California Urban Water Agencies

455 Capitol Mall • Suite 705 • Sacramento, CA 95814

Drinking Water Treatment Evaluation

Technical Memorandum 1: Definition of Study Boundaries

September 2008

Report Prepared By:

Malcolm Pirnie, Inc.

4646 East Van Buren Street
Suite 400
Phoenix, AZ
602-241-1770

3054008

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AWWA	American Water Works Association
AwwaRF	American Water Works Association Research Foundation
Basin Plan	Water Quality Control Plan
Central Valley Water Board	Central Valley Regional Water Quality Control Board
CBDA	California Bay-Delta Authority
CCL3	Contaminant Candidate List
CDPH	California Department of Public Health
CUWA	California Urban Water Agencies
DBP	Disinfection By-product
Delta	Sacramento-San Joaquin Delta
DOC	Dissolved Organic Carbon
DON	Dissolved Organic Nitrogen
DWR	Department of Water Resources
EDC	Endocrine Disrupting Compounds
GAC	Granulated Activated Carbon
HAA	Haloacetic Acid
IESWTR	Interim Enhanced Surface Water Treatment Rule
LT2ESWTR	Long-Term 2 Enhanced Surface Water Treatment Rule
LRAA	Locational Running Annual Average
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
MGD	Million Gallons per Day
MIOX	Mixed oxidants
NBA	North Bay Aqueduct
NCWA	Northern California Water Association
NDMA	N-Nitrosodimethylamine
OEHHA	Office of Environmental Health Hazard Assessment
PAC	Powdered Activated Carbon
PPCP	Pharmaceuticals and Personal Care Products
PHG	Public Health Goal
SDWA	Safe Drinking Water Act
SRCSD	Sacramento Regional County Sanitation District
SWP	State Water Project
SUVA	Specific Ultraviolet Absorbance
SWRCB	State Water Resources Control Board
SWTR	Surface Water Treatment Rule
TOC	Total Organic Carbon
TDS	Total Dissolved Solids
THM	Trihalomethane
THM4	Sum of four trihalomethanes
USEPA	United States Environmental Protection Agency
UV	Ultra Violet
WHO	World Health Organization
Work Group	Central Valley Drinking Water Policy Work Group
WDL	Water Data Library
WTP	Water Treatment Plant

1. Introduction and Project Background

The surface water in the Central Valley has the potential to impact more than 25 million Californians who receive a portion of their water from the Sacramento-San Joaquin Delta (Delta) and the tributaries to the Delta (CALFED Water Quality Program, 2008). The tributaries to the Sacramento and San Joaquin rivers that originate in the Sierra Nevada Mountains generally have high quality water; however, pollutants from a variety of sources (urban, industrial, agricultural, and natural) degrade the quality of water as it flows to and downstream of the Delta, creating a number of drinking water treatment challenges. A number of constituents potentially impact the water quality in the Central Valley. Table 1-1 highlights those most likely to impact present and future drinking water treatment.

Table 1-1.
Central Valley Water Quality Challenges

Water Quality Challenge	Potential Treatment Impact
High Organic Carbon and Bromide Concentrations	Treatment must balance the formation of disinfection by-products (DBPs) with the removal and inactivation of pathogens and indicator organisms.
Pathogens and Indicator Organisms	Removal and inactivation of pathogens and indicator organisms must be balanced with the formation of DBPs while achieving adequately protective disinfection of pathogens. If additional pathogens are regulated, additional treatment options may need to be considered.
High Nutrient Concentrations	High nutrient concentrations may lead to algal blooms, create taste and odor problems, and impact plant operations. If and when nitrogenous DBPs are regulated, additional treatment options may need to be considered.
High levels of Total Dissolved Solids (TDS)	High TDS levels create aesthetic problems and challenges for blending, groundwater storage, and water recycling.
Pharmaceuticals and personal care products (PPCPs) and endocrine disrupting compounds (EDCs) (Emerging Contaminants)	Potential future regulation of emerging contaminants may lead to increased monitoring and the need for additional treatment processes or process modifications.

Currently, water quality regulations applicable to the Central Valley include maximum contaminant levels (MCLs) issued by the California Department of Public Health (CDPH) and a Water Quality Control Plan (Basin Plan) for the Sacramento-San Joaquin River Basins. The Basin Plan was developed by the Central Valley Regional Water Quality Control Board (Central Valley Water Board) and designates beneficial uses, including municipal and domestic water supply, for the Sacramento and San Joaquin

rivers and Delta. The Basin Plan also specifies numeric and narrative water quality objectives and implementation strategies to protect designated beneficial uses.

Current plans and policies for Central Valley surface waters do not contain numeric quality objectives for several key drinking water constituents of concern, including DBP precursors and pathogens. Additionally, the current implementation strategies do not provide source water protection at a level desired by water supply agencies. For this reason, the Central Valley Water Board is working with stakeholders to develop a comprehensive Central Valley Drinking Water Policy, as described below.

1.1. Central Valley Drinking Water Policy Development

The Drinking Water Policy will be considered as a Basin Plan amendment in 2009 or 2010. To provide the technical information needed for the development of the Drinking Water Policy, a Central Valley Drinking Water Policy Workgroup (Work Group), comprised of interested stakeholders and technical experts (listed below), was formed to develop and implement a work plan.

- California Bay-Delta Authority (CBDA)
- CDPH
- Central Valley Water Board
- State Water Resources Control Board (SWRCB)
- Sacramento Regional County Sanitation District (SRCSD)
- Northern California Water Association (NCWA)
- California Urban Water Agencies (CUWA) with representatives from Contra Costa Water District, Metropolitan Water District of Southern California, and East Bay Municipal Utility District.
- United States Environmental Protection Agency (USEPA)
- Clean Water Action
- Sacramento City Stormwater

The work plan includes:

- An assessment of the ability to control sources of key drinking water constituents in the Delta and is tributaries (source water protection approach).
- An assessment of the ability to remove key drinking water constituents in water treatment plants (water treatment approach).
- An analysis of the feasibility, costs, and risks associated with both approaches to managing key drinking water constituents (source water protection and water treatment).

This project addresses the water treatment approach for priority constituents. The drinking water constituents considered to have the highest priority by the Work Group include DBP precursors, dissolved minerals, nutrients, pathogens, and pathogen indicator organisms (Table 1-2).

Table 1-2.
Priority Constituents of Concern for Central Valley Drinking Water Policy

Constituent Class	Source Water Constituents	Treated Water Constituents
Disinfection Byproduct Precursors	Total organic carbon, dissolved organic carbon, bromide, alkalinity	Disinfection byproducts, Trihalomethanes (THMs), Haloacetic Acids (HAAs), bromate
Dissolved Minerals	Total dissolved solids, electrical conductivity (EC), and chloride	Total dissolved solids, EC, and chloride
Nutrients	Nitrogen species (total, total Kjeldahl, organic, nitrate, nitrite, ammonia) Phosphorus species (total, dissolved)	Impacts of algal growth: taste and odor, algal toxins, treatment challenges
Pathogens and Indicator Organisms	*Giardia*, *Cryptosporidium*, total coliform, fecal coliform, *Enterococcus*, *E.coli*	*Giardia*, *Cryptosporidium*, total coliform, fecal coliform, *Enterococcus*, *E.coli*

Source: Drinking Water Treatment Evaluation Scope of Work

1.2. Project Objective

The objective of this project is to identify and evaluate, at a conceptual planning level, the capital and operational costs (or cost savings) and intangible benefits (or detriments) that are projected to occur as a result of future changes in intake water quality at treatment plants that utilize surface water from the Central Valley of California. Current, improved, and degraded water quality will be evaluated. In addition, current and projected future regulations will be considered. The objective of this project will be accomplished in seven tasks:

- Task 1- Define Study Boundaries
- Task 2- Develop and Describe a Representative (Virtual) Water Treatment Plant (WTP) for each Source Water Area
- Task 3- Identify Threshold Values that Trigger Treatment Changes
- Task 4- Estimate Required Future Dinking Water Treatment Process and Operational Changes
- Task 5- Estimate Water Treatment Costs Associated with Different Intake Water Quality Scenarios in Each Source Water Area
- Task 6- Evaluate Intangible Factors in the Assessment of the Costs and Benefits of Different Raw Water Quality Scenarios
- Task 7- Task Coordination, Meetings, and Project Report

1.3. Technical Memorandum Organization

The purpose of this technical memorandum is to summarize the work completed as part of Task 1- Define Study Boundaries. This memorandum is organized into five sections:

- Section 1 provides a brief description of key water quality concerns in the Central Valley, the development of a Central Valley Drinking Water Policy, project objectives, and technical memorandum organization.
- Section 2 provides a summary of current regulations and a potential future regulatory scenario for 2030.
- Section 3 provides definitions of areas with similar source water quality and a summary of current water quality conditions for each source water area.
- Section 4 provides a description of existing water treatment practices for each source water area.

Section 5 summarizes the results from Task 1 and provides a description of and recommended approach to upcoming tasks.

2. Current and Future Drinking Water Regulations

The current drinking water regulations set contaminant limits and treatment techniques that need to be considered in subsequent tasks, and the future regulation predictions will be used to evaluate what water treatment trends may occur in the future. This section discusses the current and future regulations that are of particular interest to this project.

2.1. Current Drinking Water Regulations Summary

This section summarizes the three major categories of primary drinking water regulations that have been implemented under the Safe Drinking Water Act (SDWA) and are of interest from the perspective of this project. More detailed descriptions are provided in Appendix A. Table 2-1 summarizes selected current regulations.

Table 2-1.
Selected Current Drinking Water Regulations

Contaminant	MCL (mg/L)	Secondary MCL[1] (mg/L)	CDPH Public Health Goal (mg/L)	Removal/Inactivation Requirement
Disinfection Byproducts				
Total Trihalomethanes (THM)	0.080	-	-	-
Sum of five Haloacetic acids (HAA5)	0.060	-	-	-
Bromate	0.010	-	-	-
Chlorite	1.0	-	-	-
N-Nitrosodimethylamine (NDMA)	-	-	0.000003	-
Dissolved Minerals				
Total Dissolved Solids (TDS)	-	500 (CDPH recommended level)	-	-
Pathogens and Indicator Organisms				
Giardia	-	-	-	3-log [2]
Cryptosporidium	-	-	-	2.0-log + Bin Classification [3]

[1]CDPH Secondary MCLs are enforceable.

[2]Surface Water Treatment Rule (SWTR)

[3]Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)

2.2. Future Regulatory Scenarios

The consultant team developed possible regulatory scenarios for the year 2030. These are predictions based on our team's experience with USEPA and on best professional judgment. Federal and State regulations are continuously evolving, and the exact scenarios in the year 2030 are unknown.

The regulatory scenarios focused on the priority constituents of concern for the Central Valley Drinking Water Policy, including DBP precursors, dissolved minerals, algal toxins, and pathogens and pathogen indicators (Table 1-2). The project team also reviewed the most recent Draft of the USEPA Contaminant Candidate Lists (CCL3) to determine additional contaminants of concern that may potentially be regulated by 2030. Ultimately, a plausible and an outer boundary regulatory scenario were developed (Table 2-2). The plausible regulatory scenario in 2030 includes contaminants that are likely to be regulated in some form; this is the regulatory scenario that will be used to evaluate potential WTP modifications and cost evaluations in subsequent tasks. The outer boundary regulatory scenario includes the same contaminants; however, the regulated levels are more stringent. The outer boundary scenarios will only be evaluated qualitatively. This section describes the basis for the regulatory scenarios. Appendix B identifies the specific contaminants that could be regulated under a group of contaminants (e.g., iodinated THMs), and includes available regulatory and health risk information.

Table 2-2
Potential Future Regulatory Scenarios

Constituent	Regulatory Scenarios		
	Current	**Plausible[1]**	**Outer Boundary[2]**
Disinfection Byproduct Precursors			
Organic Carbon and Organic Nitrogen	DBPR Enhanced Coagulation Requirements	DBPR Enhanced Coagulation Requirements	Control total organic carbon (TOC) as a precursor Control dissolved organic nitrogen (DON) as a precursor
Disinfection Byproducts			
Bromate	10 µg/L*	5 or 10 µg/L*	1 to 4 µg/L*
THMs			
THM4	80 µg/L (LRAA)	80 µg/*	Regulate individual species*
Iodinated THMs	-	Regulate iodinated THMs as a group*	Regulate individual species*
HAAs			
HAA5	60 µg/L (LRAA)	60 µg/L*	Individual levels for selected species
HAA9	-	80 µg/L (LRAA[5]), additional species to current regulations	1. 80 µg/L* 2. Individual levels for selected species*
Iodinated HAAs	-	-	Regulate individual species*

Constituent	Regulatory Scenarios		
	Current	**Plausible[1]**	**Outer Boundary[2]**
Nitrogenous Organic Compounds			
Nitrosamines	PHG 3 ng/L[3], Notification Level 10 ng/L[3] (NDMA)	NDMA at 3 or 10 ng/L* [4,]	(1) Control DON as a precursor (2) Regulate select compounds*
Hydrazine	-	-	10 ng/L*
Disinfection Practices and Views			
Chloramination	Accepted technology	Other technologies preferred	Technology not accepted
View of low to no use of disinfectants	View generally not accepted in U.S	View generally not accepted in U.S.	View begins to be accepted in U.S.
Dissolved Minerals			
TDS	500 mg/L secondary MCL	500 mg/L secondary MCL	Indirect reduction requirements for recycle water TDS
Algal Toxins			
Microcystin	-	1 µg/L (WHO guideline)	-
Anatoxin-a	-	-	3 µg/L (suggested, Australia)
Saxitoxin	-	-	3 µg/L (suggested, Australia)
Pathogens and Indicators			
Total coliform (TC), Fecal coliform (FC), and *E. coli*	Monitoring based upon population. Non-acute MCL for > 5% TC positive, acute MCL for FC or *E.coli* with confirmation in repeat sample.	Monitoring based upon population. Non-acute MCL for > 5% TC positive, acute MCL for *E.coli* with confirmation in repeat sample.	-
Cryptosporidium	2-log removal credit (IESWTR[6]); Additional inactivation needed based on source water concentration (LT2ESWTR)	2-log removal credit (IESWTR); Additional inactivation needed based on source water concentration (LT2ESWTR)	Additional 1-log
Other Pathogens	-	Regulated, but less challenging to remove than SWTR and LT2ESWTR standards	-

[1]Scenario will be used in treatment selection and costing.
[2]Scenario will be discussed qualitatively, but not included in costing.
[3]CDPH regulation.
[4]NDMA is considered by the regulatory agency as an indicator of other nitrosamines' levels
[5]Locational Running Annual Average (LRAA)
[6] Interim Enhanced Surface Water Treatment Rule (IESWTR)
*Single sample not to exceed.

2.2.1. DBPs

Currently regulated DBPs include THM4, HAA5, bromate, and chlorite. There are a number of reasons that the USEPA may consider modifying the current regulations for these DBPs as well as regulating other DBPs:

- Cancer is not the only health endpoint being detected in epidemiology studies; there are new concerns about potential adverse reproduction and developmental effects (Richardson 2005).
- New human exposure studies are including inhalation and dermal absorption routes of exposure to DBPs in addition to ingestion, which is revealing increased cancer risks (Richardson 2007).
- Brominated DBPs may be more carcinogenic than their chlorinated analogs (Richardson 2005, WHO 2000, Woo et al. 2002).
- Iodinated DBPs may be more carcinogenic than their brominated analogs (Richardson 2005, Plewa et al. 2004, Woo et al. 2002)

Bromate is currently regulated at 10 µg/L, which corresponds to a cancer risk factor of 2×10^{-4} (typically, the basis for MCLs is 10^{-4} to 10^{-6}). It is anticipated that this MCL could be reduced to 5 µg/L (plausible) or lower (outer boundary) in an effort to reduce the cancer risk to 1×10^{-4} or lower. This risk has to be balanced with the fact that bromate could be present in the common disinfectant chemical, sodium hypochlorite.

THMs are regulated as a group (THM4) on a LRAA basis at 80 µg/L under the Stage 2 DBP Rule (effective from 2012). Epidemiological evidence has produced uncertain and sometimes conflicting conclusions on the reproductive effects of exposure to DBPs. For example, an extensive literature review by Reif et al. 2000 found that evidence for an increased risk of spontaneous abortion and stillbirth exists but is uncertain (Health Canada 2006). A more recent study by American Water Works Research Foundation (AwwaRF) found no association between THM exposure and pregnancy loss (Savitz et al. 2005). More research is needed; however, due to the fact that contaminant levels can significantly vary with the LRAA calculation method, it is possible that the THM regulation will change to single sample not to exceed 80 µg/L to reduce variability and limit acute or reproductive health effects (plausible). As an increasing amount of health effects data becomes available, regulations may be directed to individual species to reduce associated health risks (outer boundary).

Despite the fact that occurrence of iodinated THMs is low relative to THM4 (Krasner et al. 2006), iodinated THMs are becoming increasingly important because recent research has shown increased human health risk levels compared to chlorinated and brominated DBPs (Woo et al. 2002). Currently iodinated THMs are not regulated; however, it is possible that they will be regulated (at least as a group) on a single sample not to exceed basis (plausible). It is not possible to predict a level for regulation at this time; more human health effect research is needed. Once more data becomes available, the iodinated species may even be regulated as individual species on a single sample not to exceed basis to reduce human health risks (outer boundary).

Similar to THMs, HAAs are regulated under the Stage 2 DBP Rule as a group (HAA5) at 60 µg/L on an LRAA basis. To limit variability and reduce acute human health effects, HAA5 regulation will possibly change to a single sample not to exceed (plausible). Further, as additional human health effect data becomes available, regulations may be

directed to individual species (outer boundary). It is recognized that additional regulation may be necessary to represent the entire group of HAAs that can be formed (HAA9). HAA9 is not currently regulated; however, it is possible that HAA9 will be regulated in the future and could be regulated as a group at a level of 80 µg/L LRAA (plausible). Although it is less likely, HAA9 regulation may be directed to 80 µg/L single sample not to exceed or depending on available human health affect data on an individual species basis (outer boundary).

Similar to iodinated THMs, iodinated HAAs are receiving more attention as further studies are demonstrating occurrence in finished water systems that use chloramines (Krasner et al. 2006) and increased human health risks relative to chlorinated and brominated DBPs (Richardson 2005). At this time, more occurrence and human health effect research is needed, and it is unlikely that iodinated HAAs will be regulated by 2030 (plausible). If additional data becomes available, regulation of iodinated HAAs may be directed towards individual species (outer boundary).

Another class of DBPs that may experience a change or addition to regulations are nitrogenous DBPs. NDMA, a carcinogen, has a CDPH public health goal (PHG) of 3 ng/L and a notification level of 10 ng/L. Essentially equivalent to the federal Maximum Contaminant Level Goal (MCLG), PHGs are set by California's Office of Environmental Health Hazard Assessment (OEHHA) and are based solely on scientific and public health considerations without regard to economic cost considerations. In California, PHGs are used in establishing the state's primary drinking water standards (MCLs). MCLs adopted by CDPH consider economic factors and technical feasibility, but must be set at a level that is as close as feasible to the corresponding PHG (OEHHA 2006). Currently, there is no MCL for NDMA.

It is predicted that NDMA (assuming it is representative of all nitrogenous DBPs) will pave the way for regulation of other nitrogenous DBPs. It is possible that the future regulation of NDMA will be at 3 or 10 ng/L single sample not to exceed (plausible). Although it is less likely, regulations requiring treatment for dissolved organic nitrogen (as a precursor) similar to the TOC removal requirements set forth in the Stage 1 DBP Rule could be established (outer boundary). Alternatively, if NDMA is determined to not be representative of nitrogenous DBPs, regulation of individual compounds could result (outer boundary).

Hydrazine is a probable human carcinogen that can be formed through the reaction of monochloramine and ammonia. Hydrazine is formed as a result of the addition of these chemicals, not due to source water quality. Additionally, hydrazine formation is not detectable in drinking waters with pH lower than 9.0 (Najm 2007). For this reason, regulation of hydrazine is not likely (plausible). However, the cancer risk level for hydrazine at 10 ng/L is 10^{-6}, and this risk level is within the range typically captured by an MCL. Although it is unlikely, plants using lime softening or distribution system conditions that result in pH excursions may create the need for future regulation of hydrazine at 10 ng/L single sample not to exceed (outer boundary).

2.2.2. Disinfection Practices and Views

With the increasing concern over DBPs, disinfection practices are increasingly scrutinized. The benefits of the inactivation of pathogens must continuously be balanced with the formation of compounds that adversely affect human health. For this reason, it is likely that chloramination may become the less preferred disinfection method, specifically because of potential nitrogenous DBP formation (plausible). Outside of the United States, the opinion is prevalent that residual disinfectants should minimally be used or not used at all. This viewpoint is not likely to be accepted in the United States; however, as an increasing number of studies indicate the adverse health effects associated with US disinfection practices, this view may become more accepted in the future (outer boundary).

2.2.3. Dissolved Minerals

Dissolved minerals are becoming an increasingly important issue in drinking water treatment. Currently, USEPA and CDPH have established secondary MCLs for TDS. The USEPA secondary MCL is 500 mg/L and is an unenforceable guideline. CDPH has established a secondary maximum contaminant level range for TDS. Secondary MCLs in California are enforceable limits based on a consumer acceptance contaminant level; however, the consumer acceptance contaminant level for TDS is not fixed (Table 2-3). As salinity continues to increase, adverse affects on the treatment process and the ability to recycle water may be experienced. It is likely TDS will be monitored in the future, and the regulation likely will not change (plausible). With the increasing importance of water recycling, TDS reductions may be necessary (outer boundary); however, it is unlikely that a SDWA regulation would require this.

Table 2-3.
Consumer Acceptance Contaminant Level

Constituent, Units	Recommended[1]	Upper[2]	Short Term[3]
Total Dissolved Solids, mg/L	500	1,000	1,500
Or			
Specific Conductance, µS/cm	900	1,600	2,200
Chloride, mg/L	250	500	600
Sulfate, mg/L	250	500	600

Source: CDPH, 2008.
Notes:
(1) Constituent concentrations lower than the recommended contaminant level are desirable for a higher degree of consumer acceptance.
(2) Constituent concentrations ranging to the Upper contaminant level are acceptable if it is neither reasonable nor feasible to provide more suitable waters.
(3) Constituent concentrations ranging to the short term contaminant level are acceptable only for existing community water systems on a temporary basis pending construction of treatment facilities or development of acceptable new water sources.

2.2.4. Algal Toxins

Algal toxins are toxins formed by cyanobacteria that dominate the freshwater phytoplankton communities during periods of calm, stratified conditions (AwwaRF 2008). Algal toxins are of increasing interest in the US and in other countries around the worldbecause it has been observed that increased discharges of nutrients can lead to increased algal blooms (and their toxins), which have been associated with an increased incidence of fish kills, deaths of livestock and wildlife, and human illness and death (Richardson 2007). The most common algal toxins are microcystins, anatoxins, and saxitoxins. Others have recognized the need to regulate these toxins, and it is possible that the US will follow. The World Health Organization (WHO) has a guideline value for microcystin of 1 µg/L, and it is possible that this could become an MCL by 2030 (plausible). Anatoxin-a and saxitoxin do not have WHO guidelines; however, Australia has a suggested limit for these toxins of 3 µg/L. Although it is not likely, there is a possibility that an MCL for anatoxin and saxitoxin could be established at the Australia suggested limit of 3 µg/L (outer boundary).

2.2.5. Pathogens

Currently, 2-log removal of *Cryptosporidium* is required by the IESWTR with additional inactivation required based on the bin classification outlined in the LT2ESWTR. These requirements are not likely to change by 2030, so the plausible scenario for *Cryptosporidium* inactivation will not require additional inactivation. However, future changes in source water quality could change bin classifications, triggering additional inactivation requirements. In the unlikely event that the requirements for *Cryptosporidium* removal/inactivation are increased to protect human health, it is predicted that an additional 1-log removal/inactivation will be required (outer boundary).

It is predicted that although pathogens other than *Cryptosporidium* will be regulated; none will be more challenging to remove or inactivate than *Cryptosporidium.* summarizes a number of pathogens that could possibly be regulated by 2030 based on the recommendations of expert panels from American Water Works Association (AWWA) and USEPA. Many are pathogens on the CCL3. Table 2-5 summarizes the treatment requirements that may be necessary to remove or inactive these pathogens. Based on this summary, it appears that the other pathogens that are likely to be regulated will not be more difficult to remove or inactivate compared to *Cryptosporidium.*

Table 2-4.
Recommended Pathogens for Regulation

Organism	CCL3 List	EPA Expert Recommended	AWWA Recommended
Caliciviruses (Noro Virus)	X	X	X
Campylobacter jejuni	X	X	X
Entamoeba histolytica	X	X	Exclude[1]
Escherichia coli (0157)	X	X	X
Helicobacter pylori	X	X	Exclude[1]
Hepatitis A virus	X	X	X
Legionella pneumophila	X	X	X
Naegleria fowleri	X	X	Exclude[1]
Salmonella enterica	X	X	
Shigella sonnei	X	X	
Vibrio cholerae	X	X	
Mycobacterium avium		Exclude[1]	X
Rotavirus		X	X
Enteroviruses (Coxsackieviruses and Echoviruses)		X	X
Adenovirus		X	

[1]Should not be regulated

Source: AWWA, 2008

Table 2-5.
Treatment of Pathogens

Organism	Free Chlorine	Ozone	UV
Caliciviruses	Aggregated calicicivirus required CTs greater than EPA Guidance Manual CT values. Disspersed calicicivirus required CTs less than EPA Guidance Manual CT values.[2]	<0.01 to 0.03 mg/L*min for 4-log inactivation at a pH of 7 and 5° C. [28]	29 to 36 mJ/cm2 for 4-log inactivation[3]
Campylobacter jejuni	Suseptible at doses effective for E. coli[4]	NA[1]	4.6 mJ/cm2 for 4-log inactivation[5]
Entamoeba histolytica	Similar resistance to chlorine as Giardia lamblia.6 Normal water treatment practices are able to remove Entamoeba cysts. [7]	NA[1]	NA[1]
Escherichia coli (0157)	4 log inactivation at CTs of approximately 1.1 to 1.2 mg/L*min[8]. 2-log inactivation at a CT of 0.119 mg/L* min[9]	0.09 mg/L*min for 2-log inactivation[9]	6 mJ/cm2 for 4-log inactivation[10]
Helicobacter pylori	2-log CT of 0.299 mg/L*min[9]	0.24 mg/L*min for 2-log inactivation[9]	NR[1]
Hepatitis A virus	CT table for SWTR are based on Hepatitis A	NR[1]	21 mJ/cm2 for 4-log inactivation [11]
Legionella pneumophila	2 to 13.5 mg/L*min for 2-log inactivation [12]	.5 to 1.5 mg/L*min for 2-log inactivation at a pH of 7.2 and 25° C.[12]	9.4 mJ/cm2 for 4-log inactivation [13]
Naegleria fowleri	2-log CT of 6 and 31 mg/L*min at a pH of 7.5 and 23°C for trophozoite and cyst form, respectively.[29]	NA[1]	63 mJ/cm2 for 2-log inactivation[29]
Salmonella enterica	Salmonella spp. are sensitive to chlorine and do not pose a risk when conventional drinking water treatment is applied. [14]	NA[1]	7 to 10 mJ/cm2 for 4-log of Salmonella spp. [10,15]
Shigella sonnei	Shigella spp. are sensitive to chlorine and do not pose a risk when conventional drinking water treatment is applied. [14]	0.9 to 1.4 mg/L*min for 1-log inactivation at a pH of 7.2 and 25° C. [30]	8.2 mJ/cm2 for 4-log inactivation[16]
Vibrio cholerae	Vegetative bacterium is widely known to be sensitive to chlorination and does not pose a risk when drinking water is properly disinfected.[14]	Can be inactivated by Ozone. [17]	2.9 to 21 mJ/cm2 for 4-log inactivation[18]
Mycobacterium avium	51 to 204 mg/L*min for 3-log inactivation at 23°C and a pH of 7. [19]	0.1 to 0.17 mg/L*min for 3-log inactivation at a pH of 7 and 23° C. [19]	NA[1]
Rotavirus	1.6 to 6.0 for 3-log inactivation at 4°C with pHs from 6 to 8.[20]	0.6 to 3.2 mg/L*min for 3-log inactivation with pHs from 6 to 8 at 4° C.[21]	36 mJ/cm2 for 4-log inactivation.[5]
Enteroviruses (Coxsackieviruses and Echoviruses)	0.14 to 33.66 mg/L*min for 2-log inactivation for Coxsackieviruses and 0.24 to 49.0 for Echoviruses at pHs from 6 to 10 at 5°C. [22]	0.1 mg/L*min for 3-log inactivation of unassociated coxsackievirus. 1.5 mg/L*min for 3-log inactivation of cell associated coxsackievirus at 5 NTU. [23]	32.5 to 36 mJ/cm2 for 4-log inactivation of Coxsackieviruses. 28 to 33 mJ/cm2 for 4-log inactivation of Echoviruses.[24]
Adenovirus	0.16 to 0.75 mg/L*min for 4-log inactivation at pHs from 6 to 8 and at 5° C. 36.09 mg/L*min for 4-log inactivation at pH of 8 and 15° C.[2]	0.07 to 0.6 mg/L*min for 4-log inactivation at a pH of 7 and 5° C. [25]	100 to 124 mJ/cm2 for 4-log inactivation with low pressure UV lamps. [26,27] Approximately 40 mJ/cm2 for 4-log inactivation with medium pressure UV lamps. [28]
Giardia	24 to 389 mg/L*min for 3-log inactivation depending on temperature, chlorine concentration, and pH.[32]	0.48 to 2.9 mg/L*min for 3-log inactivation depending on temperature.[32]	22 mJ/cm2 for 4-log inactivation.[31]
Cryptosporidium	Free chlorine is ineffective at inactivating Cryptosporidium. [33]	4.7 to 72 mg/L*min for 3-log inactivation depending on temperature. [31]	22 mJ/cm2 for 4-log inactivation.[31]

[1] NA = Not Available, results were not found during literature search. 2. Thurston-Enriquez et al. 2003a., 3. Thurston-Enriquez et al. 2003b., 4. Blaser et al. 1986, 5. Wilson et al. 1992, 6. Jarroll et al. 1981, 7. Karanis 2006, 8. Rice et al. 2008, 9. Baker et al. 2002 , 10. Tosa and Hirata 1999, 11. Wiedenmann et al. 1993, 12 Domingue et al 1998, 13 Oguma et al. 2004, 14 AWWA 2008., 15 Yaun et al 2003, 16 Chang et al. 1985 , 17. Burlson et al. 1975, 18. Hoyer 1998, 19. Taylor et al. 2000, 20. Vaughn et al. 1986, 21. Vaughn et al. 1987, 22. Engelbrecht et al. 1980, 23. Emerson et al. 1982, 24. Gerba et al. 2002, 25. Thurston-Enriquez et al. 2005, 26. Meng and Gerba 1996, 27. Ballester and Malley 2004, 28. Linden et al. 2007. 29. CAP 2008. 30. Lezcano et al. 1999. 31. USEPA 2006. 32. USEPA 1991. 33. Venczel et al. 1997

2.2.6. Other Contaminants of Concern

There are many contaminants of increasing concern that now are being detected in water supplies due to advances in analytical capabilities allowing for detection at the ng/L level. These contaminants include PPCPs such as antibiotics, pain killers, detergents, perfumes, disinfectants, steroids, and synthetic hormones and EDCs such as pesticides, surfactants, plasticizers, synthetic hormones, and organohalogens. Many PPCPs and EDCs are not yet regulated in the US. New regulations could be based on a common mechanism for toxicity (e.g., endocrine disruption) instead of by individual compound. Alternatively, regulations could require a specific treatment technology (e.g., granular activated carbon) for an array of chemicals, instead of setting standards for specific MCLs (Archibald Consulting, 2007; AWWARF, 2005).

The regulatory scenarios developed in this project focused primarily on the priority constituents of concern for the Central Valley Drinking Water Policy and did not address PPCPs or EDCs. These contaminants will not be considered during the treatment process selection; however, a qualitative discussion will be included as part of an intangible benefits analysis (Task 6).

3. Areas of Similar Source Water Quality

Understanding the source water quality for the existing WTPs is paramount when evaluating whether existing WTPs will meet potential future regulations and determining what treatment changes (if any) may be necessary. Accordingly, identifying areas that use Central Valley surface water that have similar water quality will simplify the necessary analyses. This section identifies the source water areas and its associated water quality that will be used in this analysis.

3.1. Determination of Source Water Areas

The Work Group identified five geographical areas that utilize water from the Delta and its tributaries, and have similar source water quality (similar levels of constituents of concern):

- Upper Sacramento and Upper-Eastern San Joaquin Watersheds (Upper Watersheds)
- North Bay Aqueduct (NBA)
- Central Delta including the South Bay Aqueduct (Central Delta)
- California Aqueduct- Coastal and East Branches (CAA)
- California Aqueduct- West Branch (CAA-West Branch)

Geographical area boundaries were not designated; the source water areas were bounded by the WTPs in each region with similar intake water quality (Figure 3-1). A total of 49 WTPs that use Delta water as a major source were considered.

3.2. Current Water Quality by Source Water Area

To characterize the water quality for each source water area, a review of available water quality data and reports was performed. Key sources of information included:

- Raw data provided by the Work Group
- Raw data from California Department of Water Resources (DWR) Water Data Library (WDL)
- California State Water Project 2006 Watershed Sanitary Survey Update (Archibald Consulting, June 2007)
- Conceptual Model for Pathogens and Pathogen Indicators in the Central Valley and Sacramento-San Joaquin Delta (Tetra Tech, August 2007)

The Work Group identified five water monitoring locations that are representative of each source water area (Table 3-1). These monitoring locations were used to summarize the water quality trends of key contaminants of concern that are discussed in the following sections. Please note that observations of water quality trends are not described in this section because additional information on current and projected source water quality will be provided by the Work Group; therefore, it is possible that any current trends shown by the data in the section below will change.

Figure 3-1: Source Water Areas[1]

[1]WTPs used to designate source water areas are described further in Section 4 and Table 4-1.

Table 3-1.
Representative Water Quality Monitoring Locations

Source Water Area	Monitoring Location	DWR Monitoring Station Number
Upper Watersheds	Sacramento River at Hood	B9D82211312
NBA	Barker Slough Pumping Plant	B9D81651476, KG000000, B9D81661478
Central Delta	Banks Pumping Plant	KA000331
CAA	Check 13	KA007089
CAA- West Branch	Castaic Lake Tower	CA002000

Source: Representative monitoring locations provided by Work Group.

3.2.1. Parameters Affecting Disinfection Byproduct Formation

Organic carbon and bromide are known as DBP precursors because they interact with chlorine during disinfection to form THMs and HAAs. Bromide can also react with ozone to form bromate, another regulated DBP. This section discusses the occurrence of organic carbon and bromide in the Delta and its tributaries and the concentrations typically found in each source water area.

Total Organic Carbon

Increased TOC concentrations can affect DBP formation in two ways: by increasing the amount of disinfectant required to achieve sufficient disinfection and by increasing DBP formation potential. TOC consists of particulate organic carbon and dissolved organic carbon (DOC).

TOC and DOC data were generally available from 1998 to 2007. These data were analyzed according to the oxidation method of analysis. The median TOC levels in the five source water areas ranged from 1.8 to 5.9 mg/L with an average of approximately 3.4 mg/L (Figure 3-2). The median DOC levels in the source water areas ranged from 1.7 to 4.2 mg/L with an average of approximately 3.6 mg/L (Figure 3-3).

Alkalinity

TOC removal can become more challenging as the alkalinity of the water increases, especially as the TOC decreases. As discussed in Appendix A, the TOC and alkalinity levels in the source water dictate treatment requirements. Based on the available data (approximately 1998 to 2007) median alkalinity values in the five source water areas ranged from 61 to 92 mg/L and had an average of approximately 78 mg/L (Figure 3-4). With these alkalinity levels, the Stage 1 DBP Rule requires the areas to remove at least 25 to 35 percent of their source water TOC (unless they meet alternative compliance criteria).

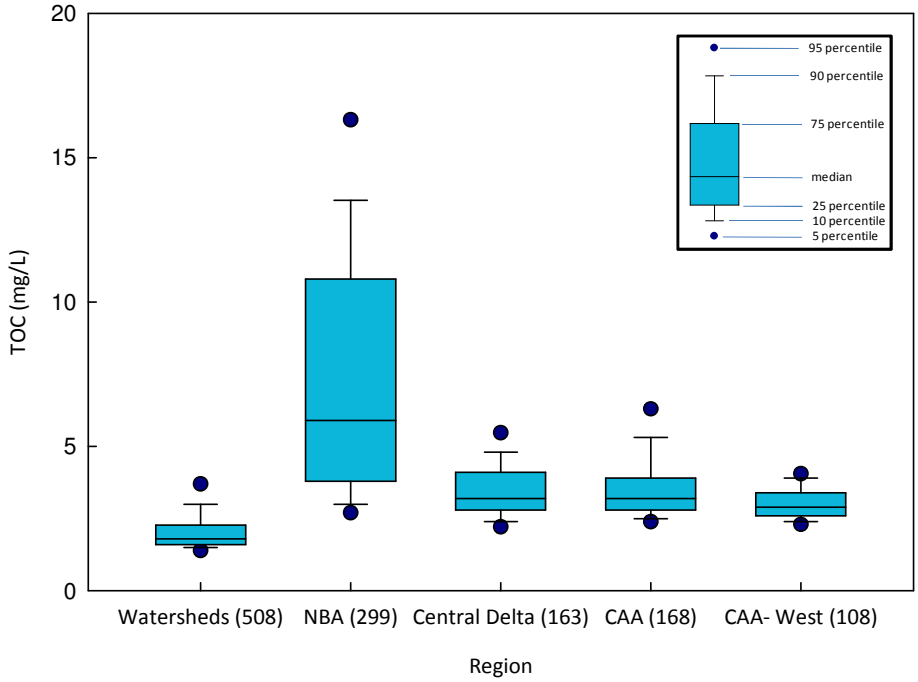

Figure 3-2: TOC Concentrations

(Number of Data Points Shown in Parenthesis)

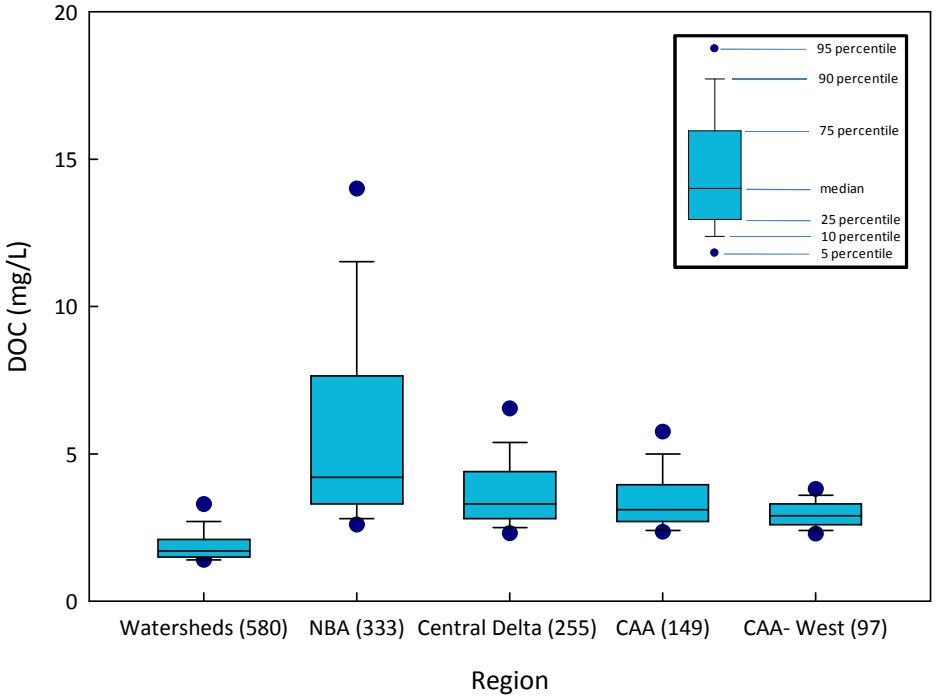

Figure 3-3: DOC Concentrations

Data obtained from California Department of Water Resources Water Quality Data Library.

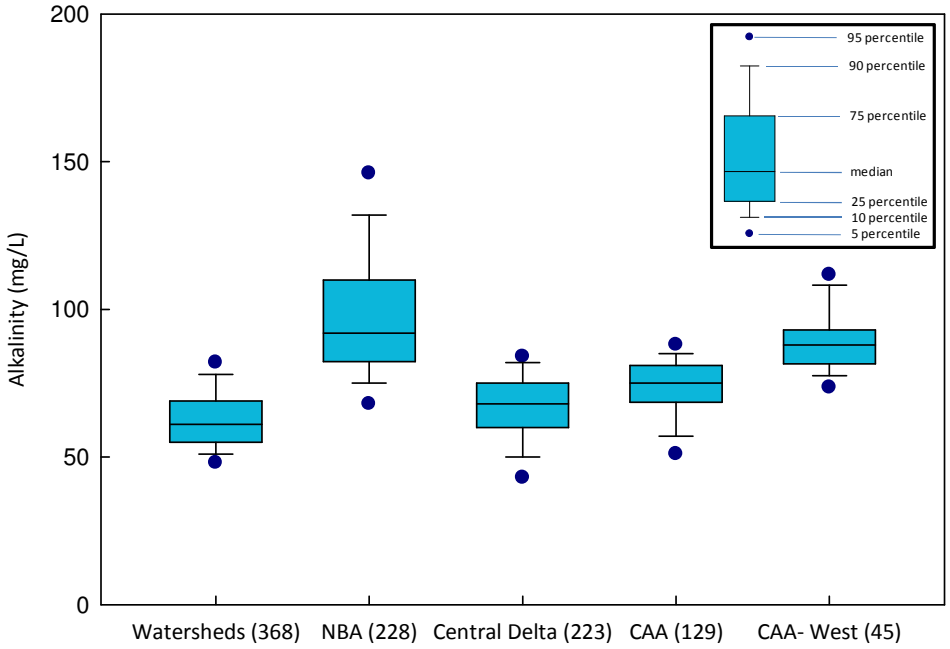

Figure 3-4: Alkalinity Concentrations

Data obtained from California Department of Water Resources Water Quality Data Library.

Specific Ultraviolet Absorbance (SUVA)

SUVA can be used to characterize the DOC, which is composed of humic and nonhumic substances. SUVA is calculated by dividing the ultraviolet absorbance at 254 nm (UV-254 measured in units of cm^{-1} and converted to m^{-1}) by the DOC concentration (mg/L), resulting in units of L/mg-m (see equation below).

$$SUVA\left(\frac{L}{mg \cdot m}\right) = \frac{UV\left(\frac{1}{cm}\right) \times 100\left(\frac{cm}{m}\right)}{DOC\left(\frac{mg}{L}\right)}$$

SUVA values less than approximately 3 L/mg-m are typical of waters containing primarily nonhumic substances. SUVA values of 4 to 5 L/mg-m are typical of waters containing primarily humic substances. SUVA can also be predictive of the organic removal capacity of water treatment practices. For instance, waters with a high SUVA result in greater reductions of TOC, and waters with low SUVA result in relatively low reductions of TOC (USEPA, 1999).

If the SUVA level is less than 2.0 L/mg-m, compliance with the TOC removal treatment technique requirements in the Stage 1 DBPR is challenging and can be achieved through the alternative compliance criteria. SUVA for four of the five source water areas was

calculated (there was insufficient data to calculate values for the CAA-West source water area), and it was found that the median SUVA values ranged from 2.7 to 3.3 L/mg-m and averaged of 3.1 L/mg-m. This indicates that the water in these source water areas is composed of primarily nonhumic substances. SUVA values in this range are not particularly low, which indicates that conventional treatment processes should be able reduce TOC concentrations in accordance with Stage 1 DBPR.

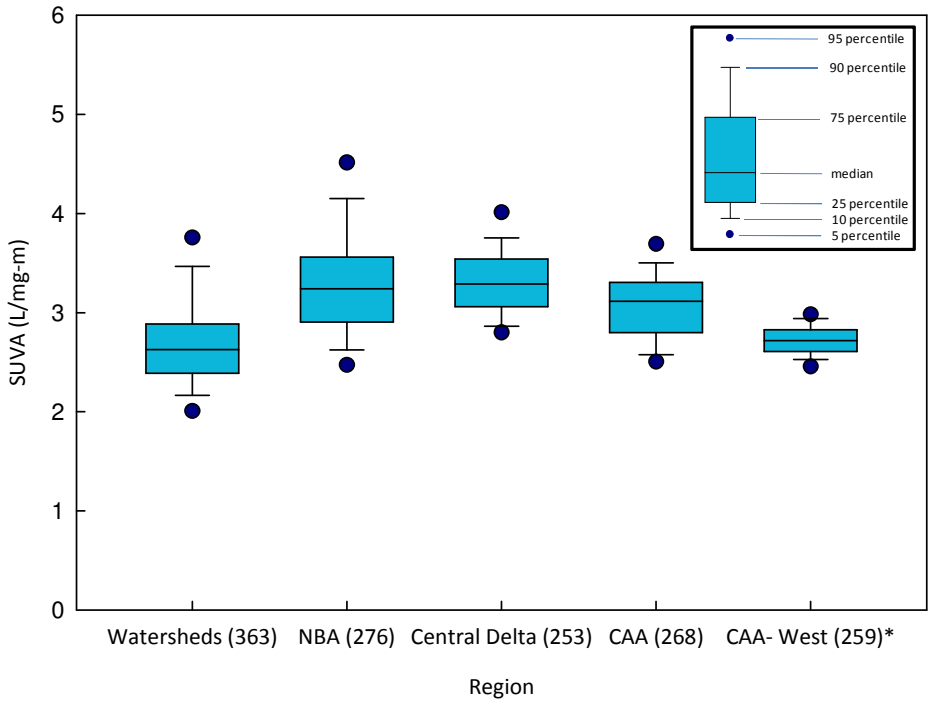

Figure 3-5: SUVA Levels

*CAA-West SUVA levels were calculated from MWD provided Jensen WTP Influent data (2000 to 2007). Castaic Lake Monitoring Station data from the WDL were not available.

Bromide

Three of the four regulated THMs and two of the five regulated HAAs contain bromide. Bromide can also react with ozone to form bromate, another regulated DBP. Median bromide levels in the Delta and its tributaries ranged from 0.01 to 0.19 mg/L with an average of 0.14 mg/L (Figure 3-6).

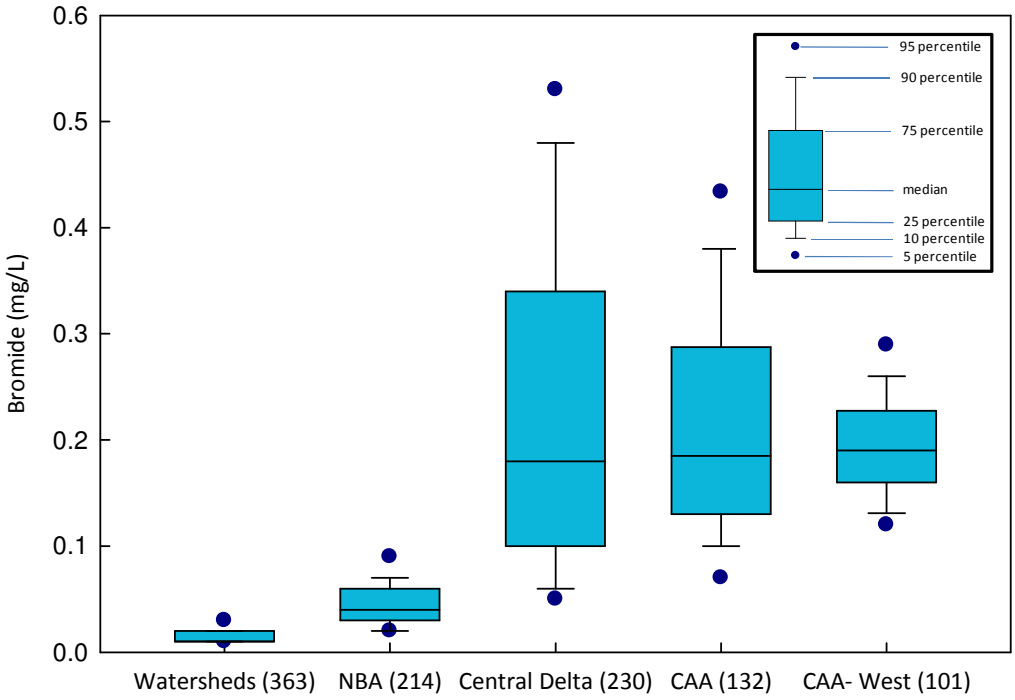

Figure 3-6: Bromide Concentrations

The regulatory scenarios projected for 2030 contain regulations for a number of DBPs including THMs, iodinated THMs, HAAs, iodinated HAAs, NDMA, and hydrazine. DBP formation will affect whether additional treatment may be necessary at existing WTPs in each source water area. Table 3-2 summarizes the key water quality parameters that affect DBP formation.

Table 3-2.
Summary of DBP Precursor Levels by Source Water Area

	Upper Watersheds	NBA	Central Delta	CAA	CAA-West
TOC (mg/L)					
Median	1.8	5.9	3.2	3.2	2.9
95 Percentile	3.67	16.2	5.3	6.3	4.0
DOC (mg/L)					
Median	1.7	4.2	3.3	3.1	2.9
95 Percentile	3.2	13.9	6.3	5.5	3.8
Alkalinity (mg/L)					
Median	61	92	68	75	88
95 Percentile	82	145	84	88	111
Stage 1 DBPR TOC Removal Requirement (percent)[1]	25	35	35	25	25
SUVA (L/mg-m)					
Median	2.6	3.2	3.3	3.1	2.7
95 Percentile	3.7	4.5	4.0	3.7	3.0
Bromide (mg/L)					
Median	0.01	0.04	0.18	0.19	0.19
95 Percentile	0.03	0.09	0.53	0.43	0.28

[1]If alternative compliance criteria are not met.

3.2.2. Dissolved Minerals

Dissolved minerals can be measured as either TDS or electrical conductivity (conductivity). The USEPA has established a secondary MCL (non-enforceable) of 500 mg/L for TDS and CDPH has secondary MCLs (enforceable) of 500 mg/L for TDS and 900 µS/cm for conductivity (CDPH 2008). The salinity in the tributaries to the Delta is influenced by natural, urban, and agricultural sources. As the tributaries flow through the Delta, they (along with urban discharges and seawater intrusion) contribute to the Delta salinity. Ultimately, the salinity in the Delta is variable and is affected by the hydraulic conditions and releases from upstream reservoirs, which influence seawater intrusion.

A review of conductivity and TDS data from approximately 1998 to 2007 revealed that salinity in the source water area are variable. Median conductivity ranged from 156 to 483 µS/cm, with an average of 383 µS/cm (Figure 3-7). Median TDS ranged from 97 to 283 mg/L, with an average of 202 mg/L.

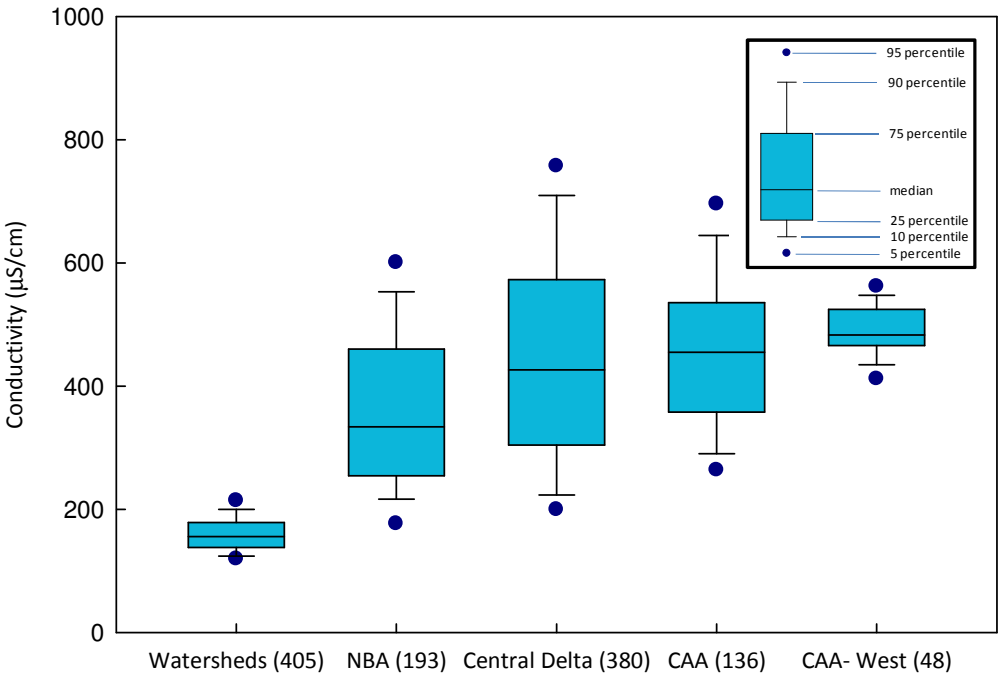

Figure 3-7: Conductivity

Data obtained from California Department of Water Resources Water Quality Data Library.

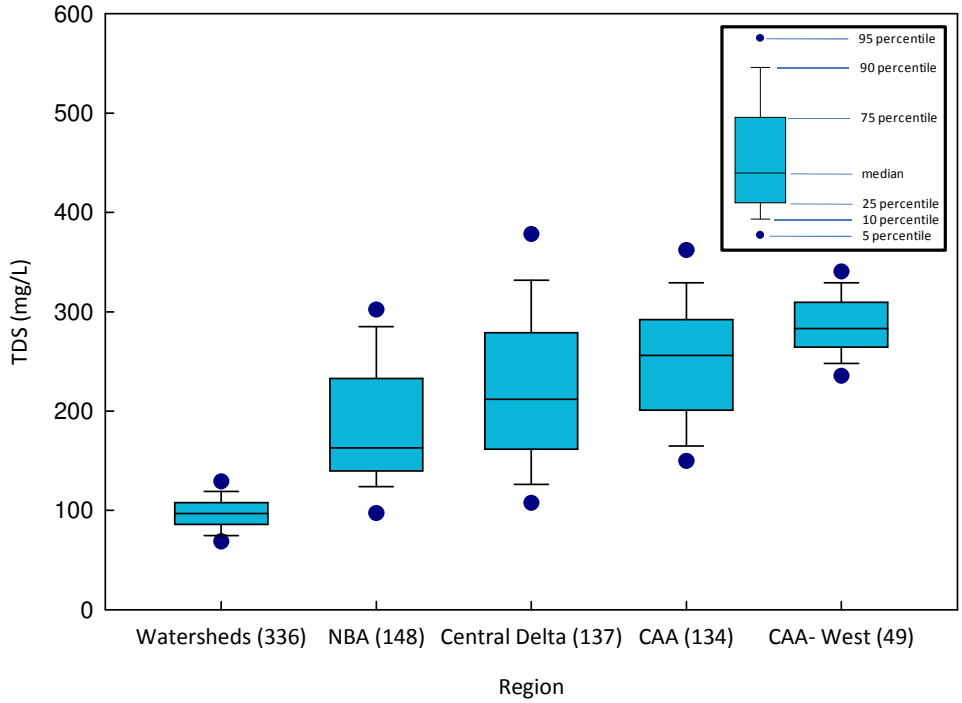

Figure 3-8: Total Dissolved Solids

Data obtained from California Department of Water Resources Water Quality Data Library.

3.2.3. Nutrients

Increased levels of nutrients such as nitrogen and phosphorus can lead to algal and vascular plant growth. Associated treatment concerns include taste and odor problems, increased levels of organic carbon, filtration impacts, and potentially higher levels of nitrogenous DBPs (e.g., NDMA) and algal toxins. The USEPA established nitrogen and phosphorus reference conditions in a 2001 Ambient Water Quality Criteria Recommendations Report to assist states in developing nutrient water quality standards for receiving waters. These values are guidelines and are not enforceable. The state of California is considering the adoption of nutrient water quality standards, but has not released an official proposal to date. The nitrogen and phosphorus reference conditions generally represent nutrient levels that protect against the adverse effects of nutrient over enrichment and generally apply to the source water areas in this analysis. The reference concentration for total nitrogen is 0.31 mg/L and total phosphorus is 0.047 mg/L (USEPA 2001a). Total nitrogen includes nitrate, nitrite, ammonia, and organic nitrogen. Total phosphorus includes particulate and dissolved phosphorus. The particulate phosphorus includes organic phosphorus incorporated in planktonic organisms, inorganic mineral phosphorus in suspended sediments, and phosphate adsorbed to inorganic particles. The dissolved phosphorus includes dissolved organic phosphorus, orthophosphate, and polyphosphates.

Data from approximately 1998 to 2007 indicated that total nitrogen and total phosphorus concentrations in the Delta and its tributaries are significantly higher than USEPA's total nitrogen and total phosphorus reference concentrations (USEPA 2001a). Median total nitrogen concentrations ranged from 0.67 to 0.96 mg/L and averaged 0.87 mg/L (Figure 3-9). Median total phosphorus concentrations ranged from 0.04 to 0.19 mg/L and averaged 0.12 mg/L (Figure 3-10).

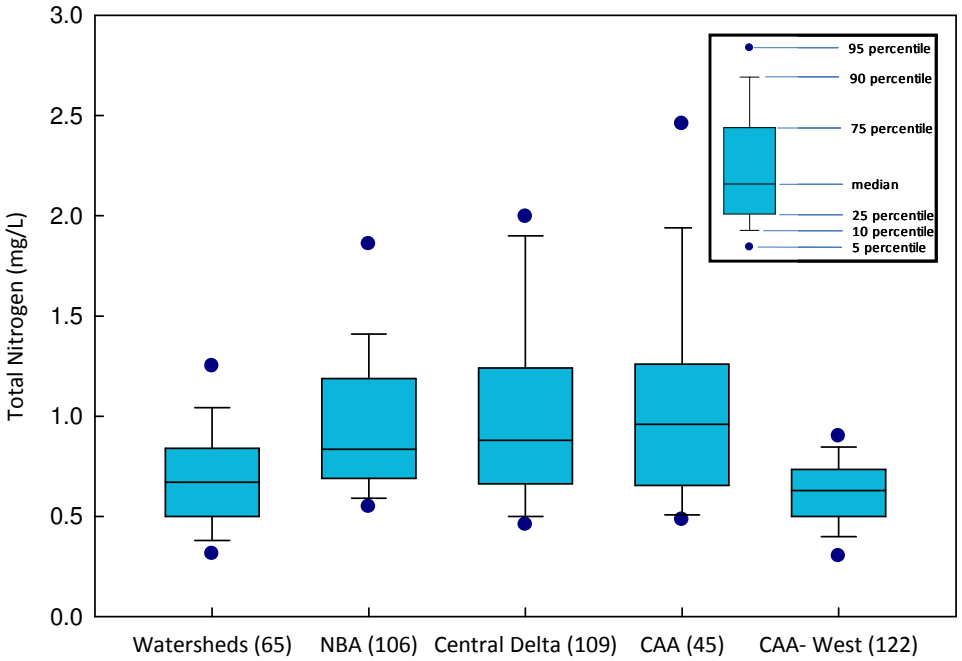

Figure 3-9: Total Nitrogen

Data obtained from California Department of Water Resources Water Quality Data Library.

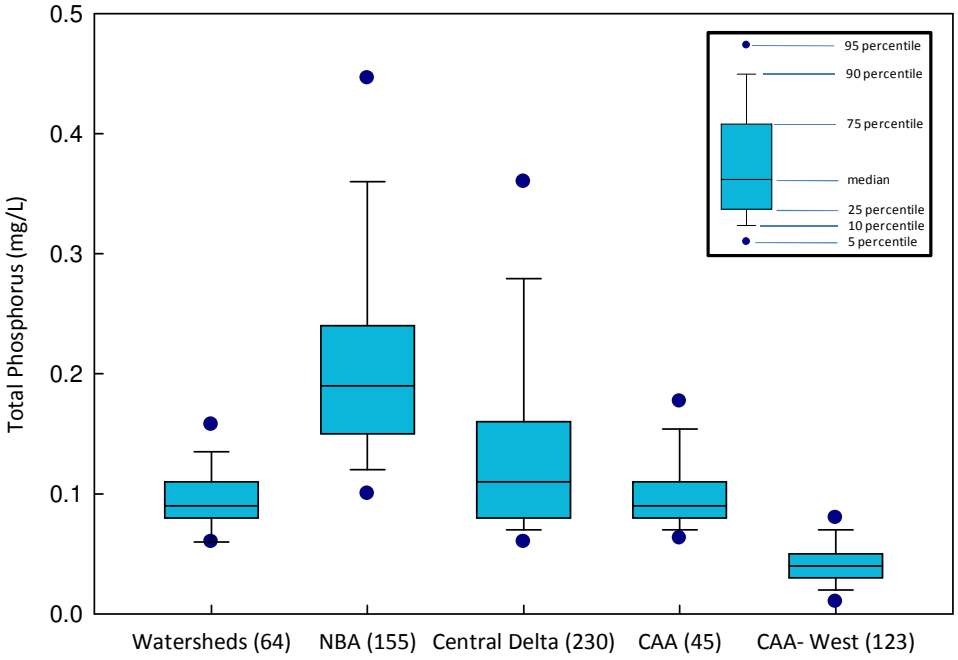

Figure 3-10: Total Phosphorus

Data obtained from California Department of Water Resources Water Quality Data Library.

In addition to considering total nitrogen levels, DON was estimated. DON is a precursor to nitrogenous DBP formation and could be used to assess the potential for increased NDMA formation. DON was not directly measured for each source water area; instead, DON was estimated as the difference between Total Kjeldahl Nitrogen (TKN) and ammonia value, assuming that the TKN sample was filtered and represents DON instead of total organic nitrogen. DON was calculated from TKN and ammonia data from approximately 1998 to 2007. Median DON values ranged from 0.22 to 0.57 mg/L and averaged

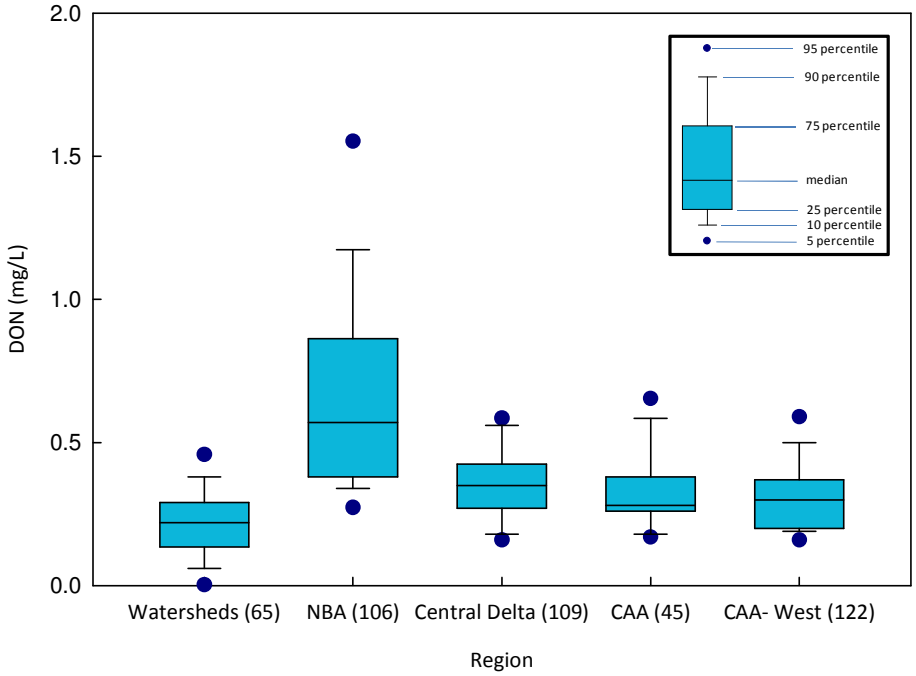

Figure 3-11: Estimated DON Levels[1]

[1]DON estimated as TKN minus ammonia. TKN and ammonia data obtained from California Department of Water Resources Water Quality Data Library.

3.2.4. Algal Toxins

With the emergence of toxic algal blooms and cyanobacteria, California DWR has recognized the importance of monitoring for algal toxins such as microcystins. California DWR monitors for microcystins from June to October, which is the time of year that the toxin is most likely to occur. Data from 2004 to 2007 in various locations throughout the Delta and the State Water Project (SWP) show that microcystins are present but at concentrations less than 1 µg/l.

3.2.5. Pathogens and Indicator Organisms

The SWTR, IESWTR, and LT2ESWTR (discussed in detail in Appendix A) set treatment requirements to protect the public from pathogenic bacteria, viruses, and protozoans.

Monitoring for all pathogens is impossible, so most monitoring is directed towards *Giardia* and *Cryptosporidium* (pathogenic protozoan). Additionally, fecal coliform, total coliform, and *Escherichia coli* (*E. coli*) are used as indicators of the microbiological quality of water. To assess the microbiological profile of the five source water areas, data from the 2006 Watershed Sanitary Survey Update, the Conceptual Model for Pathogens and Pathogen Indicators in the Central Valley and Sacramento-San Joaquin Delta (Tetra Tech 2007), and the Sacramento River Water Treatment Plant were reviewed. The data that were available were variable (varying sampling frequencies, different methods for determining bacteria densities, different periods of record) and as noted did not always correlate with the monitoring locations used previously in this water quality analysis. Table 3-3 summarizes the number and range of *Giardia* and *Cryptosporidium* detects, and Table 3-4 summarizes the fecal coliform, total coliform, and *E. coli* ranges for the source water areas (data sources and monitoring locations noted on tables).

Table 3-3.
Source Water *Giardia* and *Cryptosporidium* Detections

Source Water Area	Data Period	Number of *Giardia* Detections	Range of *Giardia* Detections (cysts/L)	Number of *Crypto* Detections	Range of *Crypto* Detections (oocysts/L)
Upper Watersheds[1]	2001 to 2004	1	0.09	0	-
NBA[2]	2000 to 2005	8	0.1 to < 0.4	5	0.1 to 0.8
Central Delta[3]	2005 to 2005	1	0.1	0	-
CAA[4]	2003 to 2005	1	0.6	0	-
CAA- West Branch[5]	2000 to 2005	0	-	1	0.1

Source: [1]Sacramento River Water Treatment Plant Presumed *Crypto* and *Giardia* detects (raw data provided to project team by Work Group).

[2]2006 Watershed Sanitary Survey Update- DWR data at Barker Slough

[3]2006 Watershed Sanitary Survey Update- Patterson Pass, Del Valle, and Penitencia WTP data

[4]2006 Watershed Sanitary Survey Update- Central Coast Water Authority Polonio Pass WTP data

[5]2006 Watershed Sanitary Survey Update- Metropolitan Water District of Southern California Jensen WTP data

Table 3-4.
Source Water Fecal Coliform, Total Coliform, and *E. coli* Detections

Source Water Area	Data Period	Range of Fecal Coliforms (MPN/100 mL)	Range of Total Coliforms (MPN/100 mL)	Range of E. coli (MPN/100 mL)
Upper Watersheds[1]	2000 to 2004	-	80 to > 16000	2 to 16000
NBA[2]	2000 to 2005	25 to 230[a]	200 to 2400	30 to 3000[b]
Central Delta[3]	2005 to 2005	-	2 to 11000	2 to 240
CAA[4]	2005 to 2006	-	10 to 320	2 to 26
CAA- West Branch[5]	2000 to 2005	2 to 300	2 to 510	-

Source: [1]Sacramento River Water Treatment Plant total coliform and *E.coli* data(raw data provided to project team by Work Group).

[2]2006 Watershed Sanitary Survey Update- monthly median total and fecal coliforms at the North Bay Regional WTP Intake.

[a]Data period was 2003 to 2005.

[b]E.coli counts associated with pathogen and indicator bacteria detection at Barker Slough (see Table 3-3)

[3]2006 Watershed Sanitary Survey Update- Patterson Pass, Del Valle, and Penitencia WTP data

[4]2006 Watershed Sanitary Survey Update- Central Coast Water Authority Polonio Pass WTP data

[5]2006 Watershed Sanitary Survey Update- Metropolitan Water District of Southern California Jensen WTP data

4. Current Water Treatment Practices

The current WTPs in each source water area are evaluated to determine the effect of the future source water quality changes and the 2030 regulatory scenario. This section summarizes the WTPs and identifies water treatment trends in each source water area.

4.1. Water Treatment Plants in Each Source Water Area

Existing WTPs in each of the five source water areas were identified. The number, size, and treatment processes of the WTPs vary within and across each source water area. Table 4-1 summarizes the WTPs that are included in each source water area and the size of each plant.

Table 4-1.
Water Treatment Plants in each Source Water Area

Source Water Area	System Name	Facility	Size (mgd)
Upper Watersheds	City of Sacramento	American River WTP (Fairbairn)	200
	Carmichael Water District	Bajamont SWTP	17
	City of Redding	Sacramento River @ Foothill WTP	28
	Yuba County	WTP	24
	City of West Sacramento	Bryte Bend WTP	160
	City of Sacramento	Sacramento River WTP	160
	East Bay MUD	Layfayette WTP	25
		Orinda WTP	175
		Walnut Creek WTP	91
	Modesto Irrigation District	Modesto Reservoir	45
	Stockton East Water District	WTP	45
	Calaveras County Water District	West Point WTP	1
		Bear Creek	*
		Mokelumne River	*
NBA	City of Fairfield and Vacaville	North Bay Regional WTP	40
	City of Fairfield	Waterman WTP	22.5
	City of Benicia	Benicia WTP	12
	City of Vallejo	Fleming Hill WTP	42

*Data not available

Table 4-1 Continued.

Source Water Area	System Name	Facility	Size (mgd)
NBA	City of Vallejo	Travis WTP	7.5
	City of American Canyon	American Canyon WTP (2 plants w/matching flow systems, 1 conventional and 1 membrane)	2.2
Central Delta	Contra Costa Water District	Bollman WTP	75
	Contra Costa Water District	Randall Bold WTP	40
	City of Antioch	Antioch WTP	26
	Zone 7 Water Agency	Del Valle	44
		Patterson Pass	21
	Alameda County Water District	WTP #2	28
		Mission San Jose WTP	8
	Santa Clara Water District	Penitencia WTP	42
CAA	Santa Clara Water District	Santa Teresa WTP	100
		Rinconada WTP	80
	City of Dos Palos	Dos Palos WTP	3
	City of Coalinga	Coalinga WTP	12
	City of Huron	Huron WTP #2	*
	City of Avenal	Avenal WTP #2	3.1
		Avenal WTP #1	2.2
	Central Coast Water Authority	Polonio Pass WTP	43
	Antelope Valley East Kern Water Agency	Rosamund WTP	14
		Quartz Hill WTP	65
		Acton WTP	4
		Eastside WTP	10
	Palmdale	Palmdale Filter Plant	30
	CLAWA	Lake Silverwood WTP	5
	Metropolitan Water Dist. Of So. Cal	Mills WTP	160
		Diemer WTP	520
		Skinner WTP	630
		Weymouth WTP	520
CAA-West Branch	Metropolitan Water District of So. Cal	Jensen WTP	750
	Castaic Lake Water Agency	Earl Schmidt WTP	56
	Castaic Lake Water Agency	Rio Vista WTP	30

*Data not available

4.2. Current Water Treatment Practices in Each Source Water Area

The treatment processes used in each source water area were evaluated to determine trends in water treatment practices. Conventional coagulation/flocculation/sedimentation is a common treatment in all source water areas. However, the filtration, disinfection, and additional treatment processes vary in each source water area. Table 4-2 describes the types of water treatment unit processes that were considered. The following sections summarize the water treatment practices in each source water area.

Table 4-2.
Water Treatment Unit Processes

Item	Purpose
Coagulation/Flocculation/Sedimentation	
Rapid Mix	Uniform coagulant dispersion
Coagulation	Particle destabilization
Flocculation	Particle agglomeration
Sedimentation	Particulate removal
Filtration	
Multi-Media/Rapid Sand/Pressure Sand*	Particulate removal
Pressure Sand	Particulate removal
Slow Sand	Particulate removal
Membranes	Particulate removal
Primary Disinfection	
Chlorine	Disinfection credit
Mixed oxidants (MIOX)	Disinfection credit
Ozone	Disinfection credit
Secondary Disinfection	
Chlorine	Maintain residual chlorine in distribution system
Chloramines	Maintain residual chlorine in distribution system
Other	
Granular Activated Carbon (GAC) (T&O)	Taste and Odor (T&O) control
Fluoridation	Public dental health
Lime-Soda Ash	Corrosion control or softening
Permanganate	T&O control, iron and manganese oxidation
GAC (DBP)	DBP control
Powdered Activated Carbon (PAC)	T&O control
Aeration	T&O control, iron and manganese oxidation
Pre- pH Adj.	Enhanced coagulation for DBP control or
Post- pH Adj.	Corrosion control
Orthophosphate	Corrosion control

*Displayed in figures as “Multi-Media”

4.2.1. Upper Watersheds Source Water Area

The Upper Watersheds source water area contains 14 WTPs with flow rates ranging from 1 million gallons per day (MGD) to 200 MGD. Approximately 93 percent of the WTPs in the Upper Watersheds source water area have media filtration with the majority also having coagulation/ flocculation/ sedimentation (Figure 4-1). This source water area also has a membrane filtration plant. The majority of the WTPs use free chlorine for primary disinfection; however, one WTP uses ozone. The WTPs use both free chlorine (79 percent) and chloramines (21 percent) for secondary disinfection. Additional treatment processes include PAC/ GAC, softening, aeration, and pH adjustment. However, the number of plants that use these technologies is limited.

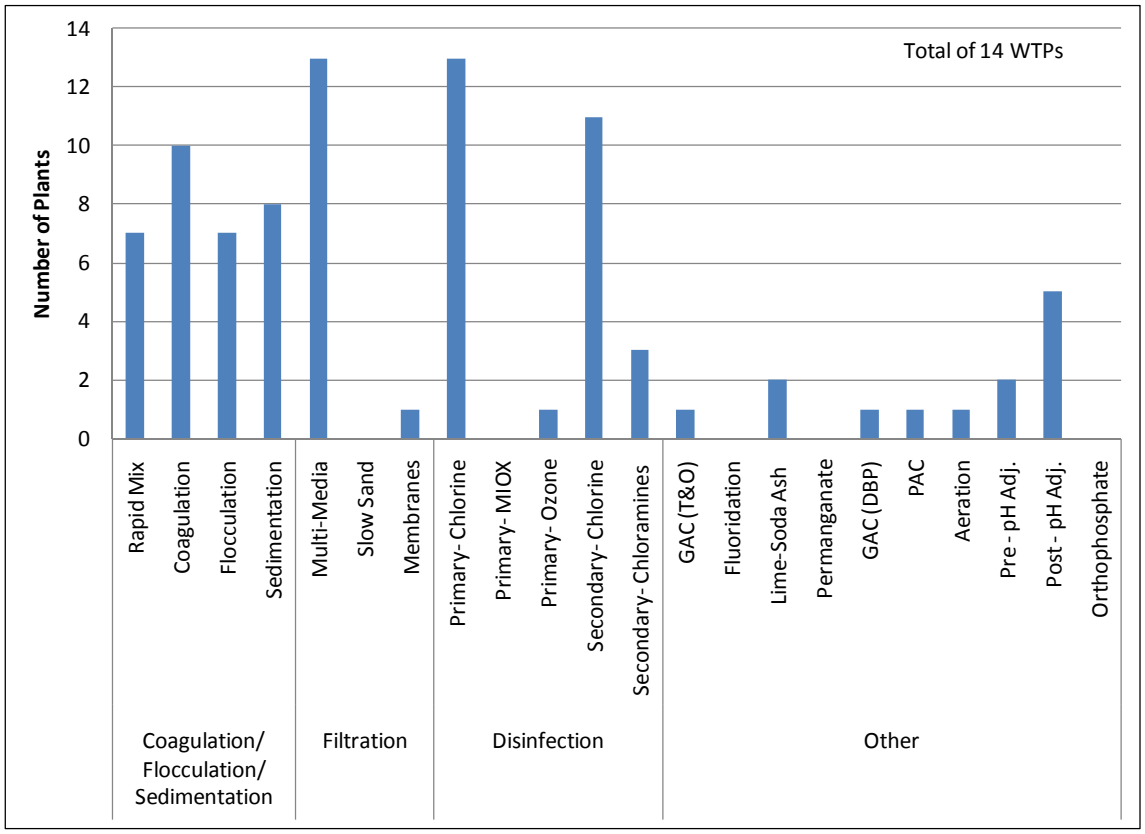

Figure 4-1: Water Treatment Plant Unit Processes in the Upper Watersheds Source Water Area

4.2.2. North Bay Aqueduct Source Water Area

The North Bay Aqueduct source water area contains 6 WTPs with flow rates ranging from 3 MGD to 40 MGD. The majority of the WTPs use coagulation/ flocculation/ sedimentation followed by media filtration (Figure 4-2). The majority of the WTPs use free chlorine for primary disinfection; only one WTP utilizes ozone. All of the WTPs use free chlorine for secondary disinfection.

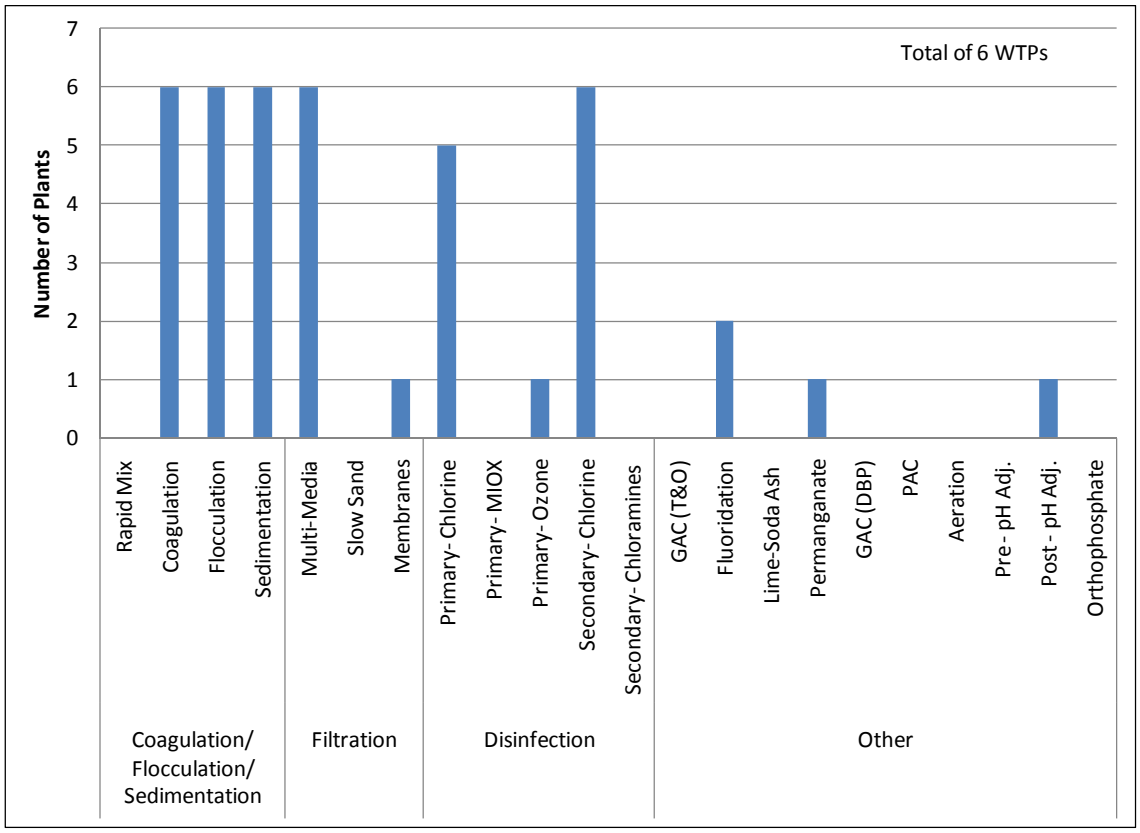

Figure 4-2: Water Treatment Plant Unit Processes in the NBA Source Water Area

4.2.3. Central Delta Source Water Area

The Central Delta source water area contains 8 WTPs with flow rates ranging from 8 MGD to 75 MGD. The majority of the WTPs in this source water area utilize media filtration (Figure 4-3). The source water area also has two slow sand filtration plants and two membrane filtration plants. One of the membrane filtration plants includes slow sand filtration as pretreatment. All WTPs use free chlorine for primary disinfection with half of the WTPs also using ozone in addition to free chlorine. The majority of the WTPs use chloramines for secondary disinfection; only one WTP uses free chlorine. Corrosion control is accomplished with pH adjustments at 5 of the 8 WTPs.

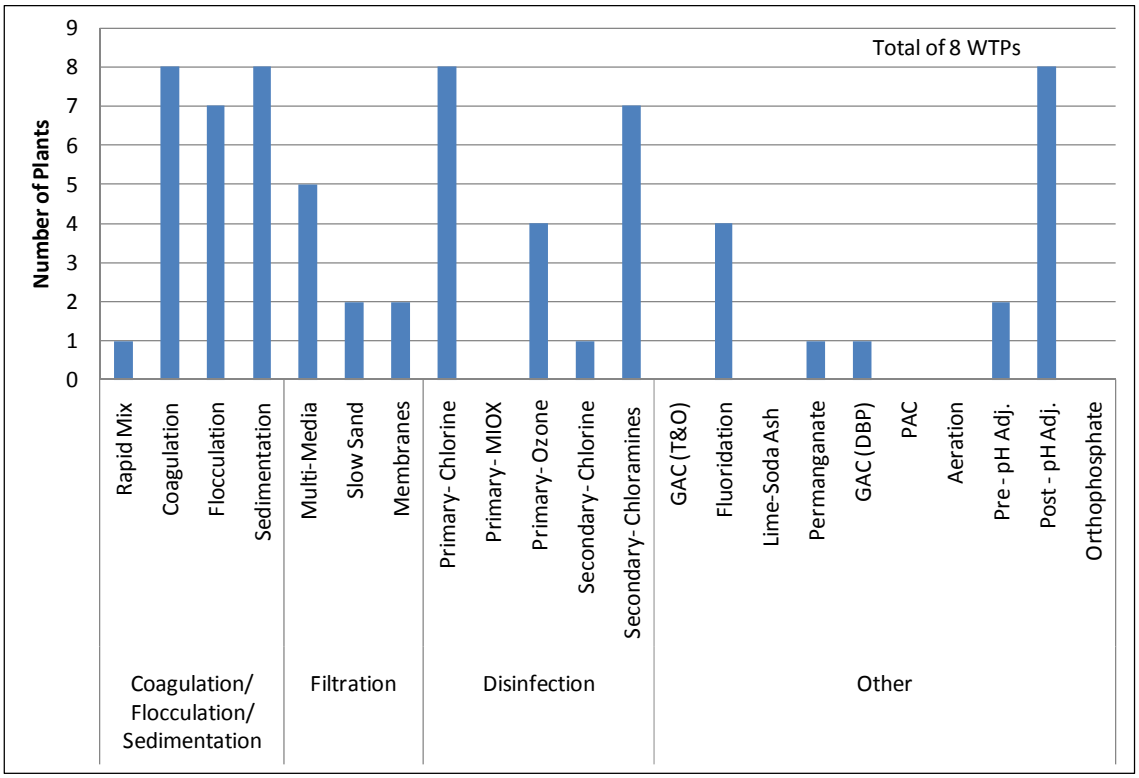

Figure 4-3: Water Treatment Plant Unit Processes in the Central Delta Source Water Area

4.2.4. California Aqueduct Source Water Area

The California Aqueduct source water area contains 18 WTPs with flow rates ranging from 3 MGD to 630 MGD. The majority of the WTPs use coagulation/ flocculation/ sedimentation followed by media filtration (Figure 4-4). Approximately 89 percent of the WTPs use free chlorine for primary disinfection, although some WTPs use MIOX (1 WTP) and ozone (2 WTPs). Approximately half of the water treatment plants use free chlorine and half utilize chloramines for secondary disinfection. Approximately 22 percent of the WTPs in this source water area also use GAC for disinfection byproduct control.

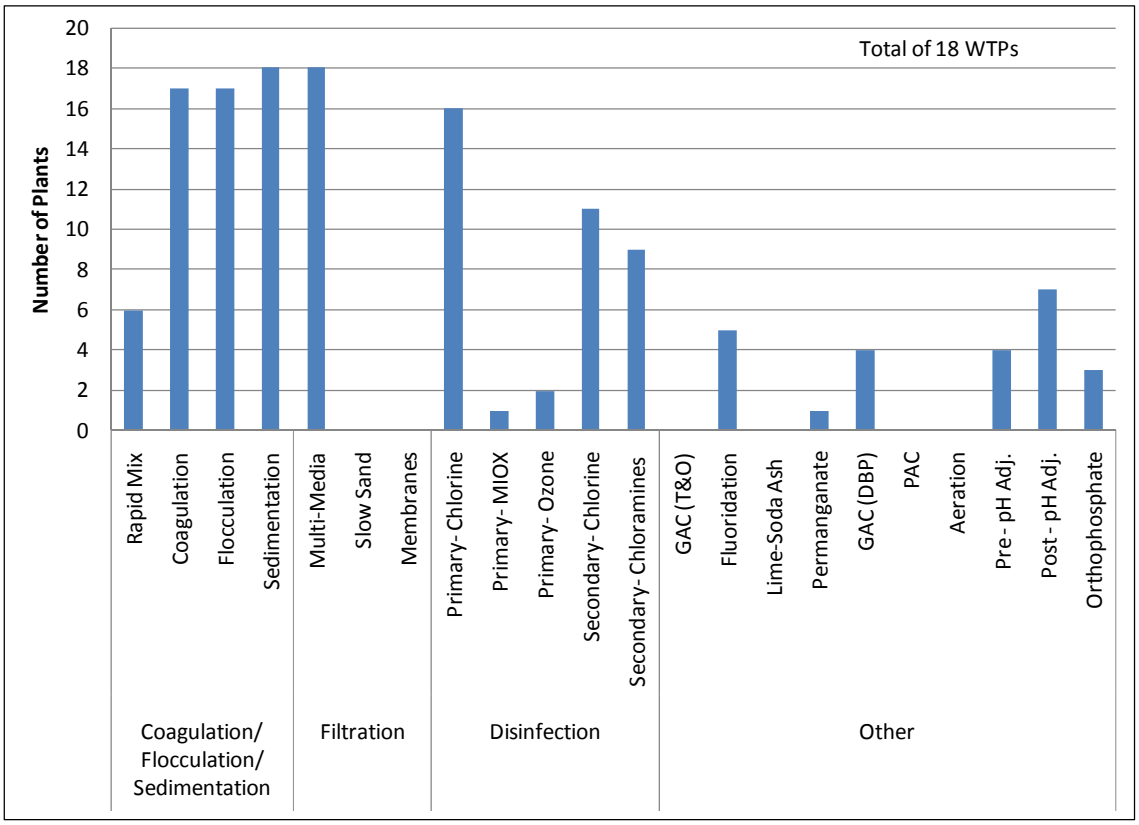

Figure 4-4: Water Treatment Plant Unit Processes in the CAA Source Water Area

4.2.5. California Aqueduct West Branch Source Water Area

The California Aqueduct West Branch source water area contains 3 WTPs with flow rates ranging from 30 MGD to 750 MGD. All of the WTPs in this source water area utilize the same treatment train that includes conventional coagulation/ flocculation/ sedimentation followed by media filtration with ozone for primary disinfection and chloramines for secondary disinfection (Figure 4-5)

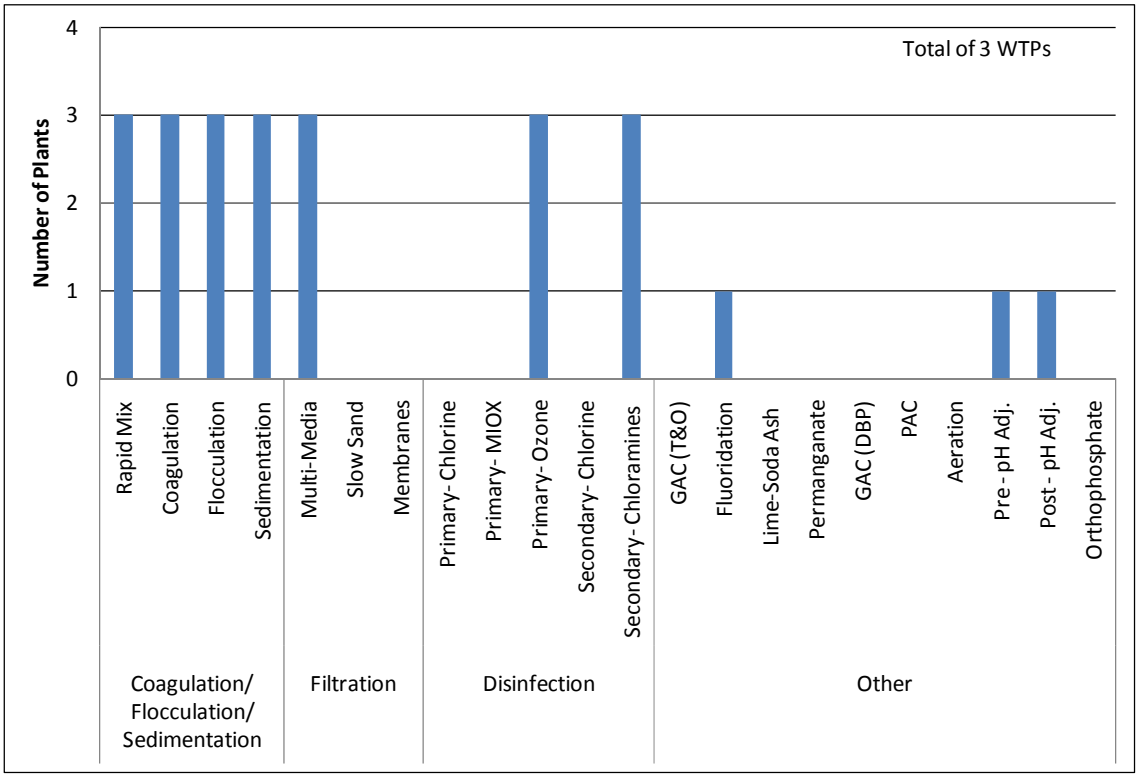

Figure 4-5: Water Treatment Plant Unit Processes in CAA West Branch Source Water Area

5. Summary and Next Steps

The purpose of the Water Treatment Plant Evaluation's Task 1 was to determine the study boundaries with respect to future regulations, source water area and associated water quality data, and water treatment technologies used in each source water area. This section summarizes the study boundary evaluation and next steps for the project.

5.1. Summary of Task 1: Definition of Study Boundaries

The Water Treatment Plant Evaluation Study boundaries were developed as summarized below.

- Malcolm Pirnie staff and technical advisors identified emerging drinking water quality issues and developed two regulatory scenarios for 2030: "plausible" and "outside boundary." The 2030 plausible regulatory scenario includes a reduction or modification to the current regulations for bromate, THM4, and HAA5. In addition, the plausible scenario identified possible regulation of iodinated THMs, HAA9, iodinated HAAs, nitrogenous DBPs (e.g., NDMA), other pathogens (not as challenging as currently regulated pathogens), and algal toxins (specifically microcystins). The plausible regulatory scenario will be used to evaluate the WTPs in each source water area to determine treatment upgrades and associated costs. The outside boundary 2030 regulatory scenario is more stringent than the plausible scenario and is provided to bracket the range of possible regulations.
- Five geographical areas of similar source water quality were identified by the Work Group: Upper Watersheds, NBA, Central Delta, CAA, and CAA-West. Source water quality for each region was compared with respect to DBP precursors, dissolved minerals, nutrients, and pathogens and indicator organisms to confirm these five source water areas were appropriate for the Study.
- The WTPs in each source water area were identified and evaluated to determine the existing water treatment practices. The results from the water treatment practice evaluation will be used in the development of virtual WTPs and threshold values.

5.2. Next Steps: Virtual Water Treatment Plants (Task 2)

The evaluation process to be used for developing the virtual WTPs is as follows:

- Identify WTPs in each source water area.
- Identify unit processes and design flowrates at each WTP.
- Identify trends is each source water area based on similar combination of unit processes.

- Select representative virtual WTPs for each source water area.
- Select representative flowrates for each virtual WTP.
- Develop conceptual level capital and O&M costs for each virtual WTP.

5.3. Next Steps: Threshold Values Development (Task 3)

The virtual water treatment plants developed in Task 2 will be used to develop threshold values for the water quality parameters identified in the plausible future regulatory summary (Table 2-2). The threshold values will be the WTP influent concentration that triggers an evaluation of adding additional treatment. Each virtual WTP will be entered into the Water Treatment Plant Model (USEPA, 2001b) to determine the removal efficiencies of each unit process. The influent threshold value will be determined based on the removal efficiencies of each virtual WTP and the target effluent concentration based on the plausible future regulatory scenarios. The effluent concentration will be set at 80 percent of the regulatory limit to prevent regulatory violations.

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Appendix A

Summary of Current Drinking Water Regulations

This appendix contains information on several of the primary drinking water regulations that have been proposed or implemented under the Safe Drinking Water Act (SDWA). Current federal regulations include:

- Surface Water Treatment Rule (SWTR)
- Total Coliform Rule (TCR)
- Lead and Copper Rule (LCR)
- Regulations for Inorganic Chemicals (IOCs), Synthetic Organic Chemicals (SOCs), and Volatile Organic Chemicals (VOCs) (Phases I, IIA, II, and V)
- Radionuclides Rule
- Filter Backwash Recycle Rule (FBWR)
- Stage 1 Disinfectant/Disinfection By-Products Rule (D/DBPR)
- Stage 2 Disinfectant/Disinfection By-Products Rule (D/DBPR)
- Interim Enhanced Surface Water Treatment Rule (IESWTR)
- Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)
- Arsenic Rule

Surface Water Treatment Rule (SWTR)

The SWTR requires that surface water and groundwater under the direct influence of surface water (GWUDI) be treated to achieve at least 3-log (99.9 percent) inactivation and/or removal of *Giardia* cysts and 4-log (99.99 percent) inactivation and/or removal of enteric viruses. Filtered water turbidity must never exceed 5 Nephelometric Turbidity Units (NTU), and 95 percent of the measurements taken must not exceed 0.5 NTU. If utilities did not meet the filtration avoidance criteria set in the SWTR, they were required to implement filtration treatment. The SWTR also requires that the secondary disinfectant residual entering the distribution system cannot be less than 0.2 mg/L for more than four consecutive hours, as demonstrated by continuous monitoring.

Total Coliform Rule (TCR)

Similar to the SWTR, the primary goal of the TCR is also to maintain microbiological quality in finished and distributed drinking water supplies. The TCR specifies a maximum contaminant level goal (MCLG) for total coliforms of zero (including both fecal coliforms and *E. coli*). Compliance is based upon the presence or absence of total

coliforms rather than coliform densities. The TCR requires 95 percent of the samples in a month to be negative.

Lead and Copper Rule (LCR)

The intent of the LCR is to minimize exposure to lead and copper from drinking water. If lead or copper exceeds a specified trigger value at the consumer tap (action level), treatment is required. The action levels for lead and copper are 15 and 1,300 µg/L, respectively. This rule includes extensive requirements for sampling and, if necessary, demonstration studies. In general, systems that comply with the lead action level will also comply with the copper action level.

Compliance is based on implementation of optimal corrosion control treatment. EPA's intent was to require all systems to install optimal corrosion control regardless of the lead and copper concentrations at consumers' taps. Optimal corrosion control treatment is defined as the technology that minimizes lead and copper levels at consumers' taps. It must be demonstrated on the basis of data from distribution system monitoring as well as results of corrosion control studies. Currently, the State is responsible for conducting all lead and copper enforcement actions and reviews of corrosion control studies.

Inorganic Chemicals (IOCs), Synthetic Organic Chemicals (SOCs), and Volatile Organic Chemicals (VOCs)

The majority of the drinking water contaminants regulated under the SDWA amendments fall into the categories of inorganic chemicals (IOCs), synthetic organic chemicals (SOCs), and volatile organic chemicals (VOCs). In total, there are 135 contaminants regulated by this rule. The rules regulating these groups of contaminants include:

- Phase I -VOCs;
- Phase IIA – Fluoride;
- Phase II - SOCs and IOCs; and
- Phase V - Additional SOCs and IOCs.

The names "Phase III" and Phase IV" were not used in the rulemaking process.

Radionuclides Rule

Radionuclides are radiological material that can enter the water supply naturally from soil or from leakage of radioactive wastes. Previously radionuclides were regulated by a rule from 1976. Of all of the changes to the old rule, the most significant is probably the sample location. According to the 1976 Rule, samples could be taken within the distribution system, which provided the "average customer" with water meeting the requirements. With the 2000 Rule, all samples must be taken at each entry point to the distribution system. Radium 226/228, gross alpha, and uranium should be monitored

four times a year. Only vulnerable utilities (*i.e.,* water contaminated by nuclear facilities) are required to monitor for beta emitters.

After community water systems (CWSs) have determined a baseline through the four consecutive quarterly samples or have been approved by the State based on grandfathered data, they may proceed with reduced monitoring based on their initial baseline.

Filter Backwash Recycling Rule (FBWR)

The FBRR requires public water systems to review their backwash water recycling practices to ensure that they do not compromise microbial control. Under the FBRR, recycled filter backwash water, sludge thickener supernatant, and liquids from dewatering processes must be returned to a location such that the recycled water is subject to all the processes in a system's conventional or direct filtration treatment train including coagulation, flocculation, sedimentation (conventional filtration only) and filtration. Systems may apply to the State for approval to recycle at an alternate location.

Stage 1 Disinfectant/Disinfection Byproducts Rule (D/DBPR)

The D/DBPR has been implemented in two stages. EPA promulgated the Stage 1 D/DBPR to reduce the levels of disinfectants and disinfection byproducts in drinking water supplies. The Stage 1 D/DBPR revised the MCLs for total trihalomethanes (TTHMs), reducing it from 0.10 to 0.08 mg/L, and included a new MCL of 0.06 mg/L for the sum of five haloacetic acids (HAA5). Additionally, MCLs for chlorite (1.0 mg/L) and bromate (0.010 mg/L) were established.

The rule designated monitoring requirements and best available technologies (BATs) for compliance and specified treatment techniques to reduce DBP precursors. This requires systems using surface water to remove specific amounts of total organic carbon (TOC) prior to adding disinfectants by implementing a treatment technique, either enhanced coagulation or enhanced softening. The percent removal required depends on the source water TOC and alkalinity (Table A-1). TOC removal compliance is based on the running annual average (RAA) of quarterly averages of monthly removal ratios. The removal ratio is the ratio of the removal achieved divided by the removal required. The RAA of the removal ratios needs to equal or exceed 1.0.

Table A-1.
TOC Removal Requirements

Source Water TOC (mg/L)	Source Water Alkalinity (mg/L as $CaCO_3$)		
	0 to 60	>60 to 120	>120
>2.0 to 4.0	35.0%	25.0%	15.0%
>4.0 to 8.0	45.0%	35.0%	25.0%
>8.0	50.0%	40.0%	30.0%

Source: USEPA 1999.

The USEPA also established alternative compliance criteria. If any of the conditions summarized below are met, the system is not required to achieve the specified TOC removal.

- Source water TOC is less than 2.0 mg/L.
- Treated water TOC is less than 2.0 mg/L.
- Source water TOC is less than 4.0 mg/L, source water alkalinity is greater than 60 mg/L, and distribution system TTHM is less than 0.04 mg/L and HAA5 is less than 0.03 mg/L.
- Distribution system TTHM is less than 0.04 mg/L and HAA5 is less than 0.03 mg/L and only chlorine is used for primary disinfection and distribution system residual.
- Source water specific ultraviolet absorbance (SUVA), prior to any treatment, is less than or equal to 2.0 L/mg-m.
- Treated water SUVA is less than or equal to 2.0 L/mg-m.

Stage 2 D/DBPR

The Stage 2 D/DBPR does not change the MCL for any of the DBPs; however, it changes how the compliance levels for TTHMs and HAA5 are calculated. Rather than determining compliance by averaging DBP concentrations throughout the distribution system, the Stage 2 D/DBPR requires each sampling point in the distribution system to comply on an average annual basis, which is referred to as a Locational Running Annual Average (LRAA).

The Stage 2 D/DBPR applies to public water systems that are community water systems or non-transient non-community water systems that add a primary or residual disinfectant other than ultraviolet light or deliver water that has been treated with a primary or residual disinfectant other than ultraviolet light.

Interim Enhanced Surface Water Treatment Rule (IESWTR)

The IESWTR and the LT2ESWTR (discussed below in Section 0) build on the requirements of the SWTR in relation to improving control of microbial pathogens, specifically *Cryptosporidium*, in drinking water. To assist with the development of these

rules, the Information Collection Rule (ICR) was implemented. The ICR gathered data from over 400 utilities to assess microbial risk and DBP formation. The IESWTR was finalized in December 1998 and implemented in conjunction with the Stage 1 D/DBPR. An important element of the IESWTR was to safeguard against significant increases in microbial risk that might occur when systems implement the Stage 1 Disinfectants/Disinfection Byproducts Rule.

The IESWTR applies to public water systems that use surface water or GWUDI of surface water, and serve more than 10,000 people. The IESWTR sets the MCLG for *Cryptosporidium* oocysts in water at zero. The IESWTR also has the following requirements, which are revisions to the SWTR:

- Inclusion of *Cryptosporidium* in list of microbial contaminants that determine whether or not a particular ground water source is under the direct influence of surface water.
- Extension of watershed control requirements to include the control of *Cryptosporidium* in the source water in a manner analogous to the existing requirements for *Giardia* cysts and viruses.
- All systems that use surface water and GWUDI have a periodic sanitary survey, regardless of whether or not they filter their supplies.
- All surface water and GWUDI systems serving 10,000 or more people cover all new treated water reservoirs for which construction began after February 1999.
- Monitoring of individual filter turbidities and lowering the combined filtered water turbidity MCL from 0.5 to 0.3 NTU.
- Cross-connection control "in the context of a broad range of issues." Issues include system pressure requirements, backflow prevention programs, categorizing service connections with respect to potential backflow, periodic review of backflow prevention devices, and the utility backflow prevention program.
- Requirement for filter backwash and other waste streams to be regulated.

Long Term 2 Enhanced Surface Water Treatment Rule (LTSESWTR)

The LT2ESWTR building on the IESWTR and requires systems to provide addition protection against *Cryptosporidium* based on monitoring results. Systems must monitor for *Cryptosporidium* for 2 years following finalization of the LT2ESWTR with the exception of systems that already provide 2.5-log removal/inactivation of *Cryptosporidium*. Based on the levels of *Cryptosporidium* in the source water, a WTP is given a bin classification (Table A-2). Based on the bin classification, a WTP may be required to implement additional treatment to achieve a certain level of removal/inactivation of *Cryptosporidium* using the components from the Microbial Toolbox. Systems currently using ozone, chlorine dioxide, UV disinfection, or

membranes in addition to conventional treatment may receive credit for those technologies toward bin requirements.

Table A-2.
Bin Classification and Action Requirements

Bin Classification	Maximum Running Annual Average (oocysts/L)	Action Required (log)
1	< 0.075	none
2	0.075 to < 1.0	1
3	1.0 to < 3.0	2
4	≥ 3.0	2.5

Depending on the *Cryptosporidium* concentration in the source water and the resulting removal/inactivation requirements (i.e., bin classification), the utility can use the treatment technique(s) listed in the microbial toolbox to achieve the required *Cryptosporidium* removal/inactivation. Meeting the removal/inactivation treatment requirements identified for each "Action Bin" may necessitate one or more actions from an array of management strategies which include watershed control, reducing influent *Cryptosporidium* concentrations, improved system performance, and additional treatment barriers.

Arsenic Rule

An MCL of 50 µg/L for arsenic was established by EPA in 1975 based on the standard set by the Public Health Service in 1943. The 1996 SDWA Amendments required EPA to revise the arsenic MCL and take into consideration peer-reviewed health effects research, treatment studies, analytical methods, occurrence, cost-benefit tradeoffs, and affordable small-system treatment technologies. The Arsenic Rule was finalized at an MCL of 10 µg/L. Surface water supplies are required to monitor and report arsenic levels once every year, and groundwater supplies are required to monitor and report arsenic levels once every three years. If the arsenic level is above the MCL, then the utility will need to monitor that location quarterly until the location is reliably and consistently below the MCL. If quarterly monitoring is performed, compliance is based on the running annual average of the quarterly samples.

List of Relevant Disinfection By-Products

Appendix B lists disinfection by-products (DBPs) that are currently regulated or could potentially regulated in the future. Classes of DBPs include trihalomethanes (THMs), haloacetic acids (HAAs), iodinated DBPs, brominated DBPs, and nitrogenous DBPs. Current state (California Department of Public Health, CDPH) and federal (USEPA) regulations are listed, as well as any available health risk information. Abbreviations, notes, and references are summarized at the end of the appendix.

All concentrations are µg/L.

Constituent	CDPH Primary MCL	USEPA Primary MCL	USEPA MCLG	CDPH PHG	CDPH Notification Level/ Response Level	One in a Million Cancer Risk for DW USEPA IRIS	USEPA SNARL	References
THMs								
Bromodichloromethane (BDCM)	80 [1]	80 [1]	0	-	-	0.6	21	1
Bromoform (CHBr3)	80 [1]	80 [1]	0	-	-	4	210	1
Chloroform (CHCl3)	80 [1]	80 [1]	70	-	-	-	70	1
Dibromochloromethane (DBCM)	80 [1]	80 [1]	60	-	-	0.4	60	1
HAA5s								
Dibromoacetic acid (DBAA)	60 [2]	60 [2]	-	-	-	-	-	1
Dichloroacetic acid (DCAA)	60 [2]	60 [2]	0	-	-	0.7	0	1
Monobromoacetic acid (MBAA)	60 [2]	60 [2]	-	-	-	-	-	1
Monochloroacetic acid (MCAA)	60 [2]	60 [2]	30	-	-	-	70	1
Trichloroacetic acid (TCAA)	60 [2]	60 [2]	20	-	-	-	20	1
HAA9								
Includes all HAA5s	-	-	-	-	-	-	-	
Bromochloroacetic acid (BCAA)	-	-	-	-	-	-	-	1

All concentrations are µg/L.

Constituent	CDPH Primary MCL	USEPA Primary MCL	USEPA MCLG	CDPH PHG	CDPH Notification Level/ Response Level	One in a Million Cancer Risk for DW USEPA IRIS	USEPA SNARL	References
-		-	-	-	-	-	-	1
Chlorodibromoacetic acid (CDBAA)	-	-	-	-	-	-	-	1
Tribromoacetic acid (TBAA)	-	-	-	-	-	-	-	1
Iodinated DBPs								
Iodate (IO3-)	-	-	-	-	-	-	-	2
Iodo acids	-	-	-	-	-	-	-	2
Bromoiodoacetic acid	-	-	-	-	-	-	-	2
(Z)-3-bromo-3-iodopropenoic acid	-	-	-	-	-	-	-	2
(E)-3-bromo-3-iodopropenoic acid	-	-	-	-	-	-	-	2, 3
(E)-2-iodo-3-methylbutenedioic acid	-	-	-	-	-	-	-	2
Iodinated THMs								
Halonitromethanes	-	-	-	-	-	-	-	2
Bromochloroiodomethane	-	-	-	-	-	-	-	2
Dichloroiodomethane	-	-	-	-	-	-	-	3
Iodinated HAAs								3
Iodoacetic acid	-	-	-	-	-	-	-	2
Bromoioacetic acid	-	-	-	-	-	-	-	3
Iodated haloaldehydes	-	-	-	-	-	-	-	3
Iodated haloamides	-	-	-	-	-	-	-	2
Brominated DBPs								
Bromate	10	10	0	0.1	-	0.05	200	
Bromoform	80	80	0	-	-	4	210	3
Dibromoacetic Acid	-	-	-	-	-	-	-	3
Bromonitromethanes	-	-	-	-	-	-	-	3
Dibromonitromethane	-	-	-	-	-	-	-	2

All concentrations are µg/L.

Constituent	CDPH Primary MCL	USEPA Primary MCL	USEPA MCLG	CDPH PHG	CDPH Notification Level/ Response Level	One in a Million Cancer Risk for DW USEPA IRIS	USEPA SNARL	References
Tribromonitromethane	-	-	-	-	-	-	-	2
Bromonitromethane	-	-	-	-	-	-	-	2
Brominated forms of MX (3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone)	-	-	-	-	-	-	-	2
Bromonated haloaldehydes	-	-	-	-	-	-	-	2
Bromonated haloamides	-	-	-	-	-	-	-	2
Monobromoacetic acid	-	-	-	-	-	-	-	2
Nitrogenous DBPs								
Halogenated N-DBPs	-	-	-	-	-	-	-	
Halonitromethanes (HNMs)	-	-	-	-	-	-	-	3
Chloronitromethane	-	-	-	-	-	-	-	3
Bromonitromethane	-	-	-	-	-	-	-	3
Dichloronitromethane	-	-	-	-	-	-	-	3
Bromochloronitromethane	-	-	-	-	-	-	-	3
Dibromononitromethane	-	-	-	-	-	-	-	3
DHNMs	-	-	-	-	-	-	-	3
TCNM	-	-	-	-	-	-	-	3
Bromodichloronitromethane	-	-	-	-	-	-	-	3
Dibromochloronitromethane	-	-	-	-	-	-	-	3
Bromopicrin	-	-	-	-	-	-	-	3
THMs	-	-	-	-	-	-	-	
Haloacetamides	-	-	-	-	-	-	-	3
Non-Halogenated N-DBPs	-	-	-	-	-	-	-	
Nitrosamines	-	-	-	-	-	-	-	

All concentrations are µg/L.

Constituent	CDPH Primary MCL	USEPA Primary MCL	USEPA MCLG	CDPH PHG	CDPH Notification Level/ Response Level	One in a Million Cancer Risk for DW USEPA IRIS	USEPA SNARL	References
N-Nitrosodimethylamine (NDMA)	-	-	-	0.003	0.01/0.3	0.0007	-	1, 4
N-Nitrosodiethylamine (NDEA)	-	-	-	-	0.01/0.1	0.0002	-	1, 4
N-Nitrosodi-n-propylamine (NDPA)	-	-	-	-	0.01/0.5	0.005	-	1, 4
N-Nitrosodiphenylamine	-	-	-	-	-	7	-	1, 4
N-nitrosopyrrolidine (NPYR)	-	-	-	-	-	0.02	-	1, 4
N-nitrosodi-n-butylamine (NDBA)	-	-	-	-	-	0.006	-	1, 4
N-nitrosomethylethylamine (NMEA)	-	-	-	-	-	0.002	-	1, 2
Hydrazine	-	-	-	-	-	0.01	-	1, 2

Abbreviations:

CDPH	California Department of Public Health
DBP	Disinfection By-products
DW	Drinking Water
HAA	Haloacetic Acid
IRIS	Integrated Risk Information System
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
PHG	Public Health Goal
SNARL	Suggested No-Adverse-Response Levels (from toxicity other than cancer risk)
THM	Trihalomethane
USEPA	United States Environmental Protection Agency

Notes:

[1] For total trihalomethanes (sum of bromoform, bromodichloromethane, chlororform, and dibromochloromethane); based largely on technology and economics.

[2] For five haloacetic acids (sum of monochloroacetic acid, dichloroacetic acid, trichloroacetic acid, monobromoacetic acid, and dibromoacetic acid.

References:

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4. USEPA. 2008. Drinking Water Contaminant Candidate List 3-Draft; Notice. Federal Register. Vol. 73, No. 35, p. 9628, February 21, 2008.