$ 0.0	$ -	$ -
Total	$ 2.8	$ 2.5	$ 0.1	$ 0.1

Note: Detail may not add due to independent rounding (some data are rounded to zero if less than $0.05 million).

Source: Derived from Exhibit 7.5; for this exhibit, Tribal system costs are apportioned by the percent of Tribal systems in each size category and source water type (see Exhibit 8.13).

Segments of the Private Sector

EPA performed an impact analysis for public and private systems (Exhibit 8.8 and 8.12). The percent public and private systems shown in Exhibit 8.12 indicate that publically owned CWSs are expected to incur greater costs than privately owned CWSs. However, costs to individual public and private water systems will not differ substantially.

Discount rates for capital costs of private systems, as presented in Exhibit 7.9, are approximately 1 percent higher than public systems. Based on these discount rates, a private system may owe $7,000 more than a public system for a $1 million loan. Since the water industry is regulated, rates of public and private systems are monitored and are not likely to fluctuate substantially over time. However, the rates can be adjusted to help a system qualify for a low-cost bond. Overall, the Stage 2 DBPR is not expected to have a disproportionate impact on public and private systems.

Exhibit 8.12 Percentages and Costs by Public and Private Sector (Costs Annualized at 3 and 7 Percent)

	% Public	% Private	Total Cost for Public Systems (3%)	Total Cost for Private Systems (3%)	Total Cost for Public Systems (7%)	Total Cost for Private Systems (7%)
Surface Water CWSs						
<100	45.7%	54.3%	$ 0.09	$ 0.11	$ 0.09	$ 0.10
100-499	62.6%	37.4%	$ 0.45	$ 0.27	$ 0.41	$ 0.25
500-999	77.0%	23.0%	$ 0.45	$ 0.13	$ 0.46	$ 0.14
1,000-3,299	84.7%	15.3%	$ 2.88	$ 0.52	$ 2.72	$ 0.49
3,300-9,999	90.7%	9.3%	$ 6.92	$ 0.71	$ 6.51	$ 0.67
10,000-49,999	90.1%	9.9%	$ 8.20	$ 0.90	$ 8.41	$ 0.93
50,000-99,999	85.8%	14.2%	$ 5.43	$ 0.90	$ 5.49	$ 0.91
100,000-999,999	87.1%	12.9%	$ 13.92	$ 2.06	$ 14.30	$ 2.12
> 1 Million	87.3%	12.7%	$ 7.06	$ 1.03	$ 7.10	$ 1.03
Subtotal			**$ 45.39**	**$ 6.63**	**$ 45.50**	**$ 6.64**
Surface Water NTNCWSs						
<100	45.4%	54.6%	$ 0.05	$ 0.06	$ 0.05	$ 0.06
100-499	48.5%	51.5%	$ 0.14	$ 0.15	$ 0.12	$ 0.13
500-999	45.8%	54.2%	$ 0.06	$ 0.07	$ 0.05	$ 0.06
1,000-3,299	48.4%	51.6%	$ 0.13	$ 0.14	$ 0.12	$ 0.12
3,300-9,999	58.8%	41.2%	$ 0.09	$ 0.06	$ 0.08	$ 0.06
10,000-49,999	56.2%	43.8%	$ 0.03	$ 0.02	$ 0.03	$ 0.02
50,000-99,999	0.0%	0.0%	$ -	$ -	$ -	$ -
100,000-999,999	100.0%	0.0%	$ 0.04	$ -	$ 0.04	$ -
> 1 Million	0.0%	0.0%	$ -	$ -	$ -	$ -
Subtotal			**$ 0.54**	**$ 0.51**	**$ 0.49**	**$ 0.45**
Ground Water CWSs						
<100	12.1%	87.9%	$ 0.13	$ 0.97	$ 0.13	$ 0.91
100-499	39.0%	61.0%	$ 1.49	$ 2.32	$ 1.38	$ 2.15
500-999	65.7%	34.3%	$ 1.67	$ 0.87	$ 1.55	$ 0.81
1,000-3,299	78.3%	21.7%	$ 3.20	$ 0.88	$ 3.02	$ 0.83
3,300-9,999	84.1%	15.9%	$ 3.93	$ 0.74	$ 3.88	$ 0.73
10,000-49,999	84.4%	15.6%	$ 6.72	$ 1.24	$ 6.06	$ 1.12
50,000-99,999	80.0%	20.0%	$ 1.43	$ 0.36	$ 1.35	$ 0.34
100,000-999,999	85.6%	14.4%	$ 2.77	$ 0.47	$ 2.68	$ 0.45
> 1 Million	100.0%	0.0%	$ 0.43	$ -	$ 0.41	$ -
Subtotal			**$ 21.76**	**$ 7.86**	**$ 20.45**	**$ 7.36**
Ground Water NTNCWSs						
<100	20.4%	79.6%	$ 0.10	$ 0.40	$ 0.09	$ 0.36
100-499	48.9%	51.1%	$ 0.32	$ 0.34	$ 0.30	$ 0.31
500-999	60.7%	39.3%	$ 0.25	$ 0.16	$ 0.22	$ 0.14
1,000-3,299	50.8%	49.2%	$ 0.10	$ 0.10	$ 0.09	$ 0.09
3,300-9,999	44.4%	55.6%	$ 0.02	$ 0.02	$ 0.02	$ 0.02
10,000-49,999	84.2%	15.8%	$ 0.02	$ 0.00	$ 0.01	$ 0.00
50,000-99,999	100.0%	0.0%	$ 0.00	$ -	$ 0.00	$ -
100,000-999,999	0.0%	100.0%	$ -	$ 0.00	$ -	$ 0.00
> 1 Million	0.0%	0.0%	$ -	$ -	$ -	$ -
Subtotal			**$ 0.81**	**$ 1.02**	**$ 0.73**	**$ 0.93**
Grand Total			**$ 68.50**	**$ 16.02**	**$ 67.17**	**$ 15.37**

Source: Derived from Exhibit 3.2 (public/private) and Exhibit 7.5 (costs).

8.7.4 Macroeconomic Effects

Under UMRA Section 202, EPA is required to estimate the potential macroeconomic effects of the regulation. These include effects on productivity, economic growth, full employment, and creation of Gross Domestic Product (GDP) (USEPA 2000j). Macroeconomic 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 GDP. In 2003, real GDP was $10,321 billion (U.S. Department of Commerce BEA 2004b); thus, a rule would have to cost at least $26 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 Stage 2 DBPR should not have a measurable effect on the national economy; the total annualized costs for the rule range from $86.2 million to $84.2 million using a 3 and 7 percent discount rate, respectively. Using these annualized figures as a measure, the annual cost of the Stage 2 DBPR is an insignificant fraction of a $26 billion annual cost that would be considered a measurable macroeconomic impact. Thus, annualized Stage 2 DBPR costs measured as a percentage of the national GDP will only decline over time as GDP grows.

8.7.5 Consultation with Small Governments

Before the Agency establishes any regulatory requirements that may significantly or uniquely affect small governments, including Tribal governments, it must develop, under Section 203 of the UMRA, a small government agency plan. The plan must provide notice of rule requirements to potentially affected small governments, enabling their officials to have meaningful and timely input in the development of EPA regulatory proposals with significant Federal intergovernmental mandates. The plan must also inform, educate, and advise small governments on compliance with the regulatory requirements.

EPA has determined that the Stage 2 DBPR does not contain regulatory requirements that would significantly or uniquely affect a substantial number of small governments (see section 8.2). Nevertheless, EPA consulted with small governments to address impacts of the rule that might uniquely affect them. As described in section 8.2.3, a variety of stakeholders, including small governments, had the opportunity for timely and meaningful participation in the regulatory development process through the SBREFA process, public stakeholder meetings, and Tribal meetings.

8.7.6 Consultation with State, Local, and Tribal Governments

Section 204 of the UMRA requires the Agency to develop an effective process to permit elected officers of State, local, and Tribal governments (or their designated authorized employees) to provide meaningful and timely input in the development of regulatory proposals that contain significant Federal intergovernmental mandates. Consistent with these provisions, EPA held consultations with the governmental entities affected by this rule prior to proposal, as described in sections 8.2.3 and 8.8.

Representatives from State, local, and Tribal governments were involved in the development of the Agreement in Principle, which was created early in the regulatory process. EPA provided the Association of State Drinking Water Administrators (ASDWA) with an opportunity to comment before officially proposing the Stage 2 DBPR. EPA accepted comments from ASDWA and other FACA members, such as the National League of Cities (NLC), on a draft of the Stage 2 DBPR posted on their Web site.

In addition to these efforts, EPA will educate, inform, and advise small systems, including those run by small governments, about the Stage 2 DBPR requirements. The Agency is developing plain-English guidance that will explain what actions a small entity must take to comply with the rule. Also, the Agency has developed fact sheets that concisely describe various aspects and requirements of the Stage 2 DBPR. Additional details on Tribal involvement in the rulemaking process can be found in section 8.8.

8.7.7 Regulatory Alternatives Considered

As required under Section 205 of UMRA, EPA considered several regulatory alternatives and numerous approaches to ensure safe levels of DBPs throughout a system's entire distribution system. Chapter 4 provides a detailed discussion of these alternatives. EPA chose the Preferred Regulatory Alternative because it provided substantial benefits at an acceptable level of costs. In addition, the FACA Committee recommended the Preferred Regulatory Alternative in the Stage 2 M-DBP Agreement in Principle.

8.7.8 Impacts on Small Governments

In developing this rule, EPA consulted with small governments pursuant to Section 203 of UMRA to address impacts of regulatory requirements in the rule that might significantly or uniquely affect small governments. In preparation for the Stage 2 DBPR, EPA conducted an analysis on small government impacts and included small government officials or their designated representatives in the rulemaking process. A variety of stakeholders, including small governments, had the opportunity for timely and meaningful participation in the regulatory development process through the SBREFA process, public stakeholder meetings, and Tribal meetings. Representatives of small governments took part in the SBREFA process for this rulemaking and attended public stakeholder meetings. Through participation and exchange in the SBREFA process and various meetings, EPA notified some potentially affected small governments of requirements under consideration.

As previously stated, EPA has determined that this rule does not contain regulatory requirements that would significantly or uniquely affect small governments. As described in section 8.2, EPA certified that the Stage 2 DBPR will not have significant economic impact on a substantial number of small entities. As shown in Exhibit 8.11, estimated annual expenditures per small system for the Stage 2 DBPR are $28.7 for CWSs and $2.8 for NTNCWSs (at a 3 percent discount rate).

8.8 Indian Tribal Governments

Executive Order 13175, entitled "Consultation and Coordination with Indian Tribal Governments" (65 FR 67249; November 9, 2000), requires EPA to develop "an accountable process to ensure meaningful and timely input by Tribal officials in the development of regulatory policies that have Tribal implications." The Executive Order defines "policies that have Tribal implications" to include regulations that have "substantial direct effects on one or more Indian Tribes, on the relationship between the Federal government and the Indian Tribes, or on the distribution of power and responsibilities between the Federal government and Indian Tribes."

Under Executive Order 13175, EPA may not issue a regulation that has Tribal implications, that imposes substantial direct compliance costs, and that is not required by statute, unless the Federal government provides the funds necessary to pay the direct compliance costs incurred by Tribal governments, or EPA consults with Tribal officials early in the process of developing the proposed regulation and develops a Tribal summary impact statement. EPA has concluded that the Stage 2 DBPR may have Tribal implications, because it may have substantial direct compliance costs on Tribal governments, as specified in Executive Order 13175.

Total Tribal costs are estimated to be approximately $403,113 per year (at a 3 percent discount rate), distributed across 755 water systems owned by Tribes. The costs for individual systems depend on system size and source water type. Of the 755 Tribal water systems that may be affected by the Stage 2 DBPR, 654 use ground water as a source and 101 systems use surface water or GWUDI. Since the majority of Tribal water systems are ground water systems serving fewer than 500 people, approximately 4.2 percent of all Tribal water systems will likely have to conduct an IDSE. As a result, the Stage 2 DBPR is most likely to have an impact on Tribes using surface water or GWUDI serving more than 500 people. Accordingly, EPA provides the following Tribal summary impact statement, as required by Section 5(b)of Executive Order 13175. The results of the analysis conducted for the Tribal summary impact statement are presented in Exhibit 8.13.

EPA consulted with Tribal officials early in the development of the Stage 2 DBPR to permit them to have meaningful and timely input. Tribes were able to have long-term input in the rule by participating in the Federal Advisory Committee. During the Las Vegas EPA/Inter-Tribal Council of Arizona in February 1999, a number of Tribal representatives requested that the All Indian Pueblo Council (AIPC) representative be the FACA representative for Federal Tribes, given his knowledge of drinking water systems. Approximately 20 Tribes are associated with the AIPC.

In addition to obtaining FACA Tribal input, EPA presented the Stage 2 DBPR at three conferences: the 16th Annual Consumer Conference of the National Indian Health Board, the National Tribal Environmental Council's Annual Conference in April 2000, and the EPA/Inter-Tribal Council of Arizona, Inc. Tribal consultation meeting. Over 900 attendees representing Tribes from across the country attended the National Indian Health Board's Consumer Conference, and representatives from over 100 Tribes attended the annual conference of the National Tribal Environmental Council. Finally, representatives from 15 Tribes participated at the EPA/Inter-Tribal Council of Arizona meeting. At the first two conferences, an EPA representative conducted two workshops on their drinking water program and upcoming regulations, including the Stage 2 DBPR. The presentation materials and meeting summary were sent to over 500 Tribes and Tribal organizations.

EPA distributed fact sheets describing the requirements of the Stage 2 DBPR and requested Tribal input at an annual EPA Tribal meeting in San Francisco and a Native American Water Works Association meeting in Scottsdale, Arizona. EPA also worked through its Regional Indian Coordinators and the National Tribal Operations Committee to mail fact sheets on the Stage 2 DBPR to all of the Federally recognized Tribes in November 2000.

After reviewing the fact sheets, a few Tribes requested more information and expressed concern about having to implement too many regulations. They were also concerned about infrastructure costs and the lack of funding attached to the rule. In response to a Tribal representative's comments, EPA explained the health protection benefits associated with the Stage 2 DBPR, which some members of the

Tribal Caucus also noted. EPA directed Tribes to the Agreement in Principle on the EPA Web site for more information.

On January 24, 2002, EPA held a teleconference for Tribal representatives as another step in Tribal consultation. Prior to the teleconference, EPA sent invitations to all Federally-recognized Tribes, along with fact sheets explaining the rule. Twelve Tribal representatives and four regional Tribal Program Coordinators attended the teleconference, requested further explanation of the rule, and expressed concerns about funding sources. Tribes also called EPA after the teleconference to provide additional feedback.

In the spirit of Executive Order 13175, and consistent with EPA's policy to promote communications between EPA and Tribal governments, EPA specifically solicited comment on the propose rule from Tribal officials. As required by section 7(a) of Executive Order 13175, when EPA sent the draft of the final rule to Office of Management and Budget (OMB) for review pursuant to Executive Order 12866, EPA included a certification from its tribal consultation official stating that EPA had met the Executive Order's requirements in a meaningful and timely manner.

Exhibit 8.13 Annual Cost of Compliance for Tribal Systems by System Type and Size (Annualized at 3 Percent)

System Size/Type	Number of Tribal Systems Affected by the Stage 2 DBPR	Systems Conducting Implementation Activities		Systems Conducting IDSE Monitoring		Systems Conducting Additional Routine Monitoring		Systems Conducting Significant Excursion Activities		Systems Conducting Stage 2 Monitoring Plans		Mean Annualized Cost per System	Estimated Total Tribal Costs
		Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number		
	A	B	C = B * A	D	E = D * A	F	G = F * A	H	I = H * A	J	K = J * A	L	M = A * L
Primarily Surface Water CWSs													
< 100	19	100%	19	62%	12	0%	0	0%	0	100%	19	$ 178	$ 3,388
100-499	46	100%	46	62%	29	0%	0	0%	0	100%	46	$ 326	$ 14,982
500-999	13	100%	13	94%	12	0%	0	1%	0	100%	13	$ 395	$ 5,133
1,000-3,299	14	100%	14	94%	13	0%	0	1%	0	100%	14	$ 1,313	$ 18,379
3,300-9,999	5	100%	5	92%	5	100%	5	3%		100%	5	$ 3,736	$ 18,682
10,000-49,999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
50,000-99,999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
100,000-999,999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
> 1 Million	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
National Subtotal	97		97		71		5		0		97		$ 60,565
Primarily Disinfecting Ground Water CWSs													
< 100	149	100%	149	4%	6	0%	0	0%	0	100%	149	$ 139	$ 20,778
100-499	233	100%	233	4%	10	0%	0	0%	0	100%	233	$ 388	$ 90,362
500-999	78	100%	78	18%	14	100%	78	0%	0	100%	78	$ 635	$ 49,527
1,000-3,299	71	100%	71	18%	13	100%	71	0%	0	100%	71	$ 841	$ 59,725
3,300-9,999	21	100%	21	18%	4	100%	21	0%	0	100%	21	$ 2,124	$ 44,594
10,000-49,999	4	100%	4	18%	1	100%	4	0%	0	100%	4	$ 6,518	$ 26,074
50,000-99,999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
100,000-999,999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
≥ 1 Million	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
National Subtotal	556		556		47		174		0		98		$ 291,059

Exhibit 8.13 Annual Cost of Compliance for Tribal Systems by System Type and Size (Annualized at 3 Percent) (Continued)

System Size/Type	Number of Tribal Systems Affected by the Stage 2 DBPR	Systems Conducting Implementation Activities		Systems Conducting IDSE Monitoring		Systems Conducting Additional Routine Monitoring		Systems Conducting Significant Excursion Activities		Systems Conducting Stage 2 Monitoring Plans		Mean Annualized Cost per System	Estimated Total Tribal Costs
		Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number		
	A	B	C = B * A	D	E = D * A	F	G = F * A	H	I = H * A	J	K = J * A	L	M = A * L
Primarily Surface Water NTNCWSs													
< 100	2	100%	2	0%	0	0%	0	0%	0	100%	2	$ 501	$ 1,003
100-499	1	100%	1	0%	0	0%	0	0%	0	100%	1	$ 914	$ 914
500-999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
1,000-3,299	1	100%	1	0%	0	0%	0	0%	0	100%	1	$ 2,886	$ 2,886
3,300-9,999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
10,000-49,999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
50,000-99,999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
100,000-999,999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
> 1 Million	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
National Subtotal	4		4		0		0		0		4		$ 4,802
Primarily Disinfecting Ground Water NTNCWSs													
< 100	31	100%	31	0%	0	0%	0	0%	0	100%	31	$ 199	$ 6,170
100-499	28	100%	28	0%	0	0%	0	0%	0	100%	28	$ 311	$ 8,719
500-999	13	100%	13	0%	0	100%	13	0%	0	100%	13	$ 699	$ 9,088
1,000-3,299	24	100%	24	0%	0	100%	24	0%	0	100%	24	$ 811	$ 19,458
3,300-9,999	2	100%	2	0%	0	100%	2	0%	0	100%	2	$ 1,625	$ 3,250
10,000-49,999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
50,000-99,999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
100,000-999,999	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
≥ 1 Million	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	$ -	$ -
National Subtotal	98		98		0		39		0		0		$ 46,686
TOTALS	755		755		118		218		0		199		**$ 403,113**

Sources: (A) Number of Indian Lands from SDWIS 4th Quarter FY2003 data.
(B, D, F, and H) Derived from Exhibit H.12.
(J) Mean costs are total annualized costs (at 3 percent) (Exhibits J.2ba, J.2be, J.2bi, J.2bm) divided by the number of primarily ground or primarily surface water CWSs or NTNCWSs in the size category (Exhibit 3.2).

8.9 Impacts on Sensitive Subpopulations

EPA's Office of Water has historically considered risks to sensitive subpopulations (including fetuses, infants, and children) when establishing drinking water assessments, advisories and other guidance, and standards (USEPA 1989, USEPA 1991a). The disinfection of public drinking water supplies to prevent waterborne disease is the most successful public health program in U.S. history (USEPA 1991a). However, numerous DBPs that result from chemical disinfection may have potential health risks. Thus, maximizing health protection for sensitive subpopulations requires balancing risks to achieve the recognized benefits of controlling waterborne pathogens while minimizing risk of potential DBP toxicity. Experience shows that waterborne disease from pathogens in drinking water is a major concern for children and other subgroups (e.g., the elderly, immunocompromised, and pregnant women) because of their greater vulnerabilities (Gerba et al. 1996). EPA believes that, based on animal studies, DBPs may also potentially pose risks to fetuses and pregnant women (USEPA 1998f). In addition, because the elderly population (age 65 and above) is naturally at a higher risk of developing bladder cancer, their health risks may further increase as a result of long-term DBP exposure (National Cancer Institute 2002).

In developing this rule, risks to sensitive subpopulations, including children, were taken into account in the assessments of disinfectants and DBPs (see sections 6.2.1 and 6.3). For each of the DBPs included in the Stage 2 DBPR, the MCLGs are derived using the most sensitive endpoint among all available data and an intraspecies uncertainty factor of 10, which accounts for human variability, including sensitive subpopulations like children. The Agency has evaluated alternative regulatory options and selected the one that balances cost with significant benefits, including those for sensitive subpopulations. The Stage 2 DBPR will result in a reduction in cancer risk and a potential reduction in reproductive and developmental risk to fetuses and pregnant women. It should be noted that the LT2ESWTR, which accompanies this rule, reduces pathogens in drinking water and further protects sensitive subpopulations.

SDWA identifies pregnant women as a sensitive subpopulation. Epidemiological and toxicological research suggests a potential association between exposure to DBPs and adverse reproductive and developmental health effects such as spontaneous abortion, stillbirth, neural tube defects, cardiovascular effects, and low birth weight. Stage 2 DBPR will help to protect pregnant women and their fetuses from adverse health effects that may be caused by exposure to elevated DBP levels. In this respect, any benefits derived from implementation of Stage 2 DBPR provisions should have a positive health impact on this sensitive subpopulation. Research outlining the potential health benefits of the Stage 2 DBPR to both sensitive subpopulations and the general public is discussed in greater detail in Chapter 6 of this EA.

8.9.1 Protecting Children from Environmental Health Risks and Safety Risks

Executive Order 13045 (62 FR 19885 April 23, 1997) applies to any rule initiated after April 21, 1998, that (1) is determined to be "economically significant" as defined under Executive Order 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 the Agency.

The Stage 2 DBPR is not subject to the Executive Order because it is not economically significant as defined in Executive Order 12866. EPA has consistently and explicitly considered risks to infants and children in all assessments developed for this rulemaking and presents the environmental health and safety effects of DBPs on children in sections 6.2.1 and 6.6.1. For each of the DBPs included in the Stage 2 DBPR, EPA has compiled analyses of the available data used for deriving the maximum contaminant level goal (MCLG) to determine if these values are protective for fetuses and children.

The Agency concluded that the Stage 2 DBPR will result in greater risk reduction for children than for the general population. The MCLGs of all DBPs in the rule help protect fetuses, infants, and children from potential adverse developmental/reproductive effects.

8.10 Environmental Justice

Executive Order 12898 (59 FR 7629) 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 Agency has considered environmental-justice-related issues concerning the potential impacts of this action and consulted with minority and low-income stakeholders.

Two aspects of the Stage 2 DBPR comply with the order that requires the Agency to consider environmental justice issues in the rulemaking and to consult with stakeholders representing a variety of economic and ethnic backgrounds. These include: (1) the overall nature of the rule, and (2) the convening of a stakeholder meeting specifically to address environmental justice issues.

The Agency has built on the efforts conducted during the Stage 1 DBPR development to comply with Executive Order 12898. On March 12, 1998, EPA held a stakeholder meeting to address various components of pending drinking water regulations and how they might impact sensitive subpopulations, minority populations, and low-income populations. This meeting was a continuation of stakeholder meetings that started in 1995 to obtain input on the Agency's Drinking Water Programs. Topics discussed included treatment techniques, costs and benefits, data quality, health effects, and the regulatory process. Participants were national, State, Tribal, municipal, and individual stakeholders. EPA conducted the meeting by video conference call between 11 cities. The major objectives for the March 12, 1998, meeting included the following:

- To solicit ideas from stakeholders on known issues concerning current drinking water regulatory efforts.

- To identify key areas of concern to stakeholders.

- To receive suggestions from stakeholders concerning ways to increase representation of communities in the Office of Ground Water and Drinking Water (OGWDW) regulatory efforts.

In addition, EPA developed a plain-English guide for this meeting to assist stakeholders in understanding the multiple, and sometimes complex, issues surrounding drinking water regulations.

The Stage 2 DBPR and other drinking water regulations promulgated or under development are expected to have a positive effect on human health regardless of the social or economic status of a specific population. The Stage 2 DBPR serves to provide a similar level of drinking water protection to all groups. Where water systems have high DBP levels, they must reduce levels to meet the MCLs. Further, to the extent that DBP levels in drinking water might be disproportionately high now among minority or low-income populations (which is unknown), the Stage 2 DBPR will work to remove those differences. Thus, the Stage 2 DBPR meets the intent of Federal policy requiring incorporation of environmental justice into Federal agency missions.

The Stage 2 DBPR applies uniformly to CWSs and NTNCWSs that add a disinfectant other than UV light or that deliver water that has been chemically disinfected. Consequently, the health protection from DBP exposure that this rule provides is equal across all income and minority groups served by systems regulated by this rule.

8.11 Federalism

Executive Order 13132, "Federalism" (64 FR 43255 August 10, 1999), requires EPA to develop an accountable process to ensure "meaningful and timely input by State and local officials in the development of regulatory policies that have federalism implications." "Policies that have federalism implications" are defined in the executive order to include regulations that have "substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government."

Under Section 6(b) of Executive Order 13132, EPA may not issue a regulation that has federalism implications, imposes substantial direct compliance costs, and is not required by statute, unless the Federal government provides the funds necessary to pay the direct compliance costs incurred by State and local governments, or consults with State and local officials early in the process of developing the proposed regulation.

EPA has concluded that the Stage 2 DPBR will not have federalism implications. It will not impose substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among various levels of government, as specified in Executive Order 13132. The Stage 2 DBPR has total annualized costs ranging from $86.2 million to $84.2 million using a 3 and 7 percent discount rate, respectively. Thus, the requirements of Sections 6(b) and 6(c) of the executive order do not apply to this rule.

Although Executive Order 13132 does not apply to this rule, EPA did consult with State and local officials early in the process of developing the Stage 2 DPBR to permit them to have meaningful and timely input into its development. On February 20, 2001, EPA held a dialogue on both the Stage 2 DBPR and LT2ESWTR with representatives of State and local governmental organizations including those that represent elected officials. Representatives from the following organizations attended the meeting: ASDWA, the National Governors' Association (NGA), the National Conference of State Legislatures (NCSL), the International City/County Management Association (ICMA), NLC, the County Executives of America, and health departments. Questions ranged from a basic inquiry into how *Cryptosporidium* gets into water to more detailed queries about anticipated implementation guidance, procedures, and schedules. No concerns were expressed. Some of the State and local organizations that attended this meeting were also participants in the Stage 2 M-DBP Federal Advisory Committee and signed the

Agreement in Principle. In addition, EPA consulted with a mayor in the SBREFA consultation. EPA considered all input from these consultations in the development of the Stage 2 DBPR.

In the spirit of Executive Order 13132 and consistent with EPA's policy to promote communications between EPA and State and local governments, EPA specifically solicited comment on the proposed rule from State and local officials.

8.12 Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use

Executive Order 13211, "Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use" (66 FR 28355 May 22, 2001), provides that agencies shall prepare and submit to the Administrator of the Office of Information and Regulatory Affairs, OMB, a Statement of Energy Effects for certain actions identified as "significant energy actions." Section 4(b) of Executive Order 13211 defines "significant energy actions" as "any action by an agency (normally published in the *Federal Register*) that promulgates or is expected to lead to the promulgation of a final rule or regulation, including notices of inquiry, advance notices of proposed rulemaking, and notices of proposed rulemaking: (1)(i) that is a significant regulatory action under Executive Order 12866 or any successor order, and (ii) is likely to have a significant adverse effect on the supply, distribution, or use of energy; or (2) that is designated by the Administrator of the Office of Information and Regulatory Affairs as a significant energy action."

The Stage 2 DBPR has not been designated by the Administrator of the Office of Information and Regulatory Affairs as a significant energy action because it is not likely to have a significant adverse effect on the supply, distribution, or use of energy. This determination represents the analysis presented below.

Energy Supply

The first consideration is whether the Stage 2 DBPR would adversely affect the supply of energy. The Stage 2 DBPR does not regulate power generation, either directly or indirectly and the public and private utilities that the Stage 2 DBPR regulates do not, as a rule, generate power. Further, the cost increases borne by customers of water utilities as a result of the Stage 2 DBPR are a small percentage of the total cost of water, except for a few small systems that will need to spread the cost of installing advanced treatment technologies over a narrow customer base. Therefore, those customers that are power generation utilities are unlikely to face any significant effects as a result of the Stage 2 DBPR. In summary, the Stage 2 DBPR does not regulate the supply of energy, does not generally regulate the utilities that supply energy, and is unlikely to significantly affect the customer base of energy suppliers. Thus, the Stage 2 DBPR would not adversely affect the supply of energy.

In response to the Stage 2 DBPR, some water utilities are expected to increase their energy use, and those impacts are discussed later in this section.

Energy Distribution

The second consideration is whether the Stage 2 DBPR would adversely affect the distribution of energy. The Stage 2 DBPR does not regulate any aspect of energy distribution. PWSs that are regulated

by the Stage 2 DBPR already have electrical service. As derived later in this section, the Stage 2 DBPR is projected to increase peak electricity demand at water utilities by only 0.009 percent. Therefore, EPA estimates that the existing connections are adequate and that the Stage 2 DBPR has no discernable adverse effect on energy distribution.

Energy Use

The third consideration is whether the Stage 2 DBPR would adversely affect the use of energy. Because some PWSs are expected to add treatment technologies that use electrical power, this potential impact of the Stage 2 DBPR on the use of energy requires further evaluation. The analyses that underlay the estimation of costs in Chapter 7 for the Stage 2 DBPR are national in scope and do not identify specific plants or utilities that may install treatment in response to the rule. As a result, no analysis of the effect on specific energy suppliers is possible with the available data. The approach used to estimate the impact of energy use, therefore, focuses on national-level impacts. The analysis estimates the additional energy use due to the Stage 2 DBPR, and compares that to the national levels of power generation in terms of average and peak loads.

The first step in the analysis is to estimate the energy used by the treatment technologies expected to be installed as a result of the Stage 2 DBPR. Energy use is not directly stated in *Technologies and Costs for Control of Microbial Contaminants and Disinfection By-Products* (USEPA 2003o), but the annual cost of energy for each treatment technology addition or upgrade necessitated by the Stage 2 DBPR is provided. An estimate of plant-level energy use is derived by dividing the total energy cost per plant for a range of flows by an average national cost of electricity of $0.076 per kilowatt hour per year (kWh/y) (U.S. DOE EIA 2004a). The energy use per plant for each flow range and treatment technology is then multiplied by the number of plants predicted to install each treatment technology in a given flow range (treatment technology selection forecasts are presented in Chapter 7). The energy requirements for each flow range are then added to produce a national total. No electricity use is subtracted to account for the treatment technologies that may be replaced by new treatment technologies, resulting in a conservative estimate of the increase in energy use. Exhibit 8.14 shows the estimated energy use for each Stage 2 DBPR compliance treatment technology in kWh/y. The incremental national annual energy usage is approximately 0.12 million megawatt-hours (MWh). Although the energy usage after implementing the Stage 2 DBPR is expected to be greater than before implementation (advanced treatment technologies typically require more energy than conventional treatment technologies), the net increase in energy usage is not expected to be significant.

Exhibit 8.15 provides a sample calculation for chloramines showing the increase in energy usage as a result of the Stage 2 DBPR.

To determine if the additional energy required for systems to comply with the rule would have a significant adverse effect on the use of energy, EPA compared the numbers in Exhibit 8.14 to the national production figures for electricity. According to the U.S. Department of Energy's Energy Information Administration, electricity producers generated 3,848 million MWh of electricity in 2003 (USDOE EIA 2004b). Therefore, even using the highest assumed energy use for the Stage 2 DBPR (i.e., 122,990,937 kWh/y, or 122,991 MWh/y), the rule when fully implemented would result in only a 0.003 percent increase in annual average energy use. This calculation is shown below:

122,991 MWh/y ÷ 3,848,000,000 MWh/y * 100 = 0.003%

Exhibit 8.14 Increase in Energy Usage as a Result of the Stage 2 DBPR

Technology	Number of Plants Selecting the Technology (a)	Average Energy Usage per Plant per Year for all Plants Selecting the Technology (kWh/plant/yr)	Total Increase in Energy Usage as a Result of the Stage 2 DBPR (kWh/yr) (b)
Chloramines (with and without advanced tech.)	2,028	1,798	3,645,659
Chlorine Dioxide	48	3,578	170,071
UV	936	35,075	32,834,769
Ozone (0.5 log)	19	98,182	1,890,156
GAC10 + Adv. Disinfectants	46	835,330	38,725,093
GAC20	101	169,458	17,113,537
GAC20 + Adv. Disinfectants	67	132,168	8,789,393
Membranes	18	1,107,461	19,822,259
TOTAL	**3,263**	**37,697**	**122,990,937**

Notes: Detail may not add due to independent rounding.

Sources: (a) Number of plants selecting each treatment technology is derived from Exhibits 5.11b, 5.11d, 5.14b, 5.14d. Note that the number of plants selecting chloramines is the number of plants selecting chloramines only PLUS the number selecting chloramines with advanced treatment technology (making the total in this exhibit higher than the total number of plants making treatment technology changes in Exhibit 7.3).
(b) Energy costs derived from the Technologies and Costs Document (USEPA 2003o) for the treatment plant design conditions listed in Exhibit 7.8. Energy costs were converted to energy usage by dividing the costs by the unit costs for energy listed in Table 4-3 of the Technologies and Costs Document. Energy usage is different for different size categories; the average per plant is the weighted average for all plants selecting the treatment technology.

Exhibit 8.15 Sample Calculation for Determining Increase in Energy Usage: Chloramines

System Size (Population Served)	Average Daily Flow per Plant (mgd)	Total No. of Plants	Chloramines (Ground Water, Ammonia Dose = 0.15 mg/l; Surface Water, Ammonia Dose = 0.55 mg/l)			
			Number of Plants Selecting Chloramines	Annual Energy Cost per Plant ($/plant/yr)	Annual Energy Requirement (kWhr/plant/yr)	Total Energy Usage for Plants Selecting Chloramines (kWhr/year)
	A	B	C	D	E = D/$0.076 per kWhr	F = C*E
Primarily Surface Water CWSs						
<100	0.01	359	21	67	876	18,674
100-499	0.03	767	55	67	876	47,831
500-999	0.08	483	34	115	1,518	52,222
1,000-3,299	0.22	1,129	89	124	1,633	145,936
3,300-9,999	0.59	1,258	100	200	2,632	262,049
10,000-49,999	2.34	1,292	146	200	2,632	384,402
50,000-99,999	3.80	579	66	200	2,632	172,427
100,000-999,999	14.61	610	69	300	3,947	272,494
≥ 1 Million	107.80	74	8	4,550	59,875	498,350
Primarily Ground Water CWSs						
<100	0.01	6,423	132	67	876	115,250
100-499	0.02	15,242	456	67	876	399,211
500-999	0.05	6,093	182	67	876	159,608
1,000-3,299	0.13	7,587	204	124	1,633	332,581
3,300-9,999	0.34	5,030	135	124	1,633	220,506
10,000-49,999	0.72	5,382	107	200	2,632	280,841
50,000-99,999	2.01	716	14	200	2,632	37,431
100,000-999,999	4.26	918	17	200	2,632	45,753
≥ 1 Million	27.22	27	1	200	2,632	1,438
Primarily Surface Water NTNCWSs						
<100	0.01	226	13	67	876	11,750
100-499	0.03	312	22	67	876	19,465
500-999	0.08	106	8	124	1,633	12,328
1,000-3,299	0.21	91	7	124	1,633	11,889
3,300-9,999	0.63	25	2	200	2,632	5,206
10,000-49,999	3.33	5	1	200	2,632	1,488
50,000-99,999	-	0	0	0	0	0
100,000-999,999	22.94	1	0	300	3,947	446
≥ 1 Million	-	0	0	-	-	-
Primarily Ground Water NTNCWSs						
<100	0.00	2,493	51	67	876	44,720
100-499	0.02	2,129	64	67	876	55,754
500-999	0.07	589	18	100	1,309	23,067
1,000-3,299	0.18	247	7	124	1,633	10,829
3,300-9,999	0.64	21	1	200	2,632	1,516
10,000-49,999	2.86	3	0	200	2,632	166
50,000-99,999	9.92	0	0	200	2,632	15
100,000-999,999	17.19	0	0	200	2,632	14
≥ 1 Million	-	0	0	-	-	-
TOTALS		**60,220**	**2,028**			**3,645,659**

Notes: Detail may not add due to independent rounding.

Sources: (A) The flows are taken from Exhibit 3.4.
(B) The baseline numbers of plants are taken from Exhibit 3.2.
(C) Numbers of plants selecting chloramines are taken from Exhibits 5.11b, 5.11d, 5.14b, 5.14d.
(D) The electricity cost per plant is taken from the Technologies and Costs Document (USEPA 2003o).
(E) Electricity cost is $0.076/kWh, as presented in the Technologies and Costs Document (USEPA 2003o).

In addition to average energy use, the impact at times of peak power demand is important. To examine whether increased energy usage might significantly affect the capacity margins of energy suppliers, their peak-season generating capacity reserve was compared to an estimate of peak incremental power demand by water utilities. Both energy use and water use peak in the summer months, so the most significant effects on supply would be seen then. In the summer of 2003, U.S. generation capacity exceeded consumption by 15 percent, or approximately 160,000 megawatts (MW) (USDOE EIA 2004b). Assuming around-the-clock operation of water treatment plants, the total energy requirement for the Stage 2 DBPR (Exhibit 8.14) can be divided by 8,760 hours per year to obtain an average power demand of 14.04 MW. This is only 0.009 percent of the capacity margin available at peak use. This calculation is presented below:

1. 122,990,937 kWh/y * (y/8,760 hr) * (MW/1,000 kW) = 14.04 MW

2. 14.04 MW ÷ 160,000 MW * 100 = 0.009%

Assuming that power demand is proportional to water flow through the plant and that peak flow can be as high as twice the average daily flow during the summer months, about 28.08 MW (14.04 MW x 2) could be needed to operate the treatment technologies installed to comply with the Stage 2 DBPR. This is still only a very small fraction (0.018 percent) of the U.S. capacity margin available at peak use (160,000 MW).

Although EPA recognizes that not all regions have a 15 percent capacity margin and that this margin varies across regions and over time, this analysis represents the effect of the rule on national energy supply, distribution, and use. While certain areas have experienced shortfalls in generating capacity in the recent past, a peak incremental power requirement of 28.08 MW nationwide is not likely to significantly change the energy supply, distribution, or use in any given area.

Conclusion

The Stage 2 DBPR is not a "significant energy action" as defined in Executive Order 13211, "Actions Concerning Regulations That Significantly Affect Energy Supply, Distribution, or Use" (66 FR 28355 May 22, 2001) because it is not likely to have a significant adverse effect on the supply, distribution, or use of energy (as a function of annual average use and conditions of peak power demand).

The total increase in energy usage by water systems as a result of the Stage 2 DBPR is predicted to approximately 123 million kWh/y, which is less than three one-thousandths of 1 percent of the total energy produced in 2003. While the rule may have some adverse energy effects, EPA does not believe that this constitutes a significant adverse effect on the energy supply.

9. Comparison of Benefits and Costs of the Stage 2 DBPR

9.1 Introduction

This chapter presents a summary and comparison of the benefits and costs of the Stage 2 Disinfectants and Disinfection Byproducts Rule (DBPR). Evaluation on a national level shows that the benefits derived from the Stage 2 DBPR are likely to exceed the costs. The following sections present summary results from the body of the economic analysis (EA), followed by a discussion of the results. The first sections focus on analysis of the Stage 2 DBPR Preferred Regulatory Alternative, followed by a comparison of this alternative to the other alternatives considered.

For comparison purposes, this chapter sometimes presents only mean estimates of benefits and costs. These estimates are discussed in Chapters 6 and 7, respectively. To avoid repetition, the following discussion assumes the reader is familiar with those chapters. The remaining sections of this chapter are organized as follows:

As described in Chapter 6 and Appendix E, benefits for the Stage 2 DBPR are estimated using three different cessation lag models, and either TTHMs or HAA5s as a chlorination DBP indicator. Note, because the maximum rate of risk reduction derived from the Smoking/Lung Cancer cessation model falls in between the maximum rate of risk reduction derived from the Smoking/Bladder Cancer and Arsenic/Bladder Cancer cessation lag models, only benefits derived from the Smoking/Lung Cancer cessation lag model are presented as a representative comparison to costs. TTHM is used as a chlorination DBP indicator unless otherwise noted.

9.2 Summary of National Benefits, Costs, and Net Benefits of the Stage 2 Preferred Regulatory Alternative

This section summarizes national benefits, costs, and net benefits of the Stage 2 DBPR Preferred Regulatory Alternative.

The rule will be implemented over time, not instantaneously, and therefore, the treatment costs incurred and benefits realized by the affected systems and population they serve will vary by year.

Exhibits 9.1a and 9.1b summarize the undiscounted benefit and cost estimates incurred by systems, according to the implementation schedule (see Appendix D), over the 25 year period analyzed in this EA. Exhibit 9.1a shows benefits calculated using a willingness to pay (WTP) surrogate for bladder cancer of lymphoma and 9.1b presents estimates using bronchitis. WTP surrogates are explained fully in Chapter 6 of this EA.

Exhibit 9.1a Summary of Benefit and Cost Estimates by Year for the Stage 2 Preferred Regulatory Alternative, Villanueva et al. (2003) for Baseline Risk, TTHMs as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model, Lymphoma WTP ($Million, 2003$)

Year	Systems <10,000		Systems ≥ 10,000		State Costs	All Systems & State	
	Benefits	Systems Cost	Benefits	Systems Cost		Benefits	Total Cost
	A	B	C	D	E	F=A+C	G=B+D+E
2005	$ -	$ 0.3	$ -	$ 0.5	$ 3.9	$ -	$ 4.6
2006	$ -	$ 6.1	$ -	$ 7.9	$ 3.9	$ -	$ 17.9
2007	$ -	$ 4.3	$ -	$ 19.5	$ 0.1	$ -	$ 24.0
2008	$ -	$ 19.0	$ -	$ 82.6	$ 2.1	$ -	$ 103.7
2009	$ -	$ 35.0	$ -	$ 106.9	$ 0.9	$ -	$ 142.8
2010	$ 5.2	$ 63.0	$ 128.2	$ 130.6	$ -	$ 133.4	$ 193.6
2011	$ 13.6	$ 65.7	$ 331.7	$ 137.6	$ 1.7	$ 345.3	$ 205.0
2012	$ 24.6	$ 71.9	$ 600.1	$ 145.4	$ 1.7	$ 624.7	$ 219.0
2013	$ 38.1	$ 78.1	$ 929.7	$ 78.1	$ 1.7	$ 967.8	$ 157.9
2014	$ 54.0	$ 54.1	$ 1,210.3	$ 53.7	$ 1.7	$ 1,264.2	$ 109.5
2015	$ 72.2	$ 27.6	$ 1,470.8	$ 36.5	$ 1.7	$ 1,543.0	$ 65.7
2016	$ 89.6	$ 27.6	$ 1,708.2	$ 36.5	$ 1.7	$ 1,797.8	$ 65.7
2017	$ 104.3	$ 27.6	$ 1,923.6	$ 36.5	$ 1.7	$ 2,027.9	$ 65.7
2018	$ 117.3	$ 27.6	$ 2,112.8	$ 36.5	$ 1.7	$ 2,230.2	$ 65.7
2019	$ 129.1	$ 27.6	$ 2,274.4	$ 36.5	$ 1.7	$ 2,403.5	$ 65.7
2020	$ 139.5	$ 27.6	$ 2,414.7	$ 36.5	$ 1.7	$ 2,554.2	$ 65.7
2021	$ 148.6	$ 27.6	$ 2,538.4	$ 36.5	$ 1.7	$ 2,687.0	$ 65.7
2022	$ 156.6	$ 27.6	$ 2,649.1	$ 36.5	$ 1.7	$ 2,805.7	$ 65.7
2023	$ 163.8	$ 27.6	$ 2,749.3	$ 36.5	$ 1.7	$ 2,913.1	$ 65.7
2024	$ 170.2	$ 27.6	$ 2,841.1	$ 36.5	$ 1.7	$ 3,011.3	$ 65.7
2025	$ 176.1	$ 27.6	$ 2,925.9	$ 36.5	$ 1.7	$ 3,102.0	$ 65.7
2026	$ 181.6	$ 27.6	$ 3,004.9	$ 36.5	$ 1.7	$ 3,186.5	$ 65.7
2027	$ 186.6	$ 27.6	$ 3,079.1	$ 36.5	$ 1.7	$ 3,265.8	$ 65.7
2028	$ 188.9	$ 27.6	$ 3,108.5	$ 36.5	$ 1.7	$ 3,297.4	$ 65.7
2029	$ 192.9	$ 27.6	$ 3,166.8	$ 36.5	$ 1.7	$ 3,359.7	$ 65.7

Notes: Stage 2 DBPR costs do not vary by choice of willingness-to-pay proxy (lymphoma or bronchitis as a surrogate for bladder cancer).

Sources: Benefits: Appendix F.2a - F.2i, F.2k - F2.s

Costs: Appendix J.2a - J.2i, J.2k - J.2s, J.2v - J.2ad, J.2af - J.2an, J.2ar

Exhibit 9.1b Summary of Benefit and Cost Estimates by Year for the Stage 2 Preferred Regulatory Alternative, Villanueva et al. (2003) for Baseline Risk, TTHMs as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model, Bronchitis WTP ($Million, 2003$)

	Systems <10,000		Systems > 10,000			All systems	
	Benefits	Cost	Benefits	Cost	State Costs	Benefits	Cost
Year	A	B	C	D	E	F=A+C	G=B+D+E
2005	$ -	$ 0.3	$ -	$ 0.5	$ 3.9	$ -	$ 4.6
2006	$ -	$ 6.1	$ -	$ 7.9	$ 3.9	$ -	$ 17.9
2007	$ -	$ 4.3	$ -	$ 19.5	$ 0.1	$ -	$ 24.0
2008	$ -	$ 19.0	$ -	$ 82.6	$ 2.1	$ -	$ 103.7
2009	$ -	$ 35.0	$ -	$ 106.9	$ 0.9	$ -	$ 142.8
2010	$ 2.6	$ 63.0	$ 63.3	$ 130.6	$ -	$ 65.9	$ 193.6
2011	$ 6.7	$ 65.7	$ 164.0	$ 137.6	$ 1.7	$ 170.7	$ 205.0
2012	$ 12.2	$ 71.9	$ 296.9	$ 145.4	$ 1.7	$ 309.0	$ 219.0
2013	$ 18.9	$ 78.1	$ 460.2	$ 78.1	$ 1.7	$ 479.1	$ 157.9
2014	$ 26.7	$ 54.1	$ 599.6	$ 53.7	$ 1.7	$ 626.3	$ 109.5
2015	$ 35.8	$ 27.6	$ 729.2	$ 36.5	$ 1.7	$ 765.0	$ 65.7
2016	$ 44.5	$ 27.6	$ 847.5	$ 36.5	$ 1.7	$ 892.0	$ 65.7
2017	$ 51.8	$ 27.6	$ 955.2	$ 36.5	$ 1.7	$ 1,006.9	$ 65.7
2018	$ 58.3	$ 27.6	$ 1,049.9	$ 36.5	$ 1.7	$ 1,108.2	$ 65.7
2019	$ 64.2	$ 27.6	$ 1,131.1	$ 36.5	$ 1.7	$ 1,195.3	$ 65.7
2020	$ 69.4	$ 27.6	$ 1,201.8	$ 36.5	$ 1.7	$ 1,271.3	$ 65.7
2021	$ 74.0	$ 27.6	$ 1,264.4	$ 36.5	$ 1.7	$ 1,338.5	$ 65.7
2022	$ 78.1	$ 27.6	$ 1,320.7	$ 36.5	$ 1.7	$ 1,398.8	$ 65.7
2023	$ 81.7	$ 27.6	$ 1,371.8	$ 36.5	$ 1.7	$ 1,453.5	$ 65.7
2024	$ 85.0	$ 27.6	$ 1,418.8	$ 36.5	$ 1.7	$ 1,503.8	$ 65.7
2025	$ 88.0	$ 27.6	$ 1,462.4	$ 36.5	$ 1.7	$ 1,550.4	$ 65.7
2026	$ 90.8	$ 27.6	$ 1,503.2	$ 36.5	$ 1.7	$ 1,594.0	$ 65.7
2027	$ 93.4	$ 27.6	$ 1,541.7	$ 36.5	$ 1.7	$ 1,635.1	$ 65.7
2028	$ 94.6	$ 27.6	$ 1,555.9	$ 36.5	$ 1.7	$ 1,650.5	$ 65.7
2029	$ 96.6	$ 27.6	$ 1,586.1	$ 36.5	$ 1.7	$ 1,682.7	$ 65.7

Note: Stage 2 DBPR costs do not vary by choice of willingness-to-pay proxy (lymphoma or bronchitis as a surrogate for bladder cancer).

Sources: Benefits: Appendix F.2a - F.2i, F.2k - F2.s
Costs: Appendix J.2a - J.2i, J.2k - J.2s, J.2v - J.2ad, J.2af - J.2an, J.2ar

The analyses in this EA assume that implementation of this rule will begin in 2005. If implementation of the rule began a year or two later, the fundamental conclusions of the analysis would not be significantly changed. In the first few years, before systems have installed treatment, no benefits are realized, although some costs are incurred for rule implementation and the Initial Distribution System Evaluation (IDSE). Some bladder cancer cases are projected to be avoided in the year following installation of treatment and each year thereafter, adjusted to account for the cessation lag (see Section 6.4.2 for a description of adjustments made to projected cancer cases avoided to account for cessation lag). By 2015, all treatment is projected to be installed, and yearly system costs thereafter are constant, representing only operations and maintenance (O&M), monitoring, and yearly operational evaluation costs. Using the rule implementation schedule presented in Appendix D of this EA, approximately 61% of the cases ultimately avoidable will be avoided by 25 years after promulgation, and 100% of the cases will be avoided by 100 years after promulgation.

9.2.1 National Benefits Summary

The Environmental Protection Agency (EPA) has determined from its analysis of the available animal toxicological studies and human epidemiological studies that the Stage 2 DBPR could provide benefits resulting from reduced incidence of cancer, particularly bladder cancer, and reduced incidence of adverse reproductive and developmental effects.

Because of limitations in the available data, it is not possible to quantify all of the health benefits of the Stage 2 DBPR. In particular, the science is not strong enough to quantify the risk of reproductive and developmental health effects resulting from DBP exposure. Nevertheless, although the results from different studies are mixed, a weight of evidence evaluation of the health effects data suggests a potential association between DBP exposure and various adverse reproductive and developmental outcomes. To help inform the assessment of the Stage 2 DBPR benefits, EPA has prepared an illustrative calculation for one specific reproductive effects end-point (fetal loss). Results from this analysis show that 250 to 4,100 fetal losses could potentially be avoided annually as a result of the Stage 2 DBPR. More detail on this analysis can be found in Appendix G. Additionally, EPA reviewed the literature on colon and rectal cancers, which combined are the third most common site (excluding skin) of new cases and deaths in both men and women in the U.S. Human epidemiology studies on chlorinated surface water have reported associations with colon and rectal cancers, although there still remains some conflicting evidence. Since Stage 1, new studies have become available that provide for an estimation of population attributable risk (PAR), explained further in Chapter 6 of this EA. Hence, EPA chose to perform a sensitivity analysis on benefits from avoiding colon and rectal cancers, the results of which are shown in Exhibit 6.31 and detailed in Appendix F.

Other nonquantified health and non-health benefits derived from rule implementation also could contribute to the overall value of benefits. Nonquantified benefits are discussed in detail in Chapter 6 and are summarized below in Exhibit 9.2.

Exhibit 9.2 Summary of Nonquantified National Benefits of the Stage 2 DBPR

Nonquantified Benefit	Group(s) Affected	Type of Cost Avoided			
		Medical Care	Pain & Suffering	Lifetime Care	Other[1]
Adverse Reproductive Health Effects Avoided	Women (and men) of reproductive age	✓	✓		✓
	Pregnant women	✓	✓		✓
Developmental Health Effects Avoided (e.g., congenital anomalies)	Fetuses	✓	✓		
	Children/adults with birth defects	✓	✓	✓	
Other Adverse Health Effects Avoided (Reduction in other cancers, including colon and rectal cancers, and benefits from reduction of other DBPs, co-occurring contaminants, or emerging contaminants)	All individuals exposed to elevated levels of DBPs in drinking water	✓	✓	✓	✓
Adverse Non-Health Effects Avoided (Perceptions of drinking water quality, ecological, and other unknown effects)	All individuals				✓

Note: Discussions of these health effects are presented in Chapter 6.
Footnote 1: Includes costs such as potential changes to life plans due to fetal loss and lost opportunities for family life. For patients of cancer or other diseases potentially induced by DBP exposure this includes opportunity costs in reduced work opportunities and reduced participation in social and family life. Adverse non-health effect costs potentially include reduced enjoyment of drinking water through perception of water as undesirable in taste or odor, and costs for bottled water or home filters.

EPA has quantified the expected range of avoided new cases of bladder cancer each year, including both fatal and non-fatal cases. [1] In addition, EPA has estimated the monetized value of avoiding these cases using estimates of willingness to pay (WTP) for non-fatal cancer[2] and the value of a statistical life (VSL) for fatal cancer cases. Exhibits 9.3 and 9.4 summarize, respectively, these quantified and monetized benefits estimates based on total trihalomethane (TTHM) and haloacetic acid

[1]Causality has not been clearly established in the association between consumption of DBPs in drinking water and bladder cancer.

[2]Because specific estimates of WTP for avoiding non-fatal bladder cancer are not available, EPA estimated the WTP from two other non-fatal illnesses: chronic bronchitis and curable lymphoma.

(HAA5) reduction as an indicator[3] for reduced levels of all chlorination DBPs. Data are generally summarized using an estimate of the mean and 90 percent confidence intervals, which account for some elements of uncertainty and variability, such as the distribution of bladder cancer cases obtained from a Monte Carlo simulation.

Exhibit 9.3 Summary of Annual Bladder Cancer Cases Ultimately Avoidable for the Stage 2 Preferred Regulatory Alternative, Villanueva et al. (2003) for Baseline Risk, TTHMs as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model

DBP Indicator	Bladder Cancer Cases		
	Mean	5th	95th
Annual Average Ultimately Avoidable[1]			
TTHM	577	229	1,079
HAA5	667	252	1,271
Annual Average Avoidable Over 25 Years[2]			
	Mean	5th	95th
TTHM	277	101	540
HAA5	321	112	636

Notes:
1) Benefits (avoided cases) are estimated using Villanueva et al. (2003) for baseline risk. Ultimately avoidable annual cases represents the number of cases to be avoided annually following the cessation lag, and its presentation is consistent with OMB recommendations to extend the horizon of analysis to include significant benefits. The ultimately avoidable number is reached approximately 100 years from the start of implementation of the Stage 2 regulation, although about 61% of the ultimate number of case avoided occurs by year 25.

2) Average annual avoided cases is based upon the 25-year period of analysis and so is much lower than the ultimate number of cases to be avoided following the cessation lag period. The cessation lag is explained in detail in Appendix E of the Stage 2 EA.

Source: Appendix E, Exhibits E.12, E.38d, E.39d

[3] The number of cases avoided and the resulting benefits were calculated using both TTHM and HAA5 as indicators of exposure to all chlorination DBPs. However, because results for both indicators were similar, only the results of calculations using TTHM as an indicator are presented, to simplify presentation. Detailed results for all analyses using both TTHM and HAA5 as indicators are presented in Appendix F.

Exhibit 9.3 shows two kinds of estimates. One is the annual average of bladder cancer cases that will be avoided following full installation of any treatment technology changes and completion of the cessation lag period; this is the maximum, or steady state number of cases that will be avoided. The second set of numbers is lower because it is the average number of cases avoided annually over the 25 year period of analysis, incorporating the years prior to full installation of treatment technology changes resulting from the Stage 2 DBPR and prior to completion of the cessation lag period. The cessation lag is explained more fully in Appendix E and Chapter 6 of this EA.

Exhibit 9.4 (below) monetizes the estimates of avoided non-fatal cases of bladder cancer using lymphoma and bronchitis WTP estimates as surrogates for bladder cancer costs of illness. The VSL is applied to estimates of fatal cases avoided, and includes factors for income growth and income elasticity that vary by year[4]. For fatal and non-fatal cases, the data in Exhibit 9.4 represent the monetized values from each year, discounted to the year 2003 (to obtain present values) and annualized over the 25 year period. These figures represent the annualized value of the estimated annual number of illnesses and deaths avoided according to the rule schedule; they are also the annualized values of the undiscounted benefit data presented in Exhibit 9.1.

Exhibit 9.4 Estimated Annualized National Benefits for the Stage 2 Preferred Regulatory Alternative, Villanueva et al. (2003) for Baseline Risk, TTHMs as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model ($Millions, 2003$)

WTP for Non-Fatal Bladder Cancer Cases, Lymphoma as Surrogate			WTP for Non-Fatal Bladder Cancer Cases, Bronchitis as Surrogate		
	90% Confidence Bound			90% Confidence Bound	
Mean	Lower (5th %ile)	Upper (95th %ile)	Mean	Lower (5th %ile)	Upper (95th %ile)
3% Discount Rate					
$ 1,523	$ 232	$ 3,518	$ 759	$ 164	$ 1,684
7% Discount Rate					
$ 1,240	$ 189	$ 2,862	$ 617	$ 134	$ 1,368

Note: Benefits (avoided cases) are estimated using Villanueva et al. (2003) for baseline risk.
Sources: Appendix F.2v, 2w, 3v, 3w
Appendix J.2as and J.2aw

[4]In the Stage 2 benefits analysis the income-adjusted VSL estimates are applied to the year in which cases have been avoided. An alternative approach supported by some economists, and used in other EPA analyses, is for the income adjustments to be applied only up to the time that exposures are reduced rather than over the cessation lag. Because of the shorter time period over which income growth would be calculated the alternative would result in smaller income adjustment. To use the alternative EPA would need to link the year cancers are avoided to a specific year of exposure reduction. This cannot be done with the risk assessment and cessation lag application in the Stage 2 analysis, where estimated cases avoided are based on a transition from one steady state to another. The VSL income adjustment approach used in this EA will tend to overstate benefits somewhat relative to the alternative described above. EPA recognizes this potential bias, but notes that is small in comparison to other uncertainties in valuation, as well as uncertainties in the risk assessment and estimates of cases avoided.

9.2.2 National Cost Summary

The national annual costs of the Stage 2 DBPR result from activities associated with rule implementation, IDSEs, monitoring plans, additional routine monitoring, operational evaluations, and changes in treatment technologies by some water systems. These costs, shown in detail in Chapter 7 of this EA, are summarized below in Exhibits 9.5a and 9.5b.

As with the benefits, these estimates of cost are best characterized by distributions. Uncertainty in the predictions of plants making treatment technology changes, together with uncertainty in the estimates of capital and O&M unit costs, contribute to the uncertainty in estimates of national costs. See Section 7.8 for further explanation of the distribution of cost estimates.

Exhibits 9.5a and 9.5b summarize the cost information by its two main components: capital and one-time costs, and O&M. Both cost components occur over time, hence, the present value is calculated at 3 and 7 percent discount rates and those amounts are annualized over the 25 year period of analysis. The estimated mean annualized cost of the Stage 2 DBPR Preferred Regulatory Alternative is $86.2 million at a 3 percent discount rate and $84.2 million at a 7 percent discount rate.

Exhibit 9.5a Annualized Costs for Stage 2 DBPR Preferred Regulatory Alternative Rule Activities ($Millions/Year, 3% Discount Rate)

System Size (Population Served)	System Costs: Capital Costs Mean Value	Capital Costs 90 Percent Confidence Bound Lower (5th %tile)	Capital Costs 90 Percent Confidence Bound Upper (95th %tile)	O&M Costs Mean Value	O&M Costs 90 Percent Confidence Bound Lower (5th %tile)	O&M Costs 90 Percent Confidence Bound Upper (95th %tile)	Non-Treatment Costs (Point Estimate) Implement-ation	IDSE	Monitoring Plans	Moni-toring	Significant Excursion	Total System Costs Mean Value	Total System Costs 90 Percent Confidence Bound Lower (5th %tile)	Total System Costs 90 Percent Confidence Bound Upper (95th %tile)	State Costs	Total Costs of the Rule Mean Value	Total Costs of the Rule 90 Percent Confidence Bound Lower (5th %tile)	Total Costs of the Rule 90 Percent Confidence Bound Upper (95th %tile)
Surface Water CWSs																		
< 10,000	$4.66	$2.38	$7.08	$6.83	$3.53	$10.16	$0.12	$0.92	$0.05	-$0.07	$0.02	$12.52	$6.95	$18.28				
≥ 10,000	$22.79	$11.66	$33.14	$16.03	$9.33	$24.79	$0.09	$1.59	$0.03	-$1.14	$0.11	$39.50	$21.67	$58.60				
Surface Water NTNCWSs																		
< 10,000	$0.30	$0.15	$0.45	$0.63	$0.33	$0.95	$0.01	$0.00	$0.00	$0.02	$0.00	$0.96	$0.50	$1.43				
≥ 10,000	$0.05	$0.02	$0.07	$0.03	$0.02	$0.05	$0.00	$0.00	$0.00	$0.00	$0.00	$0.09	$0.05	$0.12				
Ground Water CWSs																		
< 10,000	$7.47	$6.18	$8.78	$6.96	$6.39	$7.52	$0.30	$0.29	$0.12	$1.07	$0.00	$16.21	$14.35	$18.08				
≥ 10,000	$4.88	$4.38	$5.38	$6.05	$5.68	$6.41	$0.05	$0.10	$0.02	$2.33	$0.00	$13.42	$12.55	$14.29				
Ground Water NTNCWSs																		
< 10,000	$0.57	$0.48	$0.66	$0.73	$0.67	$0.79	$0.06	$0.00	$0.02	$0.43	$0.00	$1.81	$1.66	$1.95				
> 10,000	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.00	$0.01	$0.00	$0.03	$0.03	$0.03				
TOTAL	**$40.72**	**$25.26**	**$55.56**	**$37.27**	**$25.96**	**$50.68**	**$0.62**	**$2.91**	**$0.24**	**$2.64**	**$0.12**	**$84.52**	**$57.75**	**$112.77**	**$1.71**	**$86.23**	**$59.47**	**$114.48**

Notes: Detail may not add due to independent rounding. 90 percent confidence bounds reflect uncertainty in technology compliance forecasts and unit treatment costs.
Estimates are discounted to 2003, and given in 2003 dollars.

Sources: Exhibit 7.5a
Capital Costs: SW CWS, Exhibit J.2bb; SW NTNCWS, Exhibit J.2bf; GW CWS, Exhibit J.2bj; GW NTNCWS, Exhibit J.2bn.
O&M Costs: SW CWS, Exhibit J.2bc; SW NTNCWS, Exhibit J.2bg; GW CWS, Exhibit J.2bk; GW NTNCWS, Exhibit J.2bo.
Non-Treatment Costs: SW CWS, Exhibit J.2bd; SW NTNCWS, Exhibit J.2bh; GW CWS, Exhibit J.2bl; GW NTNCWS, Exhibit J.2bp.
State Costs; Appendix J, Exhibit J.2as

Exhibit 9.5b Annualized Costs for Stage 2 DBPR Preferred Regulatory Alternative Rule Activities ($Millions/Year, 7 Percent Discount Rate)

System Size (Population Served)	System Costs: Capital Costs Mean Value	Capital Costs 90 Percent Confidence Bound Lower (5th %tile)	Capital Costs 90 Percent Confidence Bound Upper (95th %tile)	O&M Costs Mean Value	O&M Costs 90 Percent Confidence Bound Lower (5th %tile)	O&M Costs 90 Percent Confidence Bound Upper (95th %tile)	Non-Treatment Costs (Point Estimate) Implement-ation	IDSE	Monitoring Plans	Moni-toring	Significant Excursion	Total System Costs Mean Value	Total System Costs 90 Percent Confidence Bound Lower (5th %tile)	Total System Costs 90 Percent Confidence Bound Upper (95th %tile)	State Costs	Total Costs of the Rule Mean Value	Total Costs of the Rule 90 Percent Confidence Bound Lower (5th %tile)	Total Costs of the Rule 90 Percent Confidence Bound Upper (95th %tile)
Surface Water CWSs																		
< 10,000	$5.06	$2.58	$7.68	$5.46	$2.82	$8.13	$0.15	$1.16	$0.06	-$0.06	$0.01	$11.84	$6.74	$17.14				
≥ 10,000	$25.76	$13.18	$37.45	$13.16	$7.66	$20.35	$0.11	$2.04	$0.04	-$0.90	$0.08	$40.29	$22.21	$59.18				
Surface Water NTNCWSs																		
< 10,000	$0.32	$0.16	$0.49	$0.51	$0.26	$0.76	$0.01	$0.00	$0.00	$0.01	$0.00	$0.85	$0.45	$1.27				
≥ 10,000	$0.05	$0.03	$0.08	$0.03	$0.01	$0.04	$0.00	$0.00	$0.00	$0.00	$0.00	$0.09	$0.05	$0.12				
Ground Water CWSs																		
< 10,000	$8.11	$6.71	$9.53	$5.57	$5.11	$6.02	$0.38	$0.36	$0.14	$0.85	$0.00	$15.40	$13.54	$17.27				
≥ 10,000	$5.42	$4.86	$5.98	$4.92	$4.62	$5.22	$0.06	$0.13	$0.02	$1.86	$0.00	$12.41	$11.55	$13.26				
Ground Water NTNCWSs																		
< 10,000	$0.62	$0.52	$0.72	$0.58	$0.54	$0.63	$0.07	$0.00	$0.03	$0.34	$0.00	$1.64	$1.50	$1.78				
≥ 10,000	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.00	$0.00	$0.00	$0.01	$0.00	$0.02	$0.02	$0.03				
TOTAL	**$45.35**	**$28.05**	**$61.93**	**$30.22**	**$21.04**	**$41.15**	**$0.78**	**$3.69**	**$0.29**	**$2.11**	**$0.10**	**$82.55**	**$56.06**	**$110.05**	**$1.70**	**$84.24**	**$57.76**	**$111.75**

Notes: Detail may not add due to independent rounding. 90 percent confidence bounds reflect uncertainty in technology compliance forecasts and unit treatment costs. Estimates are discounted to 2003, and given in 2003 dollars.

Sources: Exhibit 7.5b
Capital Costs: SW CWS, Exhibit J.2br; SW NTNCWS, Exhibit J.2bv; GW CWS, Exhibit J.2bz; GW NTNCWS, Exhibit J.2cd.
O&M Costs: SW CWS, Exhibit J.2bs; SW NTNCWS, Exhibit J.2bw; GW CWS, Exhibit J.2ca; GW NTNCWS, Exhibit J.2ce.
Non-Treatment Costs: SW CWS, Exhibit J.2bt; SW NTNCWS, Exhibit J.2bx; GW CWS, Exhibit J.2cb; GW NTNCWS, Exhibit J.2cf.
State Costs: Appendix J, Exhibit J.2aw

9.2.3 National Net Benefits

Net benefits are the difference between the estimated value of avoided cases of bladder cancer resulting from the Stage 2 DBPR and the estimated costs of complying with the rule. The Stage 2 DBPR will be implemented over time and, therefore, the treatment technology changes that PWSs implement and the benefits realized by the populations they serve will vary year to year until implementation is complete; the benefits will be at their maximum, steady state following the cessation lag period (explained further in Chapter 6 and Appendix E). Exhibit 9.6 takes the present value of the costs and benefits listed by year in Exhibit 9.1a-b, and annualizes them over the 25 year period of analysis at 3 and 7 percent discount rates. Exhibit 9.6 shows that, in using either the 3 or 7 percent discount rates, net benefits for the Stage 2 DBPR Preferred Regulatory Alternative are positive, indicating that the regulation results in a net benefit to society.

When the magnitude of uncertainty around the costs and benefits estimates differs significantly, another approach to evaluating net benefits is a "breakeven analysis." In Exhibit 9.7, costs and benefits are adjusted to present value (based on 2003 dollars) and annualized over 25 years at a 3 and 7 percent discount rate to generate the average annualized values. The upper bound on costs and lower bound on benefits are presented as a percentage of the corresponding mean estimates, since these bounds will determine if the alternative is acceptable at the lowest estimate of its net benefits. Exhibit 9.7 shows that the amount of uncertainty around the upper bound on the cost estimate is approximately 30 percent larger than the estimated mean cost; the lower bound on the benefits estimate is approximately 85 percent lower than the estimated mean benefit. Furthermore, EPA recognizes that the quantified benefits, based on reduced cases of bladder cancer as shown in Exhibit 9.3, could be zero for all alternatives since causality has not yet been established between exposure to chlorinated water and bladder cancer.

Using the estimate with less uncertainty, in this case, costs, a calculation is made of the minimum level of benefits which, if achieved, would cause the rule to break even. Comparing this breakeven level of benefits with the actual benefits estimate provides a measure of the likelihood that the Stage 2 DBPR Preferred Regulatory Alternative will have positive net benefits. Exhibit 9.8 presents the breakeven analysis for average annual cases of bladder cancer avoided for the 25 year period of analysis. Based on the estimated cost of the rule ($86 million/year at a 3 percent discount rate) shown in Exhibit 9.7, the number of bladder cancer cases that must be avoided annually to break even is a mean of 19 cases (range of 13 to 26 cases based on a 90% confidence interval), using the WTP for non-fatal lymphoma as the basis for valuing non-fatal cancer cases. Based on the WTP for avoiding chronic bronchitis, the rule must avoid a mean of 108 cases to break even (range of 74 to 143 using a 90% confidence interval).

By comparison, Exhibit 9.8 shows that the estimated mean of bladder cancer cases avoided through promulgation of the Stage 2 DBPR Preferred Regulatory Alternative is 277; the lower 5^{th} percentile and upper 95^{th} percentile bounds are 101 and 540 cases, respectively. Using a 3 percent discount rate, the mean annual number of bladder cancer cases avoided (over the 25 year analysis period) is more than 14 times the mean break even estimate using lymphoma WTP, and more than 2.5 times the mean break even estimate using chronic bronchitis WTP. Furthermore, the lower bound (5^{th} percentile = 101) on the estimated mean number of cases avoided is greater than the upper bound on the breakeven estimate using the non-fatal lymphoma WTP (95^{th} percentile = 26), and is close in value to the mean estimate using chronic bronchitis WTP (mean = 108). Results for the same calculations using a 7 percent discount rate are also shown in Exhibit 9.8.

The break even analysis indicates that the Stage 2 DBPR is likely to have more benefits than costs based upon implementation of the Preferred Regulatory Alternative. However, EPA recognizes that causality has not yet been established between DBPs and bladder cancer.

It is also important to note that the non-quantified benefits (e.g., reduction in developmental and reproductive risk) are not included in the primary benefits analysis but could be substantial. This means that the number of bladder cancer cases that must be avoided to break even could potentially be less than shown in Exhibit 9.8, if benefits are also achieved by a reduction in developmental and reproductive risks.

Exhibit 9.6 Annualized Mean Net Benefits for the Stage 2 Preferred Regulatory Alternative, Villanueva et al. (2003) for Baseline Risk, TTHMs as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model ($Millions, 2003$)

WTP for Non-Fatal Bladder Cancer Cases	Mean Benefits	Mean Costs	Mean Net Benefits
3 Percent, 25 Years			
Lymphoma	$ 1,523	$ 86	$ 1,437
Bronchitis	$ 759	$ 86	$ 673
7 Percent, 25 Years			
Lymphoma	$ 1,240	$ 84	$ 1,155
Bronchitis	$ 617	$ 84	$ 533

Sources:
Costs - Appendix J, Exhibits J.2as, J.2aw
Benefits - Appendix F, Exhibits F.2v, F.2w, F.3v, F.3w

Exhibit 9.7 Estimated Annualized National Costs and Benefits for the Stage 2 Preferred Regulatory Alternative with Uncertainty Measured as a Percent of the Mean, Villanueva et al. (2003) for Baseline Risk, TTHMs as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model ($Millions, 2003$)

Benefits			Costs			Lower Bound of Benefits as % of Mean Benefits Estimate	Upper Bound of Costs as % of Mean Cost Estimate
	90% Confidence Bound			90% Confidence Bound			
Mean	Lower (5th %ile)	Upper (95th %ile)	Mean	Lower (5th %ile)	Upper (95th %ile)		
3% Discount Rate							
$ 1,523	$ 232	$ 3,518	$ 86	$ 59	$ 114	15%	133%
7% Discount Rate							
$ 1,240	$ 189	$ 2,862	$ 84	$ 58	$ 112	15%	133%

Sources: Appendix F.2v, 2w, 3v, 3w
Appendix J.2as and J.2aw

Exhibit 9.8 Estimated Breakeven Points (Number of Bladder Cancer Cases Avoided) for the Stage 2 Preferred Regulatory Alternative, Villanueva et al. (2003) for Baseline Risk, TTHMs as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model

Average Annual Avoided Cases			WTP for Non-Fatal Bladder Cancer Cases	Breakeven Cases (at 3 Percent, 25 Years)			Breakeven Cases (at 7 Percent, 25 Years)		
	90 Percent Confidence Bound				90 Percent Confidence Bound			90 Percent Confidence Bound	
Mean	Lower (5th %ile)	Upper (95th %ile)		Mean	Lower (5th %ile)	Upper (95th %ile)	Mean	Lower (5th %ile)	Upper (95th %ile)
			Lymphoma	19	13	26	19	13	25
277	101	540	Bronchitis	108	74	143	105	72	140

Notes: The 90 percent confidence bounds around the estimates of break even cases result from the 90 percent confidence bounds around the cost estimates. Breakeven cases derived by dividing the annualized total regulation cost for the preferred alternative by the WTP estimate (2003$) for the bladder cancer surrogates in this EA (lymphoma and bronchitis).

Sources:

Breakeven cases: Total regulation cost from Appendix J, Exhibits J.2as and J.2aw; WTP estimates from "Stage 2 Valuation Inputs Model, Values by Year"

Cases avoided: from Appendix E, Exhibits E.24, E.38d

9.3 Comparison of Regulatory Alternatives

As discussed in Chapter 4, the development and evaluation of regulatory alternatives was undertaken as part of a consultation process convened under the Federal Advisory Committees Act (FACA). The FACA process narrowed hundreds of regulatory options down to four major alternatives for further evaluation, one of which was designated, in an Agreement in Principle (65 FR 83015 December 2000), as the Stage 2 DBPR Preferred Regulatory Alternative. These four alternatives are summarized below.

Preferred Alternative: 80 µg/L TTHM and 60 µg/L HAA5 as an LRAA; bromate MCL of 10 µg/L as an RAA based on monthly samples taken at the finished water point (no change from the Stage 1 DBPR for bromate). Compliance monitoring preceded by IDSE..

Alternative 1: 80 µg/L TTHM and 60 µg/L HAA5 as an LRAA; bromate MCL of 5µg/L as an RAA based on monthly samples taken at the finished water point.

Alternative 2: 80 µg/L TTHM and 60 µg/L HAA5 as the single maximum value for any sample taken during the year; bromate MCL of 10 µg/L as an RAA based on monthly samples taken at the finished water point (no change from the Stage 1 DBPR for bromate).

Alternative 3: 40 µg/L TTHM and 30 µg/L HAA5 as an RAA of all distribution samples taken; bromate MCL of 10 µg/L as an RAA based on monthly samples taken at the finished water point (no change from the Stage 1 DBPR for bromate).

Detailed benefit and cost analyses for each of the alternatives are presented in Chapters 6 and 7, respectively, and are summarized in this chapter. The following sections present several analyses that compare the Preferred Regulatory Alternative to the other three alternatives.

9.3.1 Comparison of Reductions in DBP Occurrence

Given that the goal of the Stage 2 DBPR is to reduce adverse health effects by reducing exposure to DBPs in drinking water, a useful starting point for comparing regulatory alternatives is a comparison of reduction in DBPs estimated for each alternative. Exhibit 9.9 presents percent reductions in DBPs for the Stage 2 DBPR regulatory alternatives. These reductions are calculated as the average of annual plant means at the point representing average residence time in the distribution system for each regulatory alternative.

Although Exhibit 9.9 shows much greater percent reductions in DBPs for Alternatives 2 and 3, these figures tell very little without further evaluation. Specifically, these values need to be evaluated in the context of the costs and benefits associated with achieving them.

Exhibit 9.9 Comparison of DBP Reduction (of Annual Plant Mean TTHM Data)

Regulatory Alternative	Percent TTHM Reduction from Pre-Stage 2 to Post-Stage 2		
	Mean	5th	95th
Preferred	7.76%	4.48%	11.06%
Alternative 1	7.07%	5.85%	8.28%
Alternative 2	26.32%	23.03%	29.62%
Alternative 3	36.14%	35.03%	37.26%

Note: The 90 percent confidence intervals around the mean estimate represent alternative methodologies (SWAT and the ICR Matrix Method) for surface water systems and the potential impacts of the IDSE.

Source: Exhibit 6.19

9.3.2 Comparison of Benefits and Costs

Exhibit 9.10 presents a summary of the quantified and monetized annualized benefits for each alternative considered. The average annual number of cases avoided as shown in Exhibit 9.10 is based upon the 25 year period of analysis; it represents a portion of the annual average number of cases ultimately avoided, which will be achieved following completion of the cessation lag period. The benefits derive from PWS treatment adjustments and a predicted subsequent reduction in DBP reductions, along with a corresponding reduction in risk for bladder cancer. As stated earlier, the potential nonquantified

benefits in the form of reduced risk for developmental and reproductive health effects may be significant, and would be in addition to the benefits quantified in Exhibit 9.10.

Exhibit 9.11 follows with a presentation of the quantified monetized costs of the regulatory alternatives. The annualized total costs of the rule include costs for rule implementation, IDSEs, monitoring plans, additional routine monitoring, operational evaluations, and changes in treatment technologies by some water systems; these cost estimates include costs for PWSs and the State agencies.

The regulatory alternatives are arranged in Exhibits 9.10 and 9.11 in order of increasing cost from left to right and top to bottom, respectively. Exhibit 9.10 shows that the Preferred Regulatory Alternative avoids more cases of bladder cancer than the next least expensive alternative (Alternative 1). This is because incorporating the IDSE, which increases benefits, is only considered under the Preferred Alternative (explained further in Chapter 4). Additionally, Alternative 1 would capture more benefits if potential cancer cases avoided by lowering the bromate standard (included only in Alternative 1) were quantified. The Preferred Alternative avoids far fewer cases than the more expensive Alternatives 2 and 3. The Microbial-Disinfectants/Disinfection Byproducts (M-DBP) Advisory Committee did not favor alternative A1 because they were concerned that lowering the bromate level to 5 µg/L could have adverse effects on microbial protection (see Chapter 4 for a full discussion). The committee also believed that the current health effects data were not certain enough to warrant the drastic shifts in the Nation's drinking water treatment practices likely to be caused by alternatives A2 and A3. Exhibit 9.11 shows that the costs of the Preferred Regulatory Alternative are far less than costs for the three alternatives: approximately 1/3 the cost of A1; almost 1/5 the cost of A2; and less than 1/7 the cost of A3.

Exhibit 9.10 Comparison of Number and Annualized Value of Estimated Bladder Cancer Cases Avoided for All Regulatory Alternatives, Villanueva et al. (2003) for Baseline Risk, TTHMs as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model (Millions, 2003$)

	Discount Rate, WTP for Non-Fatal Cases	Regulatory Alternative			
		Preferred	Alternative 1[1]	Alternative 2	Alternative 3
Average Annual Number of Cases Avoided		277 (101 - 540)	249 (126 - 395)	928 (477 - 1,449)	1273 (663 - 1,954)
Annualized Mean Benefits of Cases Avoided (90% Confidence Bounds)	3%, Lymphoma	$1,523 ($232 - 3,518)	$1,368 ($208 - 3,160)	$5,103 ($776 - 11,787)	$7,005 ($1,066 - 16,181)
	7%, Lymphoma	$1,240 ($189 - 2,862)	$1,119 ($170 - 2,583)	$4,174 ($636 - 9,636)	$5,731 ($873 - 13,230)
	3%, Bronchitis	$759 ($164 - 1,684)	$682 ($148 - 1,512)	$2,542 ($551 - 5,640)	$3,490 ($756 - 7,743)
	7%, Bronchitis	$617 ($134 - 1,368)	$557 ($121 - 1,235)	$2,078 ($451 - 4,606)	$2,853 ($619 - 6,324)

Notes: Average annual avoided cases is based upon the 25-year period of analysis and so is much lower than the ultimate number of cases to be avoided following the cessation lag period. The cessation lag is explained in detail in Appendix E of the Stage 2 EA. Ultimately avoidable cases are shown in Exhibit 9.3 of this chapter.

Footnote 1: Alternative 1 has lower benefits than the Preferred Alternative because it does not incorporate the IDSE. Additionally, benefits of Alternative 1 would be higher if the benefit of lower bromate MCL (and associated reduction in cancer cases) was quantified.

Sources: Appendix F.2v, 2w, 3v, 3w, 4d-e, 5d-e, 6b, 7b, 8b, 9b, 10b, 11b
Appendix E, Exhibits E.38d, 40d, 41d, 42d

Exhibit 9.11 Comparison of Costs for All Regulatory Alternatives ($Millions, 2003$)

	Undiscounted Costs at Full Implementation, 2003$												Annualized Total Regulation Costs					
	PWS Costs												Discounted at 3%, 25 Years			Discounted at 7%, 25 Years		
	Capital Costs			O&M Costs			Non-Treatment Costs (Point Estimate)											
		90 Percent Confidence Bound			90 Percent Confidence Bound									90 Percent Confidence Bound			90 Percent Confidence Bound	
Regulatory Alternative	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Implementation	IDSE	Monitoring Plans	Monitoring	Significant Excursion	State Costs	Mean Value	Lower (5th %tile)	Upper (95th %tile)	Mean Value	Lower (5th %tile)	Upper (95th %tile)
Preferred	$893	$555	$1,218	$59	$42	$81	$12	$57	$5	$4	$0.2	$13	$86	$59	$114	$84	$58	$112
Alternative 1	$2,641	$1,572	$3,788	$229	$141	$318	$12	$57	$5	$4	$0.2	$13	$277	$171	$388	$265	$163	$373
Alternative 2	$4,871	$4,047	$5,741	$337	$287	$388	$12	$57	$5	$4	$0.2	$13	$444	$375	$516	$431	$364	$502
Alternative 3	$7,433	$6,083	$8,860	$494	$414	$576	$12	$57	$5	$4	$0.2	$13	$661	$549	$778	$644	$534	$760

Notes:

Detail may not add due to independent rounding. 90 percent confidence bounds reflect uncertainty in compliance forecasts and unit treatment costs. Estimates are discounted to 2003, and shown in 2003 dollars.

Sources: Capital Costs: Appendix J, Exhibit J.1a-d
O&M Costs: Appendix J, Exhibit J.1g - h
Non-Treatment Costs: Appendix J, Exhibit J.2as
State Costs: Appendix J, Exhibit J.1h
Total regulation costs: Appendix J, Exhibit J.2aw, J.3-5(m)

Net Benefits

Net benefits are calculated as the difference between the monetized benefits and cost estimates. Exhibit 9.12 presents net benefits based upon the annualized present value of quantified, monetized benefits at 3 and 7 percent discount rates using lymphoma and bronchitis as a WTP surrogate for bladder cancer. Accounting for the unquantified benefits that may be achieved through reduction of developmental and reproductive health risks would raise the overall net benefits. Exhibit 9.12 shows that, based upon the mean values for costs and benefits of each regulatory alternative, all alternatives provide benefits greater than their costs. It should be noted that accrual of any of the non-quantified benefits, described in Exhibit 9.2, would increase these net benefits.

Maximum Net Benefits

At both 3 and 7 percent discount rates, the Preferred Regulatory Alternative achieves more net benefits than Alternative 1, while Alternatives 2 and 3 achieve more net benefits than the Preferred Regulatory Alternative. However, The M-DBP Advisory Committee did not favor Alternatives 2 and 3 because it believed that the health effects data are not certain enough to warrant such a drastic shift in the nation's drinking water treatment practices.

Incremental Net Benefits

The goal in comparing incremental net benefits is generally to identify the regulatory alternative, in a series of increasingly stringent alternatives, having marginal net benefits that come the closest to zero while still being positive. Protection to the level of this alternative captures the most benefits possible among the alternatives without experiencing diminishing marginal returns. In Exhibit 9.13, each additional regulatory alternative generally costs more per benefit dollar (monetized value of risk reduction) than its predecessors (the exception is Alternative 1, which costs slightly more per benefit dollar than Alternative 3). When the next more stringent alternative costs more than it returns in absolute benefits, the net benefit is negative: the alternative does not yield a net benefit to society. Alternative 1 is ruled out by this criterion[5]. Alternatives 2 and 3 again look worth pursuing because their incremental benefits are positive. However, net benefits do not include the unquantified benefits. Because the Preferred Alternative uses a risk targeting strategy, unquantified benefits effects for the Preferred Alternative are expected to be higher in proportion to cost as compared to Alternatives 2 and 3.

[5]Alternative 1 appears to have fewer benefits than the Preferred Alternative because it does not incorporate the IDSE, as explained in Chapter 4. Furthermore, this EA does not quantify the benefits of reducing the MCL for bromate (and potentially associated cancer cases), a requirement that is included only in Alternative 1.

Exhibit 9.12 Comparison of Annualized Mean Net Benefits for All Regulatory Alternatives, Villanueva et al. (2003) for Baseline Risk, TTHM as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model ($Millions)

WTP for Non-Fatal Bladder Cancer Cases	Rule Alternative	Mean Net Benefits (Million$)	
		3%	7%
Lymphoma	Preferred	$ 1,437	$ 1,155
	A1	$ 1,091	$ 853
	A2	$ 4,659	$ 3,743
	A3	$ 6,344	$ 5,087
Bronchitis	Preferred	$ 673	$ 533
	A1	$ 405	$ 292
	A2	$ 2,098	$ 1,647
	A3	$ 2,829	$ 2,209

Notes: All values are discounted and annualized over 25 years.
Sources: Exhibits 9.10 and 9.11

Exhibit 9.13 Incremental Net Benefits for All Regulatory Alternatives, Villanueva et al. (2003) for Baseline Risk, TTHMs as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model ($ Millions, 2003$)

WTP for Non-Fatal Bladder Cancer Cases	Rule Alternative	Annual Costs	Annual Benefits	Incremental Costs	Incremental Benefits	Incremental Net Benefits
		A	B	C	D	E=D-C
3 Percent Discount Rate						
Lymphoma	Preferred	$ 86	$ 1,523	$ 86	$ 1,523	$ 1,437
	Alternative 1	$ 277	$ 1,368	$ 191	$ -155	$ -345
	Alternative 2	$ 444	$ 5,103	$ 167	$ 3,735	$ 3,567
	Alternative 3	$ 661	$ 7,005	$ 217	$ 1,903	$ 1,685
Bronchitis	Preferred	$ 86	$ 759	$ 86	$ 759	$ 673
	Alternative 1	$ 277	$ 682	$ 191	$ -77	$ -268
	Alternative 2	$ 444	$ 2,542	$ 167	$ 1,861	$ 1,694
	Alternative 3	$ 661	$ 3,490	$ 217	$ 948	$ 731
7 Percent Discount Rate						
Lymphoma	Preferred	$ 84	$ 1,240	$ 84	$ 1,240	$ 1,155
	Alternative 1	$ 265	$ 1,119	$ 181	$ -121	$ -302
	Alternative 2	$ 431	$ 4,174	$ 166	$ 3,055	$ 2,890
	Alternative 3	$ 644	$ 5,731	$ 213	$ 1,557	$ 1,344
Bronchitis	Preferred	$ 84	$ 617	$ 84	$ 617	$ 533
	Alternative 1	$ 265	$ 557	$ 181	$ -60	$ -241
	Alternative 2	$ 431	$ 2,078	$ 166	$ 1,521	$ 1,355
	Alternative 3	$ 644	$ 2,853	$ 213	$ 775	$ 562

Sources: Costs: Appendix J.2 (as,aw), J.3-5 (i,m)
Benefits: Appendix F.2 - 3 (v-w), F.6 - 11 (c,d)

9.3.3 Cost-Effectiveness

Evaluation of the relative merits of one alternative over another is often made with regard to cost-effectiveness. This concept can be defined simply as getting the greatest benefits for a given expenditure, or imposing the least cost while achieving a given level of benefits. Although cost effectiveness does not usually account fully for social impacts, it does provide a measure of technical efficiency and can supplement a benefit cost analysis (BCA) or other analyses as part of a comprehensive EA. In a cost effectiveness analysis (CEA), generally either the costs or the benefits will be monetized and the nonmonetized factor will be quantified.

In this CEA, technical efficiency is evaluated in terms of the cost per case of bladder cancer avoided (fatal and non-fatal) reviewed in a relative sense (by comparison among alternatives) and an absolute sense (by comparison to thresholds). In calculating the cost per case avoided, the cases of illnesses and fatalities are discounted to make the benefits comparable to the discounted costs. OMB Circular A-4 provides that "there is professional consensus that future health effects, including both benefits and costs, should be discounted at the same rate....This consensus applies to both BCA and CEA"(p. 34). Costs and benefits are discounted based upon when they accrue in the analysis period, using 3 and 7 percent annual discount rates for both. Although a similar analysis cannot be made for the unquantified benefits of the rule, it is expected that the results would follow the same pattern, with more stringent alternatives generally (with the exception of Alternative 1, See Footnote 4) reaping more benefits at higher total costs than less stringent alternatives.

For the purpose of evaluating cost-effectiveness in an absolute sense, this CEA compares the cost per case avoided, shown in the two left hand columns in Exhibit 9.14, to an established threshold. If an alternative is cost effective, this cost ratio will be equal to or less than the value of the WTP estimate. In this EA, the WTP values for avoidance of non-fatal lymphoma (mean of $4.49 million in 2003$) or chronic bronchitis (mean of $0.80 million in 2003$) serve as surrogates for a measure of what society is willing to pay to avoid a non-fatal case of bladder cancer. For the purpose of this comparison, the cost ratios should be lower than these thresholds.[6] The Preferred Alternative meets this criterion for both thresholds: at discount rates of 3 and 7 percent, its cost ratios of $0.38 and $0.46 million, respectively, are less than or equal to the lymphoma and bronchitis WTP values of $4.49 million and $0.58 million, respectively. Alternatives 1, 2, and 3 meet this criterion with regard to the WTP for avoiding non-fatal

[6]The WTP values, shown here in 2003$, could be used to develop an annualized WTP value for the most accurate comparison to the annualized cost per case avoided values presented in Exhibit ES.11. First, they would be increased over the period of analysis to reflect the elasticity of WTP in response to increases in real income. Second, the WTP value would be weighted differentially over the period of analysis to reflect in the annualized value the difference in the number of cases avoided, which varies on an annual basis. Third, because the cases avoided in the CEA ratio include both fatal and non-fatal cases, the VSL would be incorporated into a weighted average (to reflect that 26% of cases are fatal) with the WTP value after it, too, was increased over time to reflect the above 2 considerations. However, each of these factors would increase the threshold used in this analysis; therefore annualized WTP values are not calculated because the Preferred Alternative, and most of the other alternatives, have costs per case avoided that are already below the lowest of the thresholds ($0.80 million in 2003$).

lymphoma, and Alternatives 2 and 3 also cost less than the WTP for chronic bronchitis. Alternative 1 is not competitive for reasons explained previously.[7]

A relative comparison determines the lowest cost per case avoided among the alternatives. Exhibit 9.14 presents each regulatory alternative in increasing order of these cost ratios. The estimated cost ratio for the Preferred Alternative is always lower than the cost ratios of the other alternatives, indicating that the Preferred Alternative is the most cost-effective by this measure at both 3 and 7 percent discount rates. Alternatives 2 and 3 have cost ratios closest to those of the Preferred Alternative and are more cost effective than Alternative 1, which has the highest cost ratio based on current available information (See Footnote 6).

An incremental CEA determines, for a series of increasingly stringent alternatives, the marginal gain for the increase in expenditure from one alternative to the next more stringent alternative. As in the previous paragraphs describing comparisons using the average cost per case avoided, the incremental analysis can provide information in an absolute sense (by comparing to thresholds) or a relative sense (by comparing among alternatives). If the incremental cost is less than the WTP values to avoid the risk (mean of $4.49 million and $0.80 million for lymphoma and bronchitis, respectively), then the regulation is cost effective. An incremental cost that is greater than the WTP value would indicate that an alternative does not avoid enough additional cases beyond the less stringent alternative to justify the additional cost. The two right hand columns in Exhibit 9.14 show that, setting aside Alternative 1 (See Footnote 5), each alternative is cost effective in an absolute sense–relative to the WTP value for avoiding non-fatal lymphoma. Additionally, the Preferred Alternative and Alternative 2 are also cost effective compared to the lowest threshold (WTP to avoid chronic bronchitis), and Alternative 3 generally costs less than the lowest threshold at a 3 percent discount rate (at a 7 percent discount rate, the ratio for Alternative 3 slightly exceeds the threshold, with a unit cost ratio of $0.87 million). In a relative comparison, the Preferred Alternative, capturing all of the benefits of implementing any reasonable regulation over maintaining the status quo, captures the largest portion of benefits and has a lower"incremental" cost than the other alternatives.[8] As expected, Alternatives 2 and 3 show a pattern of increasing incremental cost with increasing stringency.

In summary, the average cost per case avoided compares favorably to both of the thresholds (WTP surrogate values for avoiding bladder cancer) used in this EA, indicating that the alternatives are all

[7]As mentioned previously, Alternative 1 appears to have fewer benefits than the Preferred Alternative because it does not incorporate the IDSE, as explained in Chapter 4. Furthermore, this EA does not quantify the benefits of reducing the MCL for bromate (and potentially associated cancer cases), a requirement that is included only in Alternative 1.

[8]The incremental gain of a first alternative (in a series of increasingly stringent alternatives) is equivalent to the CEA ratio of that alternative and captures the large amount of benefits achieved by having a rule (compared to the status quo). The differences between subsequent rule alternatives are quite narrow by comparison. Since Alternative 1 is more expensive than the Preferred Alternative but this EA does not calculate additional benefits for it, its incremental ratio would be negative, therefore it is excluded from the comparison in Exhibit 9.14. Alternative 1 appears to have fewer benefits than the Preferred Alternative because it does not incorporate the IDSE, as explained in Chapter 4. Furthermore, this EA does not quantify the benefits of reducing the MCL for bromate (and potentially associated cancer cases), a requirement that is included only in Alternative 1.

cost effective by this measure. In a relative comparison among the alternatives (setting aside Alternative 1, for reasons explained previously), the Preferred Alternative is the most cost effective.

Exhibit 9.14 Incremental Cost Per Case Avoided[1] for All Regulatory Alternatives, Villanueva et al. (2003) for Baseline Risk, TTHMs as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model, by Discount Rate ($Millions, 2003$)

Rule Alternative	Cost Per Case Avoided		Incremental Cost Per Case Avoided	
	3%	7%	3%	7%
Preferred	$ 0.36	$ 0.45	$ 0.36	$ 0.45
Alternative 1	$ 1.30	$ 1.57	Note 2	
Alternative 2	$ 0.56	$ 0.68	$ 0.64	$ 0.78
Alternative 3	$ 0.61	$ 0.74	$ 0.73	$ 0.90

Notes: Cost per case avoided is in year 2003 dollars ($Millions), discounted for the 25 year analysis period to year 2005.

1) The cost effectiveness ratios are a potentially a high estimate in that the regulatory costs in the numerator are not adjusted by subtracting the medical costs associated with cases avoided to produce a net cost numerator. Subtraction of theses costs would not be expected to alter the ranking of alternatives. In the case where thresholds of maximum public expenditure per case avoided are prescribed, defining the numerator more precisely by making such adjustments would be appropriate.

2) In reference to conducting incremental CEA, OMB states that the analyst should make sure that "When constructing and comparing incremental cost-effectiveness ratios, [analysts] ... should make sure that inferior alternatives identified by the principles of strong and weak dominance are eliminated from consideration. " (OMB Circular A-4, p. 10) Alternative 1 is dominated by the Preferred Alternative and is therefore not included in the incremental analysis. The reason for this domination is mainly that the Preferred Alternative includes IDSE and Alternative 1 does not; and to a lesser degree because the bromate control included in Alternative 1 increases the costs but the benefits of this control are not quantified at this time. Alternative 2 is compared directly to the Preferred Alternative (skipping Alternative 1) in this analysis.

Sources:
Discounted cases avoided: Appendix E, Exhibits E.38a; E.40-E.42,a

Discounted costs: Appendix J, Exhibits J.2as,aw; J.3-5, (i,m)

Benefit Cost Ratios

Benefit cost ratios can be used to rule out an alternative that does not have at least a ratio of benefits to cost equal to or greater than 1. Exhibit 9.15 shows that each regulatory alternative of the Stage 2 DBPR has a benefit cost ratio greater than 1. However, as in the case of the CEA ratio, the information provided by the benefit cost ratios does not allow for comparison across the regulations unless either the benefits or costs are identical for all alternatives, which they are not in this case. A thorough analysis must consider the net benefits, and the absolute costs and benefits in addition to the benefit cost ratio.

Exhibit 9.15 Annualized Benefit Cost Ratios for All Regulatory Alternatives, Villanueva et al. (2003) for Baseline Risk, TTHMs as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model, Lymphoma for WTP

Rule Alternative	Benefit Cost Ratio	
	3 Percent Discount Rate	7 Percent Discount Rate
Preferred	17.7	14.7
Alternative 1	4.9	4.2
Alternative 2	11.5	9.7
Alternative 3	10.6	8.9

Source: Exhibit 9.13

9.4 Effect of Uncertainties on the Estimation of Net National Benefits

Detailed discussions of the assumptions and uncertainties associated with national benefits and costs are contained in Chapters 3, 5, 6 and 7. A summary of the key uncertainties and the effects of uncertainty in those assumptions on the benefits and cost analyses are presented in Exhibit 9.16. See Sections 3.8, 5.7, 6.6, and 7.8 for a full listing of assumptions for which there is uncertainty.

EPA is aware that there is uncertainty in the prediction of the net benefits. Where possible, this uncertainty was incorporated into the cost and benefits models and is incorporated in the range of costs and benefits shown in Exhibits 9.10 and 9.11. In some cases enough information was not available to predict the magnitude of uncertainty in either costs or benefits. Uncertainties that are not quantified are also listed in Exhibit 9.16.

One source of uncertainty in producing net benefits is the potential impacts of the IDSE on the compliance forecast, which will determine the treatment technology installed and the level of costs incurred and benefits achieved by the rule. The primary economic analysis of the Stage 2 DBPR incorporates the uncertainty of the IDSE effect by forecasting treatment technology change for large and medium surface water systems based upon a safety margin that is equally weighted between 20 and 25 percent. Because EPA is unsure of the true magnitude of the impacts of the IDSE, a sensitivity analysis of this assumption was performed by separately generating costs and benefits for the 20 and 25 percent safety margin runs using a 3 percent discount rate.

Another source of uncertainty is the approach used to estimate the number of bladder cancer cases in the baseline that can be attributed to DBP occurrence and exposure, and the number of cases that can be avoided by implementation of the Stage 2 DBPR. EPA has developed three equally valid approaches to estimating the number of bladder cancer cases attributable to DBPs. For simplicity's sake, one estimate, based on a 2003 meta-analysis by Villanueva et al., is carried through the full benefits analysis.

Results are shown in Exhibit 9.17. National benefits estimates are more sensitive to changes in the safety margin for large and medium surface water systems compared to national cost estimates. Based upon a 20 percent safety margin, the model produced net benefits that are about 22 and 24 percent lower than those in the primary run, using both lymphoma and bronchitis WTP bladder cancer surrogates, respectively. When a 25 percent safety margin was used in the model run, net benefits were about 20 and 22 percent higher than those in the primary run, using the same WTP surrogates. From these results, one can infer that if EPA's compliance forecast to account for the IDSE is underestimated, EPA is also underestimating net benefits. It should be noted that the net benefits are positive and significant in magnitude, based upon either of the three scenarios of safety margins employed: 20 percent, equally weighted between 20 and 25 percent, and 25 percent.

Exhibit 9.16 Effects of Uncertainties on National Estimates

Assumptions for Which There Is Uncertainty	Section with Full Discussion of Uncertainty	Potential Effect on Benefit Estimate			Potential Effect on Cost Estimates		
		Under-estimate	Over-estimate	Un-known Impact	Under-estimate	Over-estimate	Un-known Impact
Uncertainty in the industry baseline (SDWIS and 1995 CWSS data)	3.4			X			X
Uncertainty in observed data and predictive tools used to characterize DBP occurrence for the pre-Stage 1 baseline	3.7			X			X
Uncertainty in predictive tools used to develop the compliance forecast for surface water systems (SWAT and ICR Matrix Method)	Chapter 5, Appendix A	Quantified in primary analysis (addresses potential underestimate or overestimate)			Quantified in primary analysis (addresses potential underestimate or overestimate)		
Uncertainty in ground water compliance forecast methodologies	Chapter 5, A and B			X			X

Assumptions for Which There Is Uncertainty	Section with Full Discussion of Uncertainty	Potential Effect on Benefit Estimate			Potential Effect on Cost Estimates		
		Under-estimate	Over-estimate	Un-known Impact	Under-estimate	Over-estimate	Un-known Impact
Operational safety margin of 20%	5.2			X			X
Impacts of the IDSE on the compliance forecast for the Preferred Regulatory Alternative	5.3	Quantified in the primary analysis (addresses potential underestimate)			Quantified in the primary analysis (addresses potential underestimate)		
Uncertainty in the PAR[1]	6.1.1 Appendix E	Quantified in the primary analysis (addresses potential underestimate or overestimate)					
Reduction in TTHM and HAA5 used as proxies for all chlorination DBPs	6.3.3			X			
DBPs have a linear no-threshold dose-response relationship for bladder cancer effects	6.2.1			X			
Uncertainty in benefits valuation inputs	6.5.2	Quantified in the primary analysis (addresses potential underestimate or overestimate)					
Benefits of reduced cancers other than bladder cancer are not included in the quantitative analysis	6.7	Quantified in a sensitivity analysis (addresses potential underestimate)					
Value of potential reproductive and developmental health effects avoided is not quantified in the primary analysis	6.8	Quantified in an illustrative calculation (addresses potential underestimate)					
Treatment costs do not include costs for minor operational changes predicted by SWAT	7.4.1				X		
Median operational and water quality parameters considered for technology unit costs	7.4.1						X
Economies of scale for combination treatment technologies not considered	7.4.1					X	

Assumptions for Which There Is Uncertainty	Section with Full Discussion of Uncertainty	Potential Effect on Benefit Estimate			Potential Effect on Cost Estimates		
		Under-estimate	Over-estimate	Un-known Impact	Under-estimate	Over-estimate	Un-known Impact
Possible UV-chloramine synergy not taken into account	7.4.1					X	
Potential low-cost alternatives to treatment not considered	7.4.2					X	
Uncertainties in unit costs	7.4.3				Quantified in primary analysis (addresses potential overestimate or underestimate)		

Footnote 1: To assess uncertainty in PAR estimates, three approaches were used to estimate Pre-Stage 1 PAR, as shown in Appendix E of the EA.

Exhibit 9.17 Sensitivity Analysis for Annualized Mean Net Benefits of the Preferred Regulatory Alternative, Villanueva et al. (2003) for Baseline Risk, TTHMs as Chlorination DBP Indicator, Smoking/Lung Cancer Cessation Lag Model, 3 Percent Discount Rate ($Millions, 2003$)

Compliance Forecast Safety Margin for Large and Medium Surface Water Systems	WTP for Non-Fatal Bladder Cancer Cases	Costs A	Benefits B	Net Benefits C = B - A	Percent Change in Net Benefits from Primary to Sensitivity Analysis
Equally weighted between 20% and 25% (Primary Analysis)	Lymphoma	$ 86.2	$ 1,523.0	$ 1,436.8	
	Bronchitis	$ 86.2	$ 758.9	$ 672.7	
20%	Lymphoma	$ 85.4	$ 1,202.1	$ 1,116.7	-22%
	Bronchitis	$ 85.4	$ 598.9	$ 513.5	-24%
25%	Lymphoma	$ 86.9	$ 1,816.0	$ 1,729.1	20%
	Bronchitis	$ 86.9	$ 904.9	$ 818.0	22%

Notes: The safety margin for small SW systems and all GW systems is 20 percent. Costs and benefits shown are mean estimates for all systems.

Sources: Costs: Appendix J, Exhibits J.(6 - 7) i, J2as
Benefits: Appendix F, Exhibits F.(14-17) c, F.(2-3)v

9.5 Summary of Conclusions

The following is a summary of the important points that must be considered when weighing the benefits and costs of the Stage 2 DBPR.

1) The quantified benefits estimate is potentially understated because it does not include the benefits for reductions in adverse reproductive and developmental health effects, other health effects, and non-health effects associated with DBP reduction (Exhibits 9.2 - 9.4). At the same time, EPA recognizes that the lower bound of the quantified benefits estimates could be as low as zero since causality has not yet been established between exposure to chlorinated water and bladder cancer.

2) The mean cost estimate of $86.2 million (3 percent discount rate) to $84.2 million (7 percent discount rate) represents EPA's best estimate of the monetary impacts of the Stage 2 DBPR Preferred Regulatory Alternative.

3) The Stage 2 DBPR Preferred Regulatory Alternative provides the greatest benefits at a cost level that is considered reasonable (i.e., is not cost prohibitive) given the uncertainties in health effects data (Exhibits 9.11 and 9.12). Alternatives 2 and 3 have a greater net benefit than the Preferred Alternative. However, net benefits do not include the unquantified benefits. Because the Preferred Alternative uses a risk targeting strategy, unquantified benefits effects for the Preferred Alternative are expected to be higher in proportion to cost as compared to Alternatives 2 and 3.

4) Evaluation of the cost-effectiveness of the Preferred Regulatory Alternative shows it to be the most cost effective according to the measures evaluated (Exhibit 9.14).

5) The mean breakeven points for the estimated cases of bladder cancer avoided based on regulatory costs for the Preferred Alternative (on an average basis over the 25 year period) are about 19 cases for both 3 and 7 percent discount rates, using the WTP for non-fatal lymphoma as the basis for valuing non-fatal cancer cases. Using the WTP for avoided chronic bronchitis, the break even points are about 108 to 105 cases (using a 3 percent and 7 percent discount rate, respectively). The mean estimate of 277 bladder cancer cases avoided annually is much lower than (achieves more than) both of thresholds. (Exhibit 9.8).

As a result of all these considerations, EPA believes that the annual benefits of the Stage 2 DBPR will likely exceed the annualized national costs and will be effective in minimizing the risks to consumers from exposure to DBPs in drinking water.

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