CALFED BAY-DELTA PROGRAM

Issues with Delta Drinking Water Treatment

July 2005

BROWN AND CALDWELL

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ACRONYMS AND ABBREVIATIONS

Water Districts and Agencies

ACWD	Alameda County Water District
Avenal	City of Avenal
CCWA	Central Coast Water Authority
CCWD	Contra Costa Water District
CLAWA	Crestline Lake Arrowhead Water Agency
Coalinga	City of Coalinga
KCWA	Kern County Water Agency
MWD	Metropolitan Water District of Southern California
SCVWD	Santa Clara Valley Water District
Vallejo	City of Vallejo

Government Agencies, Organizations and Programs

AWWA	American Water Works Association
CVP	Central Valley Project
DMC	Delta Mendota Canal
DHS	California Department of Health Services
DWR	California Department of Water Resources
DWS	CALFED BDPAC Drinking Water Subcommittee
MWQI	Metropolitan Water Quality Investigation
NBA	North Bay Aqueduct
Reclamation	United States Bureau of Reclamation
RTDF	Real Time Data Forecasting
SBA	South Bay Aqueduct
SWP	State Water Project
USEPA	United States Environmental Protection Agency
WQP	CALFED Water Quality Program

Drinking Water Terminology

AF	acre feet
AOC	assimilable organic carbon
BAT	best available technology
cfs	cubic feet per second
EC	electrical conductivity
DBP	disinfection byproducts
DOC	dissolved organic carbon
DBPP	disinfection by-product precursor
HAA	halo-acetic acids
GAC	granular activated carbon
PAC	powdered activated carbon
PCPPs	Personal Care Products and Pharmaceuticals

MIEX®	magnetic ionic exchange
MIB	methylisoborneol
MIOX®	mixed oxidants (disinfection process)
THM	tri-halo methanes
T&O	taste and odor
TOC	total organic carbon
WTP	water treatment plants

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF TABLES

LIST OF FIGURES

APPENDICES

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EXECUTIVE SUMMARY

This report summarizes an initial effort of the CALFED Water Quality Program (WQP) to document Delta drinking water treatment challenges. It is based primarily on a survey of water agencies that treat Delta water, and is intended to help the WQP start to refine the role of treatment in achieving an "equivalent level of public health protection" (ELPH) and the identification of the multiple barriers available from the Delta through to the consumer. The survey was funded by the WQP and conducted by Brown and Caldwell.

Project Approach

In order to document Delta drinking water treatment challenges Brown and Caldwell surveyed a representative group of water treatment plants (WTPs) treating Delta water, including small and large utilities on each branch of the State Water Project system and Contra Costa Water District. The list of agencies and the survey questions were developed by Brown and Caldwell, with the assistance of California Department of Health Services (DHS) and WQP staff. Survey questions were designed to identify the challenges and opportunities in obtaining desired water quality, focusing on Delta water treatment and the role of source water quality, while also including water quality issues with conveyance, storage and blending, and distribution. Interviews were held with operation, planning, and management staff (when available) of each agency involved in the survey. Agencies were also asked to identify areas in which the WQP could improve communication and outreach among all treatment agencies treating Delta water and with CALFED. The information obtained from these surveys is summarized in the body of the report; the meeting summaries are provided in an Appendix.

Conclusions

Agencies identified high and variable organic carbon, turbidity, bromide, taste and odor, temperature, pH and alkalinity as the most problematic constituents of concern for drinking water treatment. Rapid fluctuations (overnight and daily) in constituent concentrations cause treatment upsets at WTPs. Reductions in the level and variability of the constituent concentrations of concern are of the highest importance. Agencies encouraged the WQP and CALFED implementing agencies to continue efforts in source water quality improvements and in preventing further water quality degradation in conveyance channels. In addition to concerns with point and non-point source pollution in the Delta and along conveyance channels, agencies stated that the conditions at Clifton Court Forebay significantly contribute to source water quality degradation.

Many of the agencies currently without storage and blending options expressed a belief that those options would help alleviate many of the treatment challenges associated with high and variable constituent concentrations by providing a buffer to income water. Agencies stated that increased "real time" monitoring would also aid many WTPs by providing operators timely water quality data which would allow them to make timely adjustments to treatment processes.

While some agencies treating Delta water are implementing emerging technologies such as membranes and ozonation, many agencies are cautious about implementing emerging technologies because of their concerns with operation challenges and economics, and thus prefer “proven” treatment technologies.

Recommendations

Based on the recommendations, concerns, and treatment challenges heard during interviews with the agencies, Brown and Caldwell developed a number of recommendations to help guide the continued efforts of the WQP.

Source Water Quality Improvements. The WQP should address all constituents of concern, communicate and compile initial project results, and fund source water quality improvement projects.

Monitoring. The WQP should determine the need for additional critical real-time monitoring stations, like those now in place at Vernalis, Hood, and Banks, to inform water quality.

Clifton Court Forebay. The WQP should evaluate the actions described in the CALFED EIS/EIR to improve conditions at Clifton Court Forebay, potentially through the development of Regional ELPH Plans.

Conveyance. The WQP should evaluate efforts that address water quality degradation in the conveyance channels: identify sources of degradation, development of best management practices, and evaluation of source relocation.

Treatment. As the WQP reviews its priorities and roles in drinking water treatment technologies it should consider investigations on both conventional treatment and “best available technologies” as well as emerging technologies.

Communication. The WQP should increase outreach, communication, and dissemination of information among all the agencies throughout California, particularly those treating Delta water.

Regional Planning. The WQP should encourage agencies participating in regional efforts to further develop and evaluate the challenges and concerns discussed in this survey.

Performance Measures. The issues described by agencies using Delta water and presented in this report could be incorporated into the development and use of performance measures by the WQP.

SECTION 1

INTRODUCTION

1.1 Project Objective

This project is an initial effort of the CALFED Water Quality Program (WQP) to better understand the spectrum of Delta drinking water treatment challenges, from the perspective of treatment plant operators as well as agency planning and management staff. The WQP is at a point where it has funded its initial treatment commitments as identified in the CALFED Record of Decision (ROD), and is seeking to better understand the role of treatment in achieving an "equivalent level of public health protection." This effort has also enabled the WQP to outreach to a larger range of water agencies than it has in the past, and inform future outreach efforts. It was not meant to be a technical analysis or data collection, as has been done through other WQP-funded projects and through both national and local organizations. The lead on this project was Brown and Caldwell, funded entirely by the WQP.

A representative group of water treatment plants (WTPs) treating Delta water were selected for involvement in this project; the group purposefully includes small and large utilities on each branch of the State Water Project system, as well as the Contra Costa Water District. Questions were developed to gather information on agency water quality goals, challenges, and opportunities from the Delta through to treatment, looking at the multiple barriers available to provide good drinking water treatment. The purpose of this report is to summarize the information obtained and outline the common themes heard during the interviews. This section provides background on the WQP, details on the approach of the project, and an outline of the following sections.

1.2 Background

For context, a brief description of the CALFED Bay-Delta Program (CALFED), the WQP, and documents relevant to the WQP assessment are provided. This background is not meant to be a comprehensive description of CALFED or the WQP.

CALFED. The CALFED Bay-Delta Program is a joint state-federal effort with four goals: to improve water supply reliability, water quality, and levee reliability, and to restore the largest estuary on the West Coast. CALFED is implemented by several state and federal agencies, with oversight and coordination by the California Bay-Delta Authority. The program was originally envisioned with a thirty-year planning horizon. The four goals are implemented through eleven CALFED program elements, which include the WQP and several other programs that can also positively affect water quality such as storage, conveyance, ecosystem restoration, and watershed. The ROD outlines a general water quality goal of "continuously improving Delta water quality for all uses, including in-Delta environmental and agricultural uses." CALFED also has programmatic goals of coordination, transparency, and accountability.

Water Quality Program. One of the eleven CALFED program elements, the WQP focuses on drinking water quality and indirectly on agricultural water quality. The WQP is implemented by the U.S. Environmental Protection Agency, the California Department of Health Services (DHS), the State Water Resources Control Board, and the Regional Water Quality Control Boards, referred to as "implementing agencies." The implementing agencies also coordinate closely with the California Department of Water Resources and the U.S. Geological Survey, referred to as "participating agencies."

As stated in the ROD, the goal of the WQP is to provide "safe, reliable, and affordable drinking water in a cost-effective way," with a target to "achieve either: (a) average concentrations at Clifton Court Forebay and other southern and central Delta drinking water intakes of 50 μg/L bromide and 3.0 mg/L total organic carbon, or (b) an equivalent level of public health protection using a cost-effective combination of alternative source waters, source control, and treatment technologies." This "equivalent level of public health protection" (ELPH) approach is the backbone of the WQP, and the program is based on the concept of a "cost-effective combination of alternative source waters, source control, and treatment technologies." Through other efforts supported by the WQP, such as the Central Valley Drinking Water Policy development, ELPH seeks to formalize the linkage between source and treated water quality. When the ROD targets were initially developed, more stringent regulations were anticipated. Although these regulations have been delayed, more stringent regulations are likely within the 30-year planning horizon of the program, which will require an adaptive approach to water quality constituents of concern

To better identify the elements of ELPH, the Drinking Water Subcommittee (DWS) assisted the WQP in developing a visual representation of the range of alternatives or tools to protect water quality from source water improvement, to conveyance and storage, to treatment technologies, given the geography of the Bay-Delta water operations systems. This representation is referred to as the "ELPH diagram" (Appendix A), and the representation is described in a narrative called the "CALFED Drinking Water Quality Conceptual Framework[1]." The challenge for the WQP is to combine this construct with conceptual models of constituents of concern to produce an overall strategy to achieve its water quality goals. Regional ELPH planning (or regional drinking water quality management planning) has emerged as a critical tool for making these important connections. ELPH provides a way of looking at the multiple barrier approach to provide the highest possible drinking water quality, rather than solely focusing on the water quality of the Delta alone. ELPH is such a critical construct for the WQP that many of the current efforts are structured using the tools that the "ELPH diagram" describes.

The WQP has identified a number of water quality constituents of concern in addition to bromide and total organic carbon (TOC) which also are important to drinking water treatment. Numeric targets for these constituents were originally listed in the Appendix to the Water Quality Program Plan and have been reiterated in recent Multi-Year Program Plans. Numeric targets include: chloride (250 mg/L, 150 mg/L, same as D1641), nutrients (10 mg/L or no increase in nitrate levels), total dissolved solids (<220 mg/L 10-year average or <440 mg/L monthly average), pathogens (< 1 oocyst/100L for *Giardia* and *Cryptosporidium*), and turbidity (50 NTU). These key constituents are being addressed in the development of the Central Valley Drinking Water Policy. The relevance of these goals will continue to be examined through the Central Valley Drinking Water Policy process, conceptual model and performance measure development, and through adaptation to changing treatment regulations.

Performance Measures. Measuring performance and using performance to guide implementation is a major emphasis of the CALFED program, as seen in the ROD. Currently a broad and

[1] Available at the CALFED WQP Website: http://calwater.ca.gov/Programs/DrinkingWater/DrinkingWater.shtml.

comprehensive set of specific performance measures has not been adopted for drinking water. These performance measures would likely include looking at source water improvements from a treatment facility perspective and inform funding targets for treatment technology demonstration projects and continued source water improvement.

1.3 Project Approach

Brown and Caldwell worked with DHS and WQP staff to develop a list of representative WTPs that primarily treat Delta water, while also capturing different regions, Delta intakes, conveyance channels, blending capabilities, and demographics. Figure 1.1 is a map of the agencies/WTPs that were visited for this survey. A list of the agencies and representatives interviewed is provided in Appendix B. Agency names, rather than treatment plant names, are generally used throughout this report for convenience and familiarity.

In all, ten WTP representatives and two DHS District engineers were interviewed, covering 90 percent of the targeted list. While a number of the agencies interviewed have treatment facilities that do not treat Delta water, the focus was on those WTPs that treat some volume of Delta water. The exception to this was the City of Vallejo, which was included because they implemented a process at their Green Valley Treatment Plant based on the results of a WQP-funded project.

Brown and Caldwell, with the assistance of DHS and the WQP, carefully developed questions to identify the challenges and opportunities in obtaining the highest water quality, focusing on treating Delta water and on the role of source water quality, but including issues with conveyance, storage and blending, and distribution. Interviews covered both operational and planning perspectives. Another topic of discussion was communication, to identify areas in which the WQP could improve communication to drinking water agencies and potentially, among agencies as well. The interview questions are provided in Appendix B.

Brown and Caldwell identified and interviewed both operation and engineering managers; interviews lasted approximately 1-2 hours. The number of individuals at different agencies varied and some comments reported here may not be the views of the entire agencies. Meeting summaries and a draft version of this report were reviewed by all agencies for their approval. Meeting summaries are provided in Appendix C, D, and E, broken up into Bay-Delta Area, San Joaquin Valley, and Southern California regions respectively. Section 3 provides a summary of interview findings grouped by the commonalities identified.

1.4 Report Contents

Section 2 provides background information regarding Delta water quality, intakes and conveyance, drinking water treatment, and more detailed information on the participating treatment plants and their source waters. Section 3 summarizes the information heard during the water agency interviews including topics related to Delta source water, conveyance, blending and storage, treatment, distribution, and current and future communication. To obtain a full perspective on the information shared and specifics from different agencies, readers are encouraged to review the meeting summaries provided in Appendices C, D, and E. Section 4 provides a summary of general agency recommendations on drinking water quality improvement and specific recommendations for the WQP developed by Brown and Caldwell.

Figure 1-1. Locations of agencies interviewed and major California water conveyance channels

SECTION 2

BACKGROUND

This section provides a summary of Delta drinking water intakes and conveyance, drinking water treatment, WTPs participating in this survey, and Delta water quality. The Delta Intake and conveyance section is primarily a summary of DWR materials. The reader is referred to the CALFED WQP Initial Assessment Report[1] for more information on Delta operations, hydrology and water quality.

2.1 Drinking Water Intakes and Conveyance Systems

The Sacramento – San Joaquin Delta is the source of water for 23 million residents of the state of California, delivered through two of the nation's most complex and extensive government-developed water delivery systems; the California State Water Project (SWP) and the Federal Central Valley Project (CVP). The SWP is comprised of over 600 miles of conveyance channel and pipeline and 20 storage facilities and delivers 3 million acre-feet per year (AF) of water through the Delta to 29 different agencies[2]. The Central Valley Project (CVP) delivers 7 million AF per year (partially through the Delta) to 2 million consumers and 3 million acres of farmland. The CVP and SWP work closely together because they both use the San Luis Reservoir, O'Neill Forebay, and more than 100 miles of the California Aqueduct and its related pumping and generating facilities. The two water projects meet at the San Luis Joint-Use Complex, where both conveyance systems merge into the San Luis Reservoir and then separate again into the Delta Mendota Canal and the California Aqueduct. Water is pumped out of the Delta principally through five intake locations: Barker Slough Intake, Harvey O. Banks Pumping Plant (Banks), Tracy Pumping Plant (Tracy), Old River Intake, and Rock Slough Intake.

This report focuses on a selected, representative group of WTPs using Delta water from different intakes and conveyance networks. The major conveyance systems are described below.

2.1.1 Barker Slough Intake and the North Bay Aqueduct

The North Bay Aqueduct (NBA) diverts Delta water through the Barker Slough Intake, located northwest of the junction of the Sacramento River Deepwater Ship Channel and the Sacramento River. Runoff from the local watershed has a significant impact on its water quality, especially in late winter. The NBA conveys water to communities in Napa and Solano counties. The main agencies that take water from the NBA are the Solano County Water Agency (SCWA) and the Napa County Flood Control and Water Conservation District. The SCWA resells water to the cities of Benicia, Dixon, Fairfield, Rio Vista, Suisun City, Vacaville, and Vallejo.

2.1.2 Rock Slough Intake, Old River Intake, and the Contra Costa Canal

Contra Costa Water District's (CCWD) Rock Slough Intake and Old River Intake are located in the Southwestern portion of the Delta, northwest of Clifton Court Forebay. CCWD also has a less

[1]http://calwater.ca.gov/CALFEDDocuments/CALFEDDocuments.shtml
[2]http://www.publicaffairs.water.ca.gov/swp/swptoday.cfm

frequently used intake at Mallard Slough. The Rock Slough Intake pumps water into the Contra Costa Canal, a CVP facility. CCWD stores Delta water in Contra Loma (1,700 AF capacity), Mallard (2,100 AF capacity), Martinez (230 AF capacity), and Los Vaqueros (100,000 AF capacity) Reservoirs. CCWD provides water to a large portion of Contra Costa County, both raw and treated, resale and wholesale, to a variety of municipal, industrial, and agricultural users.

2.1.3 Harvey O. Banks Pumping Plant, the South Bay Aqueduct, and the California Aqueduct

Banks Pumping Plant is located on the southern end of Clifton Court Forebay, which was originally constructed to provide a large settling basin for Delta water before it is pumped into the California Aqueduct. The California Aqueduct flows into Bethany Reservoir (5,070 AF capacity), where the South Bay Aqueduct (SBA) branches from the California Aqueduct. The SBA provides water for Alameda and Santa Clara Counties and uses both open and enclosed channels and pipelines. SBA water can be stored within Lake Del Valle, which has a capacity of 77,110 AF (30,000 AF of which is specifically reserved for water supply needs) and Patterson Reservoir, a small 100 AF storage facility.

Delta water continues down the California Aqueduct from Bethany Reservoir and into O'Neill Forebay. O'Neill Forebay and the San Luis Reservoir are part of the San Luis Joint-Use Complex, which is used for water supply, power generation, and recreation. This complex contains the San Luis reservoir (2.028 million AF capacity, the nation's largest offstream reservoir) among an integrated network of pumping plants, dams, and forebays, operated by the California Department of Water Resources (DWR). San Luis reservoir feeds the CVP Delta Mendota Canal (DMC), which primarily serves agricultural water, the CVP San Felipe Unit, which serves Santa Clara and San Benito Counties, and the SWP California Aqueduct, which primarily serves drinking water.

The 400 mile long California Aqueduct then conveys Delta water to the San Joaquin Valley and Southern California regions. The Central Coast Branch of the California Aqueduct splits off close to Kettleman City and serves San Luis Obispo and Santa Barbara Counties. Following the Coastal Branch connection, the California Aqueduct continues over the Tehachapi Mountains before splitting into the West and East Branches. Water from the West Branch is stored in Quail Lake, Pyramid Lake, and terminates in Castaic Lake. The East Branch, the final leg of the California Aqueduct, feeds Lake Silverwood and ends at Lake Perris.

2.1.4 Tracy Pumping Plant and the Delta-Mendota Canal

Tracy Pumping Plant is located in the Delta east of Banks and pumps water directly into the DMC. The CVP, operated by the United States Bureau of Reclamation (Reclamation), conveys irrigation water to the largely agricultural region of the Central Valley and drinking water to nearly two million people, including the City of Tracy. For this evaluation it was not possible to meet with facilities treating water directly delivered via the DMC. One CVP contractor, the SCVWD, was interviewed, but they contract with both the SWP and CVP.

2.2 Treatment Background

This section presents a brief background on drinking water treatment technologies currently applied to Delta water. The primary function of drinking water treatment is to provide healthy and safe drinking water to consumers. A secondary function is to provide good aesthetic quality (for both human consumption and for household and industrial usability).

2.2.1 Conventional Treatment

In a conventional treatment process, the treatment train consists of the following sequence of processes: coagulation/flocculation, sedimentation, and filtration. A number of variations exist within each process that change effectiveness or constituents targeted, the driving factors for these variations are usually economics and water quality. There are also non-conventional treatment processes, such as direct filtration, which omit the sedimentation process and consists only of coagulation/flocculation and filtration.

Disinfection using chemicals may occur at any point in the treatment train, and frequently chemical disinfection is practiced at more than one location in a treatment plant. Disinfection through oxidation can serve multiple purposes: it can inactivate pathogenic microorganisms, resolve taste and odor issues, and oxidize some problematic organics. Disinfection using physical methods, such as ultraviolet radiation and membranes, are emerging technologies that usually following the filtration process. Disinfectant residuals are maintained in the distribution system to prevent microbial re-growth, while at the same time maintaining the water quality of the system to prevent corrosion of pipes on its way to the tap.

The coagulation/flocculation process employs chemical coagulants and rapid mixing to bind nonsettleable solids into larger, settleable solids, to aid and accelerate the sedimentation and filtration processes. Some treatment plants practice enhanced coagulation, adjusting coagulant dose and pH to produce the greatest possible reduction of TOC. Different chemicals such as aluminum sulfate or propriety polymers can be added to further enhance the process.

The sedimentation process traditionally uses gravity to remove larger suspended particles; water is slowly moved through a large tank which allows heavier particles to settle to the bottom. Several agencies have reported that up-flow clarifiers, also called solids-contact clarifiers, achieve good suspended solids removal and alleviate taste and odor (T&O) problems, by combining coagulation, flocculation, and sedimentation in a single tank. While up-flow clarifiers can reduce operations costs they also require more adjustments in response to incoming water quality to achieve effective solids removal.

The filtration process removes the remaining suspended particles by running water through a gradation of fine grained media. Gravity filtration systems use gravity to move water vertically through the filter media. Pressure filtration systems employ pressure to either accelerate the process or allow horizontal flow through filter media, pushing the water through the filter media. Granular activated carbon (GAC) is sometimes included in the filtration media because of its high capacity to adsorb organic compounds. Other types of filtration media include ion exchange resins, which allow for different flow regimes - for example, magnetic ion exchange resin (MIEX®) uses a magnetized resin to enable adsorption of dissolved organic carbon (DOC) in a stirred contactor.

2.2.2 Disinfection Practices

Chemical disinfection processes inactivate pathogenic microorganisms; disinfectants (oxidants) include chlorine and its derivatives and ozone. The three critical measures of disinfection are oxidant concentration, contact time – the amount of time the oxidant remains in contact with the water, and inactivation – the resulting removal or disinfection of microorganisms. Chemical dose and time required to inactivate microorganisms is highly dependent on the type of microorganism and oxidant being used. When using chemical oxidants (e.g. chlorine or ozone), virus, bacteria, and protozoan, in that order, require increasing dose and contact times (i.e. viruses require lowest and protozoa require the highest). *Cryptosporidium*, however, is much more difficult to inactivate than *Giardia*, although both are protozoa. In addition to disinfection where a specified "contact time (CT – mg min L^{-1})" must be achieved for a desired log removal, the United States Environmental Protection Agency (USEPA) regulates disinfection through "removal credits" based on physical removal of microorganisms during coagulation/sedimentation and filtration. Removal is generally referred to as "log removal" where one log is 90 percent removal, two log is 99 percent removal, and so on.

The USEPA also regulates disinfection by-products (DBPs) in treated drinking water through the Disinfection and Disinfection Byproducts Rule. Bromide and organic carbon are frequently referred to as disinfection by-product precursors (DBPP), because during disinfection, they interact with chlorine to form DBPs such as tri-halomethanes (THMs) and halo-acetic acids (HAAs). Ozone also interacts with bromide to form bromate. There are several approaches known to reduce DBP formation, such as point of disinfectant application, alternative disinfectants, precursor removal strategies (which can include pre-oxidation), source shifting and blending, and disinfection process modifications. For example, chloramines or chlorine dioxide can be used rather than free chlorine. Choosing a disinfectant is often based on an evaluation of tradeoffs. For example, ozone does not produce THMs or HAAs but produces bromate, and the formation of bromate can be reduced by pH suppression. A concern for many treatment facilities is the further formation of DBPs in the distribution system because of requirements to maintain disinfectant residual system to prevent microorganism re-growth. A more detailed description of disinfectants is provided as follows:

Free chlorine in the gaseous form or hypochlorous acid in the liquid form is the most commonly used disinfectant for drinking water treatment. The use of free chlorine frequently results in the highest concentrations of THMs and HAAs when compared to other oxidants.

Chloramines, formed by a mixture of chlorine and ammonia, are an effective disinfectant for water treatment because they produce lower concentrations of DBPs than chlorine and maintain a measurable residual in treated water. Chloramines are much less potent than free chlorine. Chloramines can also result in increased nitrates (a regulated drinking water constituent) in the distribution system, which form indirectly from the breakdown of ammonia.

Chlorine dioxide is an effective disinfectant for water treatment and produces lower concentrations of THMs and HAAs. Chlorine dioxide addition to water can also produce chlorite, another regulated DBP. The WQP has funded a project managed by MWD to look at chlorine dioxide in combination with UV, titled "Integrating Ultraviolet Light to Achieve Multiple Treatment Objectives."

Ozone is a highly effective, but short-lived and highly unstable, disinfectant produced onsite by combining gaseous oxygen from air or liquid oxygen with a high electrical voltage. Disinfection using ozone does not produce a measurable residual in the treated water and therefore another disinfectant is added (usually chloramines) prior to distribution. Ozone will interact with bromide to form bromate, a regulated drinking water constituent.

Physical Disinfection processes include both ultraviolet radiation (UV) and membranes are physical disinfection processes which inactivate and remove microorganisms, respectively. Physical disinfection processes do not produce a measurable residual in treated water and therefore a disinfectant such as chlorine or chloramines must be added prior to distribution. The primary advantage of physical disinfection processes is that currently there are no identified or regulated disinfection byproducts associated with them.

Ultraviolet radiation disrupts various cellular organic components, causing cellular changes that are fatal to microorganisms. UV disinfection is an emerging technology that WTPs have implemented on a limited basis in the United States. Previous studies have indicated that UV disinfection can effectively inactivate some microorganisms, particularly *Cryptosporidium*, without producing DBPs. However, UV is less effective at disinfecting viruses. CCWD and MWD are conducting WQP-funded demonstration-scale studies on UV disinfection.

During membrane filtration, permeable particles pass through a membrane whereas impermeable particles are retained on the feed side. Whether or not a particle is permeable or impermeable is dependent on the particle size and the pore size of the membrane, including microorganisms. For example, microfiltration will remove many bacteria and protozoan because most bacteria and protozoan oocysts (*Giardia* and *Cryptosporidium*) are larger than 1 μm (protozoan oocysts are also usually larger) while the microfiltration membrane pore size is usually between 0.1 to 1 μm. However, to remove viruses a smaller pore size is necessary because viruses are usually smaller than 0.1 μm, so ultrafiltration or nanofiltration, are used. Membrane filtration is an emerging technology that agencies in California, such as Alameda County Water District (ACWD), have started to implement on a limited basis.

2.2.3 Distribution Systems

The purpose of a water distribution system is to deliver an adequate water supply at sufficient pressures while maintaining water quality. Disinfectants are maintained through the distribution system or added prior to the distribution to prevent microbial regrowth. Ineffective operation of a water treatment plant may result in contaminants of concern being discharged into the distribution system and ultimately to end-users. Additionally, disinfectants may react further with organic carbon in the distribution system to form more DBPs.

2.3 Water Treatment Plants Included in this Survey

This section provides background information on the surveyed WTPs and their source waters. More detailed information is included in the meeting summaries (Appendix C, D, and E). Table 2-1 presents a breakdown of each WTP treatment strategy, including water treatment plant capacity, process description, primary and residual disinfectants, and key treatment processes that provide optimal results. This evaluation focused only on those treatment plants that treat Delta water, with one exception. The City of Vallejo's Green Valley WTP recently implemented a new technology (MIEX®) that was demonstrated as part of a WQP-funded project.

The majority of agencies practice enhanced coagulation in one form or another to reduce high influent concentrations of DBP precursors. Many agencies have implemented modifications and upgrades to conventional systems in response to Delta water quality issues, some of which are discussed in Section 3. Of the ten water treatment agencies interviewed, only CCWD's Randall-Bold WTP currently does not have conventional treatment process and uses a direct filtration system with mixed media GAC. This will soon change, as CCWD is currently in the process of adding sedimentation at their Randall-Bold WTP due to treatment operation difficulties resulting from high organic carbon concentrations and variability in Delta water.

Table 2-2 provides a summary of source waters for the agencies' WTPs participating in this survey. The summary includes percentage of Delta water at WTP intakes, raw water storage facilities, Delta source water constituents of concern, alternate source waters, and alternate source water constituents of concern. Of the WTPs interviewed, eight of the ten agencies have WTPs primarily dependent on the Delta water[3]: ACWD, CCWD, Santa Clara Valley Water District (SCVWD), the City of Avenal (Avenal), the City of Coalinga (Coalinga), Crestline Lake Arrowhead Water Agency (CLAWA), MWD, and Central Coast Water Authority (CCWA). The remaining treatment plants have supplemental water sources that are blended with Delta water, including: the City of Vallejo and Kern County Water Agency (KCWA). KCWA exchanges almost all of their Delta supply for alternative source water and only uses about 10 percent Delta water for drinking water when it is at its highest quality.

Bay/Delta Region – North Bay Aqueduct

The City of Vallejo was the only agency treating Delta water on the NBA system interviewed for this survey. They receive the majority of their raw water from the NBA and operate three drinking water treatment plants within their domain: Fleming Hill, Travis, and Green Valley. The Green Valley WTP obtains water from Lake Berryessa.

Bay/Delta Region – Contra Costa Water District

CCWD diverts Delta water from Contra Costa Canal, through the Old River system which includes Los Vaqueros Reservoir (an offstream reservoir, primarily storing Delta water with a small amount of local runoff), or through Mallard Slough when Delta water quality is good enough. CCWD treats this water at two treatment plants, Bollman WTP and Randall Bold WTP.

[3] Some agencies have other treatment plants not using Delta water. These plants are not included in this report.

Table 2-1. Treatment Summary

Water Agency	Water Treatment Plant (Capacity, MGD)	Conventional/ Non-conventional	Primary Disinfectant	Residual Disinfectant	Key Treatment Methods/Processes
Barker Slough Intake – North Bay Aqueduct					
City of Vallejo (Vallejo)	Fleming Hill WTP (42)	Conventional Pre-ozonation, GAC Filtration	Chlorine (intermediate ozonation)	Chloramines	Intermediate ozonation
	Travis WTP (7.5)	Conventional	Chlorine	Chlorine	
	Green Valley WTP	Conventional MIEX ion exchange system	Chlorine	Chlorine	Effective organic carbon removal from MIEX Ion Exchange system
Banks Intake – South Bay Aqueduct					
Alameda County Water District (ACWD)	Mission San Jose WTP (8.5)	Conventional Membrane ultra-filtration, PAC addition	Chlorine	Chloramines	Membrane ultra-filtration, PAC used for T&O reduction
	WTP Number 2 (21)	Conventional	Pre-ozonation	Chloramines	Ozonation, pH-suppression using carbon dioxide
Old River and Rock Slough Intake – California Aqueduct					
Contra Costa Water District (CCWD)	Randall-Bold WTP (40)	Non-conventional/ Direct filtration, mixed-media GAC filtration	Ozonation: Pre (raw water) and post filtration	Chloramines	Future switch pre/post ozonation to intermediate ozonation
	Bollman WTP (75)	Conventional mixed-media GAC filtration	Intermediate ozonation (after sedimentation)	Chloramines	Intermediate ozonation
Banks Intake – South Bay Aqueduct and Tracy Intake – Delta Mendota Canal, San Felipe Unit					
Santa Clara Valley Water District (SCVWD)	Penitencia WTP (42)	Conventional, PAC GAC filtration	Chlorine (switching to intermediate Ozone)	Chloramines	
	Rinconada WTP (80)	Conventional, PAC Upflow clarifiers	Chlorine (switching to intermediate Ozone)	Chloramines	
	Santa Teresa WTP (100)	Conventional, PAC GAC filtration	Chlorine (switching to intermediate Ozone)	Chloramines	
Banks Intake – California Aqueduct					
City of Avenal (Avenal)	WTP No. 1 (2.2)	Conventional Upflow clarifiers	Chlorine	Chlorine (switching to chloramines)	
	WTP No. 2 (3.1)	Conventional Upflow clarifiers	Chlorine	Chlorine (switching to chloramines)	
Banks Intake – California Aqueduct					
City of Coalinga (Coalinga)	Coalinga WTP (12)	Conventional Dual-media filtration, PAC addition	Chlorine (switching to chloramines)	Chlorine (switching to chloramines)	
Banks Intake – California Aqueduct					
Kern County Water Agency (KCWA)	Henry C. Garnett WTP (45)	Conventional PAC addition, Gravity multi-media filtration,	Chlorine	Chlorine	Pre-oxidation of raw water with potassium permanganate; Seasonal use of PAC system for T&O reduction (algae growth)
Banks Intake – California Aqueduct, Coastal Branch					
Central Coast Water Authority (CCWA)	Polonio Pass (43)	Conventional GAC filtration	Chlorine (considering ozone)	Chloramines	TOC removal by GAC filtration; Pre-oxidation with free chlorine
Banks Intake – California Aqueduct, East Branch					
Crestline Lake Arrowhead Water Agency (CLAWA)	Lake Silverwood WTP (5)	Conventional Upflow clarifier multi-media pressure filtration, GAC filtration	MIOX® (mixed oxidants) on-site generation	Chlorine	TOC removal and DBP reduction by GAC filtration
Banks Intake – California Aqueduct, East Branch					
Metropolitan Water District of Southern California (MWD)	Henry J. Mills WTP (160)	Conventional: Gravity bio-filtration	Pre-ozonation	Chloramines	Ozone disinfection system for DBP and T&O reduction

Table 2-2. Source Water Summary

	Water Treatment/ Filtration Plant (Capacity, MGD)	Percentage of Delta at Plant Intake	Delta Water Storage	Delta Source Water Constituents of Concern	Alternate Source Water	Alternate Source Water Constituents of Concern
Barker Slough Intake – North Bay Aqueduct						
City of Vallejo (Vallejo)	Fleming Hill WTP (42) Travis WTP (7.5)	0-100%		• High & variable TOC • Low alkalinity	Lakes System: Solano Water Project -Lake Berryessa, Lakes Frye and Madigan	
	Green Valley WTP	0%		• High & variable TOC	Lake Frye, local watershed	
Banks Intake – South Bay Aqueduct						
Alameda County Water District (ACWD)	Mission San Jose WTP (8.5)	100%	Lake Del Valle	• High & variable TOC, pH, & temp • T&O • Turbidity	None	None
	WTP Number 2 (21)			• High & variable bromide, TOC, pH, & temp • T&O • Turbidity		
Old River and Rock Slough Intake						
Contra Costa Water District (CCWD)	Randall-Bold WTP (40) Bollman WTP (75)	100%	Los Vaqueros, Contra Loma, Mallard, and Martinez Reservoirs	• High & variable TOC & bromide • Salinity		
Banks Intake – South Bay Aqueduct and Tracy Intake – Delta Mendota Canal, San Felipe Unit						
Santa Clara Valley Water District (SCVWD)	Penitencia WTP (42) Rinconada WTP (80) Santa Teresa WTP (100)	90%	Lake Del Valle San Luis Reservoir	• High & variable TOC & bromide • T&O • Turbidity	Anderson, Coyote, Calero, and Almaden reservoirs	T&O, pathogens
Banks Intake – California Aqueduct						
City of Avenal (Avenal)	WTP No. 1 (2.2) WTP No. 2 (3.1)	100%	None	• High TOC • Turbidity • Variable alkalinity	None	None
Banks Intake – California Aqueduct						
City of Coalinga (Coalinga)	Coalinga WTP (12)	100%	None	• High TOC • T&O	None	None
Banks Intake – California Aqueduct						
Kern County Water Agency (KCWA)	Henry C. Garnett Water Purification Plant (45)	0%-10%	Complex water exchange	• High & variable TOC	Kern River exchange Friant-Kern canal	Background arsenic levels
Banks Intake – California Aqueduct, Coastal Branch						
Central Coast Water Authority (CCWA)	Polonio Pass WTP (43)	100%	None	• High TOC • T&O • Variability in turbidity, pH alkalinity	None	None
Banks Intake – California Aqueduct, East Branch						
Crestline Lake Arrowhead Water Agency (CLAWA)	Lake Silverwood WTP (5)	100%	Lake Silverwood	• High TOC • Turbidity • T&O	Lake Silverwood watershed	High turbidity
Banks Intake – California Aqueduct, East Branch						
Metropolitan Water District of Southern California (MWD)	Henry J. Mills WTP (160)	100%	None	• High & variable TOC & bromide • Increasing turbidity • T&O	Emergency supply from Colorado River	• High salinity

Bay/Delta Region – South Bay Aqueduct

ACWD and SCVWD both divert Delta water through the South Bay Aqueduct, which is connected to Lake Del Valle. SCVWD also diverts Delta water from the San Luis Reservoir through the Santa Clara and Pacheco Conduits. ACWD operates two water treatment plants, Mission San Jose WTP and Water Treatment Plant 2, which treat almost 100% Delta water diverted from the South Bay Aqueduct. ACWD uses membrane ultra filtration coupled with conventional flocculation/coagulation at the smaller Mission San Jose WTP, while relying on a straight conventional system at Water Treatment Plant 2. SCVWD manages three water treatment plants receiving about 90 percent of their water from the Delta: Penitencia WTP, Rinconada WTP, and Santa Teresa WTP.

California Aqueduct – San Joaquin Valley

KCWA, Avenal, and Coalinga are some of the water agencies in the San Joaquin Valley that divert water from the California Aqueduct. Coalinga and Avenal have been identified by DHS as disadvantaged communities because of a lower average per-capita income. A large percentage of the populations that they serve are residents of penitentiaries and/or state hospitals. Avenal operates two adjacent and nearly identical conventional treatment plants that divert water directly from the California Aqueduct. Coalinga diverts water from the Coalinga Canal, a small branch off the California Aqueduct. Both Coalinga and Avenal have previously experienced episodes of non-compliance with DBPs and therefore are in the process of looking at disinfection alternatives.

KCWA treats only about 10 percent Delta water at their conventional Henry Garnett Water Purification Plant (WPP), even though they receive about 25 percent of the total water in the California Aqueduct. KCWA has a complex system of water exchanges in which they exchange the majority of their Delta water for irrigation and receive higher quality Kern River water in return. KCWA also operates a complex banking system, where they store Delta water in a groundwater aquifer for later use.

California Aqueduct – Southern California

MWD, CCWA, and CLAWA are water agencies in Southern California that divert Delta water from conveyance channels that branch off the California Aqueduct. MWD operates five treatment plants, but discussions focused on their Mills Water Filtration Plant, which treats 100 percent Delta water diverted from the East Branch of the California Aqueduct. CLAWA diverts Delta water from the East Branch, stores it in Lake Silverwood along with a small amount of local watershed runoff, and treat it at the Lake Silverwood WTP. CCWA diverts water from the Coastal Branch of the California Aqueduct and treat it at the Polonio Pass WTP.

2.4 Delta Water Quality

Within the CALFED Water Quality Program Initial Assessment Report[4], water quality data at selected locations on the Sacramento and the San Joaquin Rivers and the five primary Delta Intakes are presented. Some of the water quality data for selected constituents of concern are repeated in

[4]Available at the CALFED website, http://calwater.ca.gov/CALFEDDocuments/CALFEDDocuments.shtml

this report for the five principal Delta water intakes: Banks, Tracy, Rock Slough, and Old River Intakes (collectively the "South Delta Intakes") and Barker Slough Intake. Other previous water quality assessments of the Bay-Delta system include *Organic Carbon Trends, Loads, Yields to the Sacramento-San Joaquin Delta, California*, *Water Years 1980 to 2000*[5], which characterizes organic carbon and nutrients from the primary tributaries to the Delta, and *Sources and Magnitudes of Water Quality Constituents of Concern in Drinking Water Supplies Taken from the Sacramento-San Joaquin Delta*[6], which provides additional information on water quality in the tributaries and at intakes.

The water quality data presented here provides information on water quality at the Delta Intakes. Constituent concentrations at the Delta Intakes are not necessarily representative of what is seen at WTPs due to water quality changes during conveyance, storage, and/or blending with other sources.

2.4.1 Intake Pumping Rates

The monthly average and standard deviation for pumping rates at Banks and Tracy intakes from 1998 to 2004 are presented in Figure 2-1. The years from 1998 to 2004 most closely represent the current pumping rates at Delta intakes after a number of pumping operation changes, including the addition of Los Vaqueros Reservoir. Monthly average pumping rates typically range from 1,000 – 6,000 cubic feet per second (cfs) at both Banks and Tracy, and vary seasonally with significantly less pumping occurring in spring/early summer and peak pumping occurring in late summer/early fall. Monthly average and standard deviation of pumping rates at Barker Slough, Old River, and Rock Slough Intakes from 1998 to 2004 are presented in Figure 2-2. Monthly averages for pumping rates at the smaller intakes are typically in between 20 and 200 cfs and exhibit a different seasonal pattern, with significantly less pumping occurring in winter and maximum pumping in the late spring/early summer.

[5] United States Geological Survey. 2003. Organic Carbon Trends, Loads, and Yields to Sacramento-San Joaquin Delta, California Water Years 1980 to 2000.

[6] Woodard, Richard. Sources and Magnitudes of Water Quality Constituents of Concern in Drinking Water Supplies taken From the Sacramento-San Joaquin Delta. Prepared for the CALFED Bay-Delta Program. September 2000.

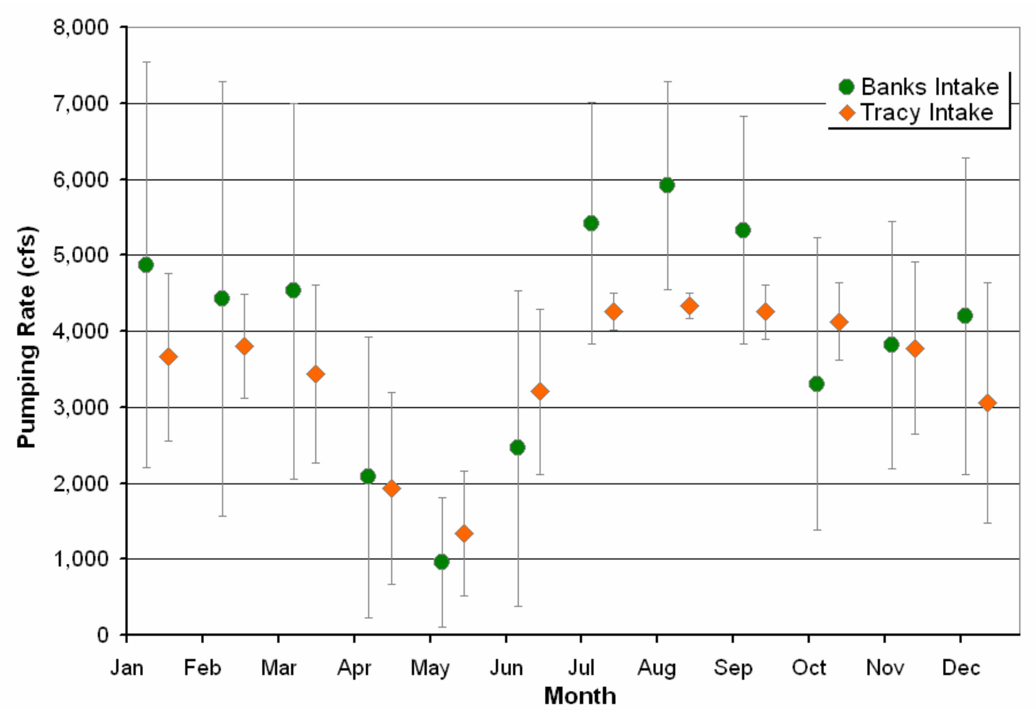

Figure 2-1. Monthly average and standard deviation of pumping rates at Banks and Tracy Intakes (calendar year 1998-2004) [Data obtained from DWR and USBR]

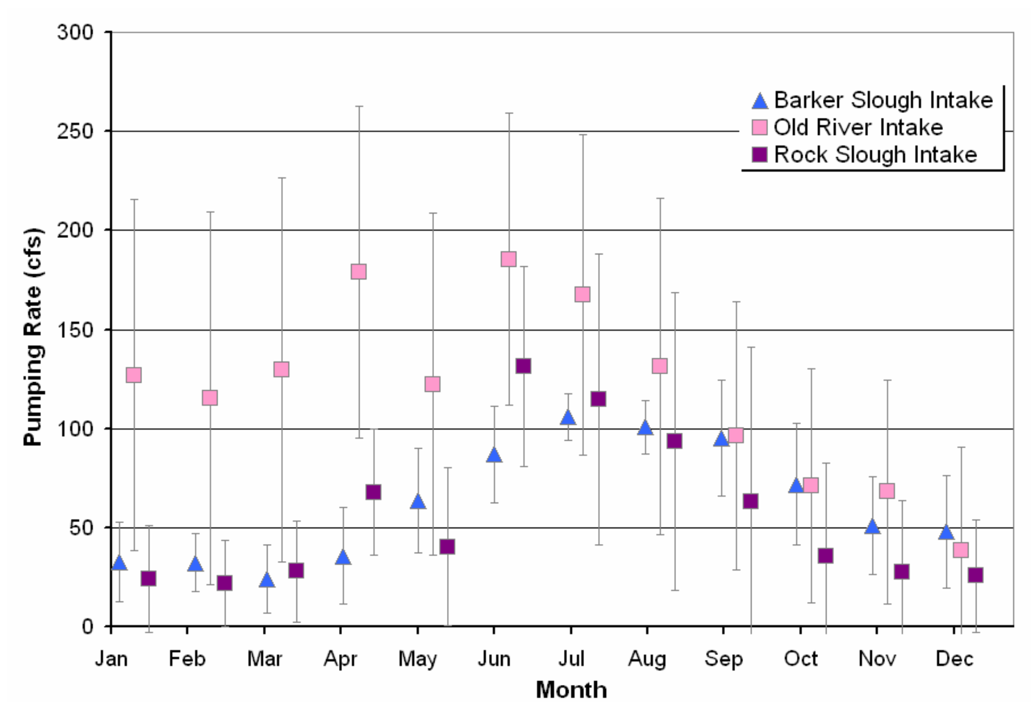

Figure 2-2. Monthly average and standard deviation of pumping rates at Barker Slough, Old River, and Rock Slough Intakes (calendar year 1998-2004) [Data obtained from DWR and CCWD]

2.4.2 Salinity

Salinity in the Delta is commonly measured in several different ways, including electrical conductivity (EC), total dissolved solids (TDS), bromide, and chloride. High concentrations of bromide and chloride are particularly a concern because they contribute to formation of total trihalomethanes (THMs) and bromate. The monthly average of salinity at Delta intakes, as measured by EC, dissolved bromide, and dissolved chloride, are shown in Figures 2-3 through 2-5. Measures of salinity, as seen in these figures, exhibit a different seasonal pattern at Barker Slough Intake than at the other South Delta Intakes. The EC monthly averages for the South Delta Intakes are typically between 200 and 1,000 μS/cm and seasonal peaks primarily occur during winter months, with the lowest EC values in summer months. In contrast, the monthly average EC values at the Barker Slough Intake exhibit different seasonal patterns, where EC average values are between 200 – 500 μS/cm, peak in late spring/early summer, and are lowest in the late summer.

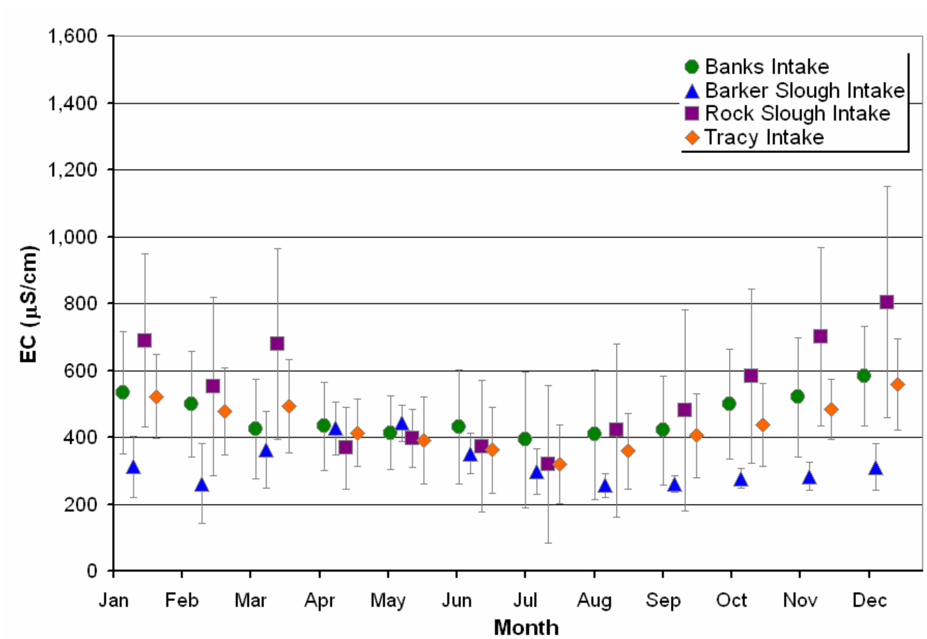

Figure 2-3. Monthly average and standard deviation of electrical conductivity at Delta Intakes (calendar year 1990-2004) [Data obtained from MWQI and for Tracy data for years 1999-2005 from USBR]

Similar to EC, bromide concentrations at the South Delta Intakes are highest in early winter, and concentrations are typically higher than 100 μg/L and can be as high as 700 μg/L (Figure 2-4). Bromide concentrations at Barker Slough Intake are usually less than 50 μg/L, and the highest concentrations are in the spring. The numeric ROD intake target of 50 μg/L for bromide is consistently exceeded year round at all the South Delta Intakes while concentrations are below the Intake target at Barker Slough except during the peaks in the summer months.

Chloride concentrations at the South Delta Intakes exhibit the same seasonal pattern as observed for EC and bromide with monthly average concentrations from 48 to 150 mg/L. Chloride concentrations at Barker Slough Intake also follow a similar pattern to EC and bromide and rarely exceed 50 mg/L, which is significantly less than at the South Delta Intakes.

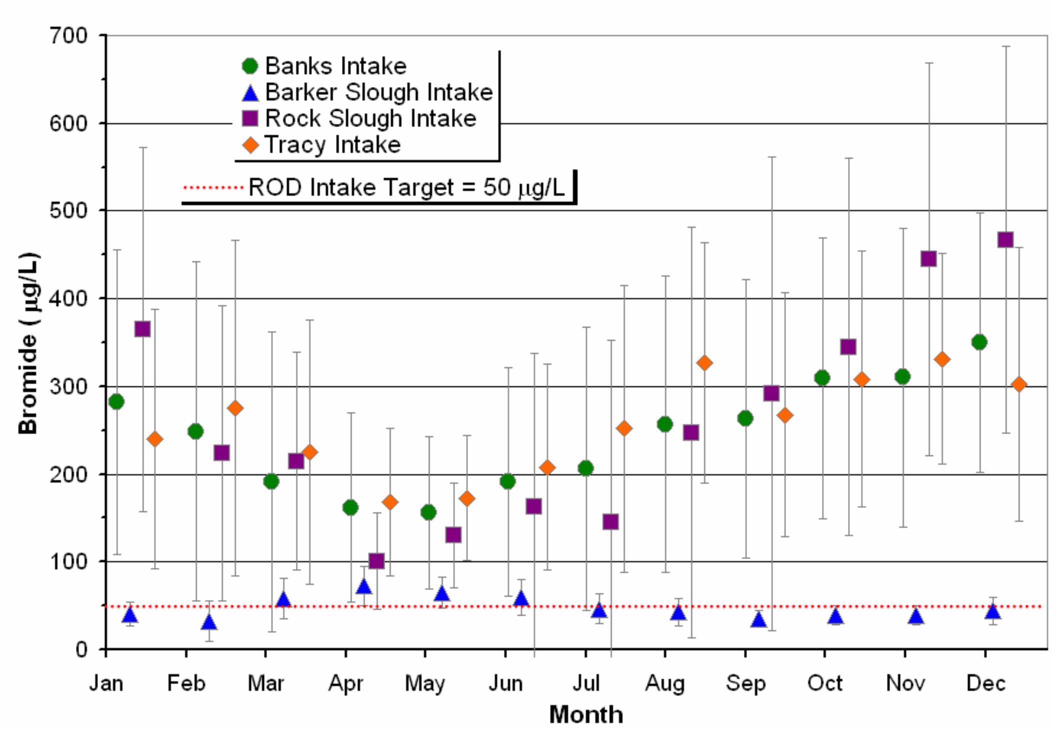

Figure 2-4. Monthly average and standard deviation of bromide concentrations at Delta Intakes (calendar year 1990-2004) [Data obtained from MWQI and for Tracy 2003-2005 from USBR]

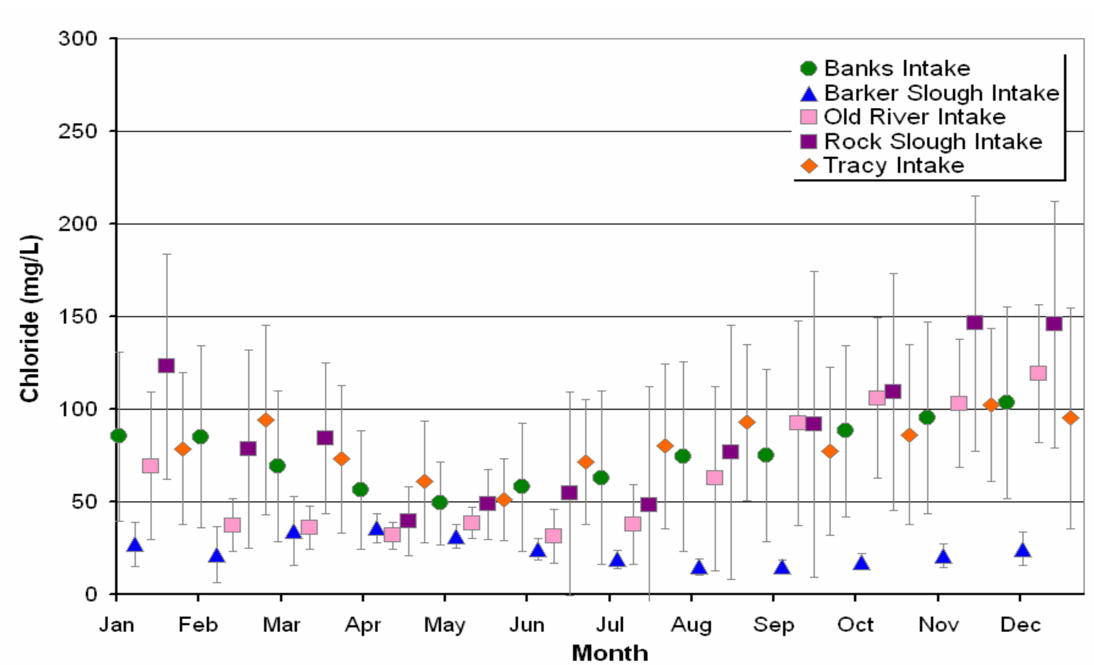

Figure 2-5. Monthly average and standard deviation of chloride concentrations at Delta Intakes (calendar year 1990-2004) [Data obtained from MWQI for Banks, Barker Slough and Tracy, Rock Slough, and from CCWD for Old River]

2.4.3 Organic Carbon

Drinking water agencies are primarily concerned with organic carbon compounds in their source water due to the potential formation of DBPs, as discussed above. The monthly average and standard deviation of DOC for years 1990 to 2004 is presented in Figure 2-6. DOC at the South Delta Intakes exhibits a seasonal peak in the mid-to-late winter, with the lowest values typically in the late summer and fall. DOC at Barker Slough Intake exhibits a different pattern, with DOC values usually greater than the South Delta Intakes and peak values occurring in late fall early spring. In general, the ROD TOC target is frequently exceeded at all intakes (based on DOC concentrations which are usually about 90 percent of the TOC concentrations in the Delta), except during the summer and early fall when DOC concentrations are at their lowest.

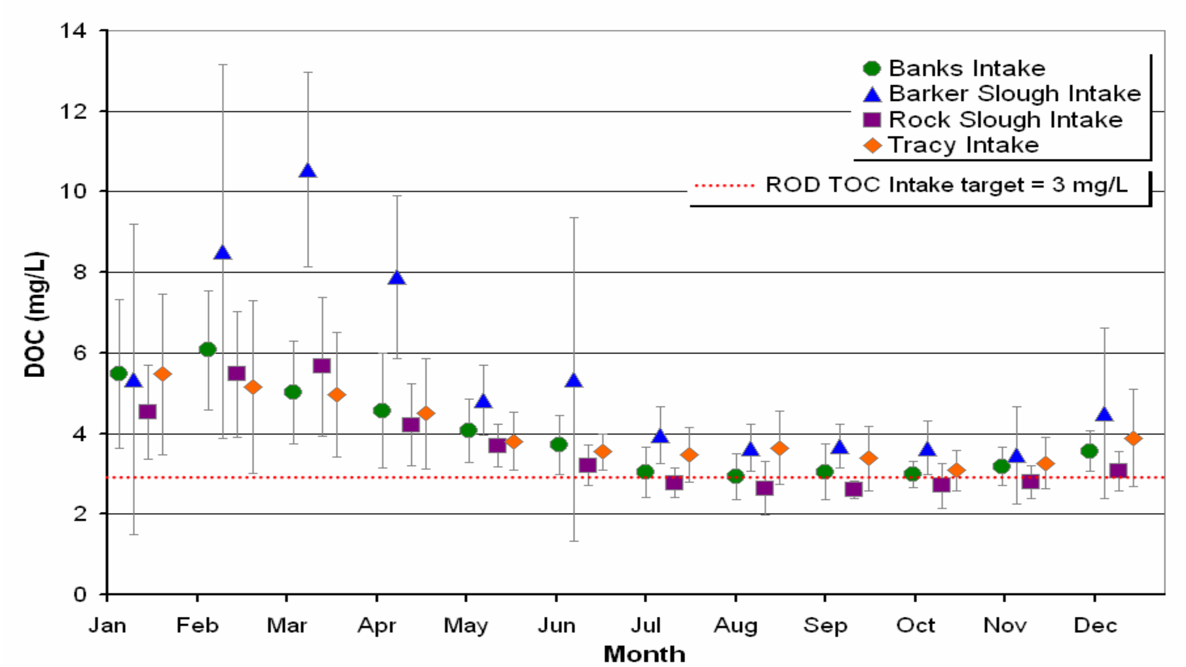

Figure 2-6. Monthly average and standard deviation of DOC concentrations at Delta Intakes (calendar year 1990-2004) [All data obtained from MWQI except Tracy (2003-2005) from USBR]

2.4.4 Nutrients

Nutrient data at Delta Intakes is more temporally sparse and not available at some intakes. At sampling locations within the Delta, nitrogen is commonly measured as NO_2, NO_3, the sum of NO_2 and NO_3, and Total Kjeldahl Nitrogen (TKN), which is the sum of ammonia and organic nitrogen. The sum of dissolved nitrate and nitrite (NO_3+NO_2) is presented in Figure 2-7 because it is the most frequent nitrogen measurement among all the selected sites. Measurements for NO_3+NO_2 do not include organic nitrogen and ammonia, which can represent significant fractions (30-95 percent) of the total nitrogen present. While data is limited, there does appear to be a seasonal pattern in nitrogen concentrations, with the highest concentrations in the early spring and lower concentrations in the fall. However, there is not sufficient data for a conclusive statement. Figure

2-8 shows the limited available phosphorous data. Due to the limited data no conclusions or seasonal patterns can be observed.

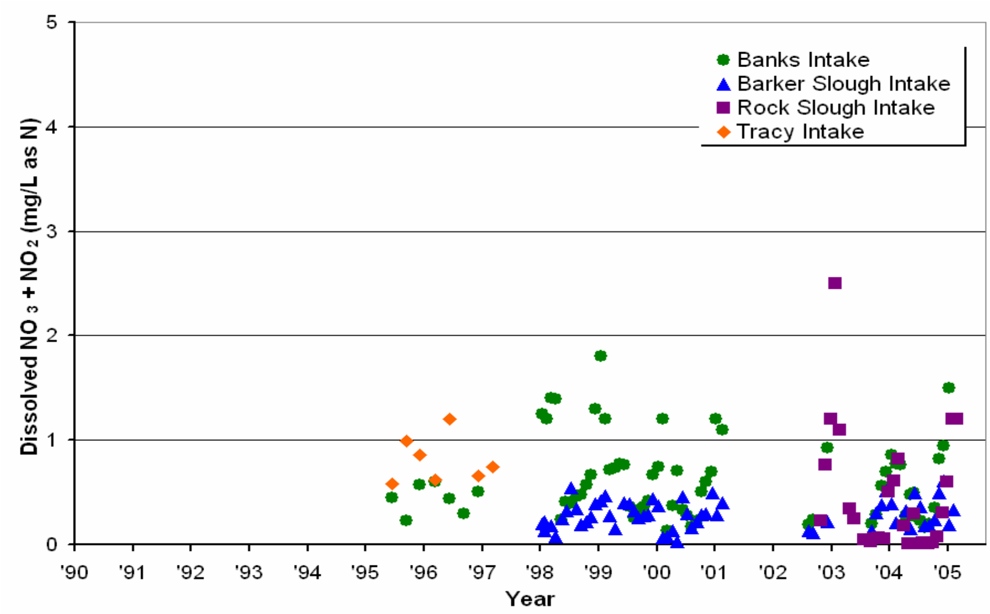

Figure 2-7. Nitrogen at Delta Intakes (calendar year 1995-2005) [Data obtained from MWQI]

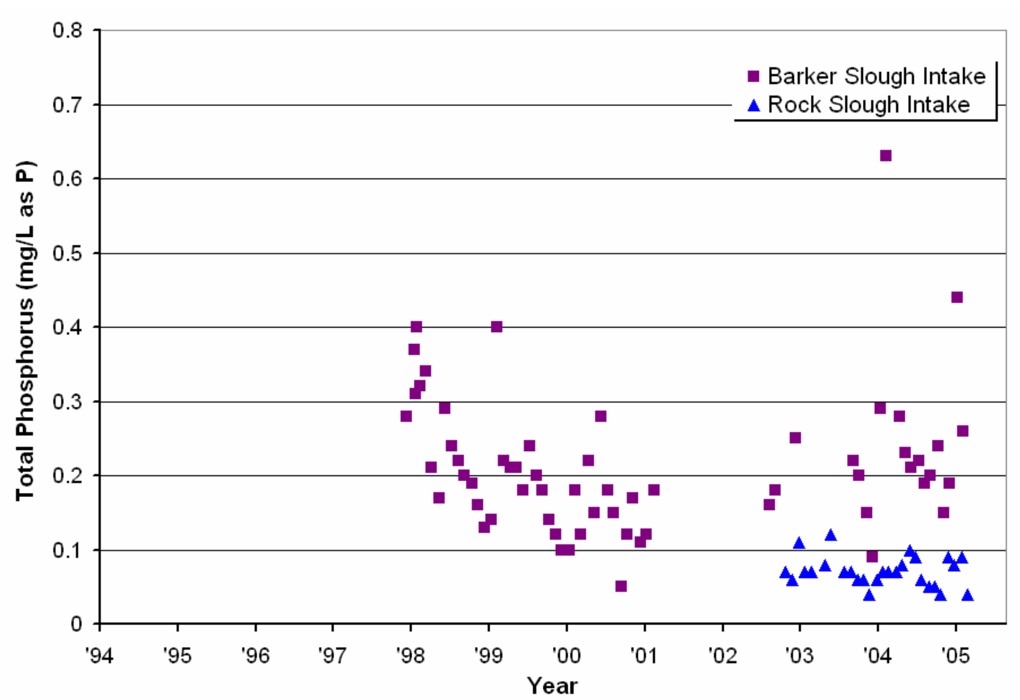

Figure 2-8. Total Phosphorus at Barker Slough and Rock Slough Intake (calendar year 1997-2005) [Data obtained from MWQI, other intake data was not available]

2.4.5 Real Time Data Forecasting

The Municipal Water Quality Investigation program of DWR initiated the Real Time Data and Forecasting program (RTDF) in 2002. The RTDF surveyed SWP utilities and CCWD to determine water quality data needs and uses. Based on this survey, the RTDF's goal is to enhance utilities' operational flexibility by providing real time water quality data and near term forecasts of water quality in both the Delta and California Aqueduct. In 2004, RTDF began producing weekly water quality reports that analyze available recent water quality data of interest. Ultimately RTDF will couple monitoring and individual models in the Delta, tributaries, and conveyances to forecast water supply, demand and quality, and collect and disseminate high frequency water quality data in real time.

SECTION 3

RESULTS OF WATER TREATMENT INTERVIEWS

This section summarizes the information obtained from participating water treatment plant (WTP) representatives and DHS district engineers as common themes heard during the interviews. WTPs treating Delta water were selected for involvement in this project; the group purposefully includes small and large utilities on each branch of the State Water Project system, as well as the Contra Costa Water District. Questions were developed to gather information on agency water quality goals, challenges, and opportunities from the Delta through to treatment, looking at the multiple barriers available to provide good drinking water treatment. For detailed information, it is suggested that the meeting summaries be reviewed. Meeting summaries have been divided into subsections by Bay-Delta, San Joaquin Valley and Southern California regions and located in Appendix C, D, and E respectively.

3.1 Delta Source Water

Agencies were queried as to their definitions of water quality reliability, constituents of concern, concerns with Delta source water quality, concerns with conveyance, and suggestions for water quality improvement. General themes heard in response are summarized below. Information gathered about specific WTPs and source water quality is presented in Section 2 (Table 2-2).

3.1.1 Definitions of Water Quality Reliability

Agencies were asked to define water quality reliability and identify their priorities with respect to water quality reliability. All the agencies responded that raw water quality reliability is paramount for the production of high quality and safe drinking water. Reliability concerns tended to be a reflection of operating parameters specific to individual treatment process needs and the quality of Delta water they receive. There was no uniform definition of Delta water quality reliability but three key aspects were emphasized: consistency and stability, predictability, and treatability.

Consistency and Stability

Water quality that does not continually fluctuate, particularly overnight, was identified as the most important aspect of reliability (i.e. consistency and stability). Delta water quality reliability could be improved by reducing the overall daily (sometimes hourly) variability of TOC, bromide, turbidity, temperature, algae growth and pH.

Predictability

Some agencies stated that predictability is a more realistic goal than stability, and would allow treatment plants to better utilize their resources and tools. Predictability gives treatment plants flexibility to make treatment adjustments when Delta water quality is not consistent and stable.

Treatability

A reliable source has to be treatable. A number of agencies have made significant investments in treatment processes to meet the challenges of treating Delta water. Therefore, there is concern that if Delta water quality degrades it will be increasingly difficult to treat the water and further costly adjustments and/or upgrades may be required.

Both MWD and KCWA suggested that the CALFED numeric Record of Decision (ROD) targets for TOC and bromide are not feasible with the current proposed Delta improvements. For example, KCWA's highest priority is a stable source water quantity. For KCWA, variability and high constituent concentrations are less of a concern because of their unique water banking system and they prefer not to compromise Delta water quantity for improved quality.

3.1.2 Constituents of Concern in Delta Water

Organic Carbon

Both unpredictable TOC spikes and generally high concentrations are a concern for most agencies. CLAWA said that TOC has been "a thorn in the saddle for over twenty years." Coalinga and Avenal have experienced periods of non-compliance with THM maximum contaminant levels (MCLs) due to high and variable organic carbon concentrations. Coalinga was concerned that the DBP formation potential rises as raw water is transported down the California Aqueduct.

Avenal said that an event in which they were in non-compliance with DBPs was caused by unpredictable and episodic high TOC concentrations and fluctuations. These fluctuations are often identified only when chlorine residuals change. Coalinga expressed concern that they are unable to identify and address any other potential constituents of concern, beyond organic carbon, because they need to remain focused on meeting DBP regulations.

Several agencies expressed interest in better understanding organic carbon fractionation and concentration of DOC compared to TOC, so that they could more effectively remove organic carbon during treatment.

Turbidity

Many agencies stated that substantial sediment deposition in Clifton Court Forebay and turbulence from strong winds has resulted in high turbidity concentrations in SWP water. Both MWD (for Delta water treatment plants) and Avenal noted that turbidity was on the rise and Avenal experiences nightly fluctuations that they attribute to sedimentation in the California Aqueduct.

Bromide

A number of agencies are increasingly concerned about unexpected spikes in bromide concentrations and resultant bromate formation as they switch from chlorination to ozonation. ACWD noted that problems with bromide concentrations are compounded by variable pH values that result in difficulties when employing pH suppression strategies to reduce bromate formation. DBP formation was discussed by all agencies but only the agencies currently using ozone or planning on switching to ozone specifically expressed concerns with bromide.

Taste and Odor

A number of agencies expressed concern with taste and odor (T&O) compounds. For some agencies algae growth occurs in storage reservoirs, while for others algae growth occurs in Clifton Court Forebay and/or conveyance channels. Several agencies noted that Clifton Court Forebay has become shallower, which allows high light penetration throughout the water column and leads to an increase in water temperature, which, when combined with high nutrient concentrations, enhances algae growth.

Temperature, pH, and alkalinity

A few agencies also mentioned problems with temperature and pH which cause treatment difficulties overnight. Problems with alkalinity fluctuation and poor buffering of NBA waters were mentioned by Vallejo.

3.1.3 Concerns with Delta Source Water Quality

Variability in Concentration

The majority of agencies identified source water quality variability as their top concern. TOC variability is a predominant concern; some agencies also stated that they experience frequent changes in bromide, turbidity, pH, alkalinity, T&O compounds (related to algae growth) and temperature. This variability was said to pose a major challenge because of the need to continually adjust treatment processes. Variability often occurs on a timescale of hours and days, creating insufficient response time for WTPs and leading to potentially avoidable higher treatment costs.

Levee Integrity

A number of agencies mentioned that the Jones Tract levee failure and associated pumping caused both immediate high organic carbon concentrations after the failure and continued high organic carbon concentrations during the pump off. Agencies expressed concern that, in the future, organic carbon and release of T&O causing compounds from levee failures and Delta Island pumping could cause treatment problems and potential compliance failures. MWD suggested the need for a contingency plan in dealing with future levee failures.

Blending and Storage

Smaller facilities along the SWP, like Avenal, currently have no options for blending or storage of SWP water and frequently have to modify their operations to accommodate changes in incoming water quality. Avenal and Coalinga were particularly interested in investigating banking options.

Blending and storage options attenuate the variability in Delta water quality. Many agencies that do not currently have blending or storage options said they would like to investigate this as an alternative to treatment changes, in order to reduce the treatment challenge of highly variable Delta water quality. In general, those agencies that have storage and blending options expressed less of a concern about water quality variability and periodic high spikes in constituent concentrations.

Water quality within SWP conveyances was also discussed, with some agencies expressing concerns with the water quality impacts of blending and exchange programs and water transfers, where lower quality water is introduced into conveyances. In addition, agencies have noticed that at times, poor quality water remains in the California Aqueduct longer because some agencies opt to utilize water from other sources, leaving other agencies with the poorer quality water from the aqueduct.

Discharges into the Delta

Most agencies desire better understanding, identification, and characterization of point and non-point sources of water quality degradation. One source specifically mentioned was wastewater effluent, and the percentage thereof at intakes. The primary constituents of concern from point and non-point discharges are nutrients and emerging contaminants, such as Personal Care Products and Pharmaceuticals (PCPPs).

3.1.4 Concerns with Water Quality in Conveyances

There were two primary concerns expressed regarding impacts to water quality during conveyance: pollutants introduced into conveyance channels and algae growth within conveyance channels.

A number of agencies believe that non-point sources of pollutants need to be identified and addressed, because they contribute to water quality degradation. Specifically there was concern that construction at Arroyo Pasajero was a large contributor of turbidity and sometimes asbestos from construction site runoff. San Joaquin Valley and Southern California agencies expressed concern over the potential for indirect discharges of arsenic into the California Aqueduct from agricultural use of groundwater with high background concentrations of arsenic.

Algae growth in both Clifton Court Forebay and the conveyance channels, particularly the open portions of the SBA, are believed to impair treatment processes and cause taste and odor problems.

3.1.5 Suggested Areas for Water Quality Improvement

The primary suggestions by agencies for Delta water quality and SWP system improvements can be organized into five broad categories: reduction of contaminants of concern, monitoring improvements, development of emergency contingency plans, alternative storage and blending, and remedial actions to Clifton Court Forebay. Other specific concerns are included in the treatment interview meeting summaries (Appendix C, D, and E).

Reduction of Constituents of Concern

A number of actions were recommended to reduce constituents of concern, including organic carbon, bromide, turbidity, and nutrients. Specific recommendations for source protection included better management of point and non-point discharges into the Delta, regulatory controls, Delta island drainage reduction, Clifton Court Forebay Best Management Practices (BMPs), and tertiary treatment of wastewater discharges, especially to minimize and/or control emerging contaminants such as PCPPs.

CCWA also mentioned it would be useful to research strategies to increase water circulation in the Delta by altering water flow paths through the levee systems to better control the direction of Delta flow. Understanding the flow paths would help determine the effects water transport have on constituents of concern.

Monitoring Improvements

A number of agencies expressed continuing support for the Municipal Water Quality Investigation (MWQI) program and Real-Time Data Forecasting project (RTDF), including support of an expansion of the RTDF project to more comprehensively capture the water quality variations occurring throughout the SWP system (in conveyance channels). Other augmentations suggested were coupling flow measurements with constituents and providing more timely data and analysis.

Some agencies discussed the need for integrating an early warning system into monitoring improvements to alert them of unexpected events of immediate and acute water quality degradation.

Development of Emergency Contingency Plans

Several agencies suggested that the development of long-term contingency plans for levee failures or other catastrophic natural and human derived events would be a beneficial preventative measure to enable appropriate actions in response to emergency situations.

Remedial Actions for Clifton Court Forebay

A number of suggestions were made to improve water quality in Clifton Court Forebay. It was suggested that dredging Clifton Court Forebay, to bring it back to its nominal depth would reduce turbidity concentrations, temperature, and algae growth. Development of BMPs for physical and chemical algae removal and treatment of point and non-point sources directly in and around the Forebay were also recommended.

Storage and Blending Improvements

A number of the agencies that rely solely on SWP water were interested in blending with alternative water supplies or adding local storage to attenuate the high concentrations and variability for specific water quality constituents. One potential option for increased storage is groundwater banking, similar to KCWA.

3.2 Treatment

All but one WTP surveyed uses conventional treatment processes, but a number of agencies stated that they benefit from unique processes that enable them to meet regulations and individual facility goals. Where possible, agencies tailor their treatment trains to the overall characteristics of incoming raw water. Many agencies use similar approaches to water treatment based on common source waters and shared concern over the raw water concentrations of specific constituents. In Section 2, Table 2.1, a breakdown summary of each WTPs treatment is presented.

3.2.1 Drinking Water Treatment Plant Goals

Agencies have implemented treatment strategies to satisfy regulatory requirements while simultaneously satisfying the aesthetic standards of their consumers. Most said that their decisions and treatment objectives were driven by compliance with the Stage 2 Disinfection/Disinfection by-Products D/DBP Rule and the potential for future reduction in DBP MCLs, but the majority of the water agencies also said they strive to surpass treated water quality regulations. Some of these agencies said that they had set their water treatment goals at levels that were more stringent than required by state regulations because of the variability in the quality of their source water. By maintaining a gap between treated water levels and regulations, treatment plants could operate within a zone that could accommodate deviations in raw water quality from the norm that would normally push their treated water quality into non-compliance.

Failure to effectively resolve T&O problems results in unsatisfied customers, so many agencies want to go beyond regulations to continually address aesthetic concerns. For example, MWD established an objective for their treatment plants to have "no complaints" from consumers. For Avenal and Coalinga, ensuring healthy and safe drinking water for their family and friends motivates them to exceed compliance regulations and maintain the aesthetic quality.

3.2.2 Overarching Treatment Topics

A number of recurring topics came up during discussions with agencies; the highlights are presented as follows.

Algae and T&O

A number of agencies identified concerns over high algae concentrations and resulting T&O problems from Clifton Court Forebay and subsequent conveyance channels. Agencies are also addressing algae growth in local storage reservoirs, at the end of the conveyance channels. Many agencies believe the use of ozone alleviates many of the T&O problems associated with MIB and geosmin. However, high algae concentrations can affect coagulation, sedimentation, and filtration processes prior to disinfection.

Concerns with Implementing New Technology

A few agencies expressed concerns about implementing new technologies. These concerns included apprehension with construction and/or operations of alternative technologies and doubts regarding their benefits.

For Avenal, Coalinga, and other small farming communities with limited resources, implementing new technologies are considered too risky because testing and implementing new techniques and equipment is both very expensive and very risky for smaller facilities that lack a large customer base to spread out capital and operating costs. Because of these concerns, smaller agencies tend to implement proven technologies. Both Avenal and Coalinga have chosen to use chloramines rather than ozone or chlorine dioxide.

Results from demonstration projects do not always translate into full-scale practice. For example, ACWD identified unexpected problems during full scale implementation of an ultra-filtration membrane process. They have experienced a decline in clarifier performance because of the recycled backwash streams from the membrane system as well as performance upsets due to fluctuating temperatures in Delta raw water. These problems were not identified during demonstration scale experiments of the new system. ACWD is investigating resolution of these problems and expects they will be costly. In the future, barring other considerations, ACWD would prefer to implement more proven treatment technologies.

Effective TOC Removal

CCWA and CLAWA said that the installation of GAC filters at Polonio Pass WTP and the Lake Silverwood WTP has yielded excellent TOC reduction and has overcome DBP concerns while retaining the use of free chlorine. However, recharge of activated carbon media in GAC filters is becoming more frequent at both WTPs and TOC removal efficiency decreased by 10% at Polonio Pass WTP after three months.

Vallejo has investigated several organic carbon removal systems, and it is their opinion that only two technologies can effectively reduce the concentrations of DBP precursors: GAC and the MIEX® (magnetic ionic exchange resin). Results from the WQP-funded MIEX® pilot study, managed by the Solano County Water Agency (water purveyor of NBA water), led Vallejo to implement this technology at their Green Valley WTP. Vallejo also investigated enhanced coagulation, as recommended by the USEPA, prior to the MIEX® system but found it to be an ineffective and costly temporary solution. Because of the addition of MIEX® at Green Valley WTP, the previously unmanned plant now requires an operator to adjust and monitor the system daily in response to high and variable TOC in water supplied from Lake Frye (not Delta water).

Water Treatment Improvements over Source Water Improvements

A number of agencies said that treatment improvements will be more effective in achieving higher drinking water quality than source improvements, because they have no control over source water improvements. Investments have primarily been made by agencies at their WTPs to address organic carbon removal and reduction in DBP formation. At the same time these same agencies realize that investments in treatment technology alone are not the final solution.

KCWA has found that investments in raw water supply exchanges and transfers are more cost effective than investments in treatment technologies to meet the challenges posed by varying Delta water quality. Their complex source shifting network addresses their concerns about Delta water quality.

Cost

A number of facilities mentioned that coagulant and pH buffering chemical costs are climbing without any sign of leveling off or reducing, due to high concentrations and variability in raw water TOC, bromide, turbidity, and algae levels. Similar concerns were also mentioned regarding operation and maintenance costs of filtration processes.

Other

Other areas of concern for treatment are arsenic concentrations in groundwater, *Cryptosporidium* analysis, and potential emerging contaminants such as PCPPs. A few agencies expressed concerns about increasing concentrations of non-Delta specific constituents like arsenic and nitrate that could be brought into conveyance systems through water exchanges or indirect discharges. There are also concerns regarding the lack of modern in-house laboratories and resources to develop techniques to carry out *Cryptosporidium* analyses at treatment plants. Agencies repeatedly mentioned a need for increased research and updates on the potential health effects of PCPPs and appropriate removal techniques.

3.2.3 Disinfection Processes

Current and prospective regulations for (DBPS) have resulted in a focus by agencies on disinfection and implementation of new disinfection processes. Variable Delta raw water quality, with its high organic carbon and salinity concentrations, increase the difficulties encountered in disinfection.

Ozone

The majority of agencies surveyed are either using ozone at some point in their treatment process, in the process of switching to ozone, or considering the possibility of using ozone (Table 2-1). Of the utilities employing ozone, optimizing point of use for ozone systems is clearly an integral part of the system's success. Ozonation provides excellent inactivation of targeted pathogens and DBP reduction; however, some smaller facilities have chosen to remain with chlorine disinfection because of process complexities, resource limitations, or current satisfaction with chlorine.

Two difficulties in using ozonation were noted: power requirements and bromate formation (due to high bromide concentrations in the Delta). CCWD and MWD noted that large power requirements and minimal fluctuations in power supply are needed for ozonation. ACWD uses CO_2 addition for pH suppression to reduce bromate formation during ozone disinfection. Control of this process is difficult because of the need for constant adjustment to accommodate variable raw water pH and bromide levels and because the reaction oxidizing bromide in the presence of ozone (creating bromate) is highly dependent on pH. After the pH suppression system was installed, ACWD benefited from a WQP-funded study which investigated bromate formation reduction resulting from pH suppression using CO_2.

MWD, Avenal, and CCWD evaluated chlorine dioxide prior to implementing ozonation, but determined that ClO_2 was impractical and more costly than an ozone system. At the time of MWD's chlorine dioxide feasibility study, state MCLs for chlorate concentrations in treated water (produced during disinfection with chlorine dioxide) were lower than current federal regulations, a factor in their disinfectant decision. The added benefits of T&O control also persuaded most agencies to implement ozone over other alternatives.

Chlorination

A number of agencies plan on retaining chlorine as their primary disinfectant at some WTPs, some because of limited resources to investigate other disinfectants, others because problems are resolved in other parts of the system. Smaller facilities have experienced difficulties with DBP MCL compliance, because they lack the ability to buffer high and often variable concentrations of organic carbon in raw water. The lack of available funding to conduct pilot studies for more advanced alternatives and to train staff members on a more complex system prevents many smaller facilities from switching away from chlorination. Avenal is currently investigating the use of chloramines as a primary disinfectant based on recommendations by DHS, but has delayed implementation due to a lack of resources.

CLAWA has installed a new onsite hypochlorite generation system called MIOX® (mixed oxidants) to replace its chlorine gas disinfection system. The decision was driven by risk management requirements, and the installation of MIOX® resulted in only minor THM and HAA reduction. The subsequent addition of GAC filtration, however, provided signification reduction in DBP formation. Agencies continue to use chlorine disinfection at their treatment plants because they are able to effectively limit DBP formation by removing organic carbon prior to disinfection. KCWA's unique source-shifting strategy allows them to continue using chlorine and still limit DBP formation, permitting them to invest their resources elsewhere.

3.2.4 Challenges with Future Regulations

Agencies primarily using Delta water stated that they are constantly trying to adhere to increasingly stringent standards using their own resources. Apprehension over further reductions in MCLs for THMs, HAAs, and bromate remain a continual concern even for agencies that have made numerous modifications to enhance TOC removal and optimize disinfection processes.

Treatment technology demonstrations and research that precede implementation of future regulations would be very helpful, particularly for smaller agencies with more limited resources.

3.2.5 Suggestions for Future Treatment Demonstrations

A number of research areas were suggested for future treatment technology demonstrations. Agencies are interested in additional research on detection and treatment information on emerging contaminants like PPCPs before they become regulated, particularly directed towards understanding the percent removal that conventional treatment offers.

Agencies are also interested in treatment demonstrations of best available technologies (BATs), focusing on organic carbon removal. In general, there is a consensus that the focus needs to be placed on demonstration projects for conventional and proven technologies, rather than focusing on new and emerging technologies. Many agencies believe that modifications to conventional treatment would be a more cost effective alternative than relatively new and expensive advanced treatment processes.

3.3 Distribution

3.3.1 Overall Concerns

Only a few agencies expressed concern about complying with the proposed Stage 2 D/DBP rule. These agencies cited distribution systems with long residence times and the inability to regularly flush the systems. Consequently, water quality in the distribution system has the potential to degrade to non-compliance levels.

Other agencies stated that they do not have concerns about the formation of disinfection byproducts in the distribution system for three reasons: (1) the residence time in the distribution system is low, thereby minimizing the degradation of water quality; (2) chloramines are used to minimize the formation of disinfection byproducts; and (3) an established water quality monitoring program is used to ensure that areas of non-compliance are identified and remedied.

3.3.2 Suggestions for Distribution System Future Efforts

Agencies that use chloramines expressed interest in learning ways to control nitrification in distribution systems. There is interest in studies and/or information seminars to identify operational factors such as detention time, pH, temperature, TOC concentrations, and the chlorine-to-ammonia ratios that influence nitrification in distribution systems.

3.4 Communication

Rapidly changing regulations and issues with changing water quality have elevated the need for water agencies to increase their level of external communication. All agencies participate in organizations and communicate with other neighboring agencies in varying degrees, however, it was noted that increased communication to discuss Delta water quality and treatment specific issues would be beneficial.

Agency to Agency Communication

Facility size and geographical location influence trends in local communication. The smaller, more isolated agencies typically interact less with other water agencies or with larger urban agencies. The majority of treatment plant operators expressed that communication with other treatment plants only occurred, for the most part, during emergency and highly problematic situations. Poor communication was not attributed to the fault or lack of discourse of any one group and there is strong desire to increase the level of local communication. The sharing of information about raw water quality, treatment, and even distribution issues was recognized as a very beneficial way to build on the experiences of other agencies with similar situations.

Although Avenal benefits from monthly meetings with representatives of the California Rural Water Agencies discussing new and forecasted regulations, free treatment workshops, and other information; many issues discussed, like groundwater, are not relevant to their interests. Avenal, like many other smaller agencies, is interested in more communication with local agencies using Delta water.

Larger agencies recognized the importance of establishing and maintaining a good network of local contacts and many facilities participate in organizations specific to their demographic area. As an example, ACWD has regular communication with the South Bay Aqueduct Water Quality Task Force. Many references were made to involvement in broad water organizations such as the State Water Contractors, California Urban Water Agencies, and frequent contact with government agencies like the DWR for water quality information.

Unlike many of the other agencies, KCWA continually directly interacts with the agricultural community, including the California Farm Water Coalition, because the farming community is such an important component of their water community.

Regional and Global Communication

Apart from communication with local agencies and drinking water groups, most agencies do participate to some extent in American Water Works Association (AWWA) activities. Many smaller facilities experience difficulty in sending staff members to AWWA national and AWWA California-

Nevada section conferences, limiting their use of that resource. Larger agencies tend to send a number of staff members to AWWA conferences and workshops, and find that material applicable to treating Delta water is presented. A number of agencies said that they would still benefit from more Delta focused workshops.

MWD noted their management and participation in several CALFED-funded projects, but felt the CALFED Science Conference is not the appropriate venue for Delta water treatment concerns and challenges because it does not specifically relate to drinking water.

"Delta Users" Web Forum

The majority of treatment agencies voiced a strong desire for access to multiple sources of Delta-related information in one location, such as a tailored web-based forum. A number of suggestions were made on what content would be most advantageous, such as research proposals, pilot scale results, and problems encountered during treatment. In addition to pilot scale studies, treatment facilities suggested providing information from full scale implementation. ACWD suggested that it would have been helpful to hear about other treatment experiences prior to their implementation of membrane treatment and that they would be happy to provide information on their experiences. A web forum could also provide updates on the progress of ongoing projects and future projects, and emphasize beneficial project information. CALFED could also use the web forum to provide information on the development of grant funding criteria and solicit agency comments. Awareness of grant funding cycles at the start of the cycle allows agencies to determine if they should do preliminary work ahead of the application period (e.g., perform preliminary site assessments or monitor water quality).

Providing these materials in an easily accessible and user-friendly forum is paramount. Data, research, and project material must be accessible in an easily downloadable and printable form. It should provide additional benefit to already established sources, not overlap existing forums, and enhance the capabilities of CALFED member agencies, such as DWR, to communicate with treatment facilities using Delta water.

To further communication among all Delta water users, a "Delta-focused" session of the AWWA California-Nevada section meeting was suggested. This should have an operations-based agenda and remain focused on the problematic areas of Delta water. However, smaller facilities also noted difficulty in sending operators to local or regional conferences and workshops, because operation of their plant is dependent on their limited staff. The web forum could provide a link to the conferences when operators cannot attend by providing conference materials, information and project highlights, identifying Delta specific or applicable issues discussed, and contact information for attendees and speakers.

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SECTION 4

CONCLUSIONS AND RECOMMENDATIONS

Brown and Caldwell, under the direction of the WQP, interviewed a representative sample of water agencies to obtain their perspective on the difficulties, challenges, and opportunities regarding treating Delta water. During these interviews agencies also recommended a number of actions that would address their concerns. This report summarizes water quality information and WTP information in Section 2; difficulties, challenges, and opportunities in Section 3; and recommendations in this section.

Brown and Caldwell also reviewed agency recommendations to determine where specific recommendations could be made to the WQP. Some of these recommendations are currently being addressed by the WQP or other CALFED programs while others could potentially be addressed collaboratively within the CALFED Program. More importantly, some of the recommendations identified by the agencies should be analyzed in the context of developing Regional Drinking Water Quality Management (ELPH) Plans or Integrated Regional Water Management Plans (IRWMP).

4.1 Key Areas for Future Efforts

Table 4-1 provides a matrix of concerns expressed by agency representatives during interviews. Interviews lasted 1-2 hours and were based on a set of interview questions, so the results do not necessarily reflect the opinions of the entire agency or the full range of their concerns. Meeting summaries and draft reports were provided to all participating agencies for their review and approval. The majority of agencies' concerns focus on the variability of source water quality and its high constituent concentrations, which significantly influence their ability to effectively treat Delta water. Many of the agencies identified multiple areas for improvement, in line with the CALFED "equivalent level of public health protection" or ELPH construct and with the multiple barriers principle, to ultimately obtain the best combination of actions to achieve the desired drinking water quality goal. Agency recommendations are arranged from the Delta source water through to treatment. Specific recommendations to the CALFED WQP are presented in a subsequent section.

Source Water Quality Improvements

Problems with Delta water quality primarily revolve around DBP precursors: TOC and bromide. Additional constituents of concern include nutrients, turbidity, MIB and geosmin (resulting from algae growth), and variability in pH and alkalinity.

To address source water quality concerns agencies suggest a number of potential actions. One action is to conduct a comprehensive evaluation of discharges into the Delta, including wastewater discharges, agricultural drainage, Delta Island discharges, and urban runoff, and use this evaluation to further limit identified discharges and loading of constituents of concern. Another action suggested was an investigation into the optimization of Delta operations for drinking water quality.

Table 4-1. Matrix of Drinking Water Treatment Plants Primary Concerns

	Vallejo	ACWD	SCVWD	CCWD	Avenal	Coalinga	KCWA	MWD	CLAWA	CCWA
Reduce High & Variable TOC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Reduce High and Variable Bromide		✓	✓	✓				✓		✓
Address Taste & Odor Problems		✓	✓	✓		✓		✓	✓	✓
Reduce Turbidity Variability		✓	✓		✓	✓		✓	✓	✓
Improve Source Predictability-Monitoring	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Investigate Discharges into Delta		✓	✓	✓	✓			✓		✓
Conventional Treatment Demonstrations	✓	✓			✓	✓	✓	✓	✓	
Increase Research Organic Carbon and DBP Formation	✓	✓		✓		✓		✓		
Improve Storage/Blending Capabilities	✓	✓	✓	✓	✓	✓				✓
Develop Emergency Contingency Plans	✓	✓	✓	✓			✓	✓	✓	✓
Improved BMPs for Delta, Clifton Court, and Conveyance	✓	✓	✓		✓	✓		✓	✓	✓
Delta Water Forum	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Increase Communication with WTPs	✓		✓	✓	✓	✓		✓	✓	✓

Monitoring Improvements

Significant progress has recently been made in expanding drinking water monitoring programs, both through DWR and CALFED, such as the MWQI program's Real Time Data and Forecasting (RTDF) project and through high-frequency monitoring equipment investments. In general, monitoring recommendations are focused on the RTDF project. The potential use of RTDF for treatment forecasting is largely supported by the majority of agencies and they also recommended some improvements to the existing program, such as increased and improved data reporting. For example, they would like to see flow data along with water quality data, Barker Slough water quality information, and have information provided in "real-time." Agencies are very interested in completion of the RTDF's water quality model for the California Aqueduct, which will model Delta water quality as it changes in the California Aqueduct with variable detention times and with the introduction of potentially degrading discharges.

Some agencies find it challenging for water treatment staff to translate water quality data from Delta intake locations to the local intakes of their WTPs. Agencies would benefit from training sessions on the use of RTDF and other surface water monitoring, analysis, and modeling, and the relationship of such information to their WTPs.

Clifton Court Forebay

One of the primary concerns for a number of agencies is water quality degradation in Clifton Court Forebay, mainly turbidity and algae growth caused by high nutrient concentrations, shallow water, and warm temperatures. Agencies recommend that BMPs be implemented and followed up by ongoing research to improve conditions in Clifton Court Forebay and prevent water quality degradation. Specifically, agencies recommend dredging Clifton Court Forebay to maintain a nominal water depth, which would reduce turbidity as well as algae-forming conditions, such as light penetration and water temperature. Direct actions to control algae growth were also suggested, including appropriate chemical addition (copper sulfate) and mechanical removal techniques. A balanced approach is recommended, using a combined method of consistent and effective chemical addition with mechanical removal techniques. Some agencies have concerns with the potential excessive use of chemicals in Clifton Court Forebay and the effects of anthropogenic chemicals on the surrounding ecosystem.

Delta Conveyance Channels

Concerns with water quality degradation are not confined to the Delta. Discharges along major conveyances are considered by some agencies to have significant impacts to water quality in the form of increased nutrients, pathogens, turbidity, and other unexpected constituent concentrations. Principle discharges of concern include direct and indirect agricultural drainage discharge, urban runoff, episodic events such as flooding, and unexpected events, such as drainage from construction and contaminant spills. Unexpected constituents are described by agencies as random releases such as asbestos and epoxy-compounds from construction events along the California Aqueduct and SBA. Unexpected releases can also include contaminant spills or episodic events like flooding. Agencies also recommended alleviating sediment buildup and algae growth along conveyance channels.

Source Water Storage and Blending Improvements

A number of agencies are interested in raw water storage facilities and water banking to buffer variations in Delta water quality prior to entering WTPs. Many of these agencies have either inadequate or nonexistent storage capabilities. In these cases, the effects of spikes in constituent concentrations carry over directly to the treatment plant, causing significant impacts to process efficiencies and overall treatment costs. Those facilities that have storage, blending, and banking options are able to alleviate short-term concerns with variability in quality and episodes of poor water quality in the Delta.

Contingency Plans for Emergency Situations

Unexpected degradation of raw water quality and service interruptions are detrimental to agencies' abilities to produce safe and reliable drinking water for their customers. Problematic events described by agencies included levee failures, earthquakes, forest fires, floods, and other unexpected disasters. The development of contingency and response plans for these types of events is needed to help minimize water quality and supply impacts or their duration, and expedite a return to normal operations.

Water Treatment Projects

Many agencies recommended focusing research on conventional treatment technologies as well as emerging constituents of concern, rather than just emerging technologies. For example, research focused on best available technologies (BATs) for enhanced coagulation, organic carbon removal, and taste and odor reduction at both demonstration and pilot scale. Several cases of successful installations of conventional technologies, such as GAC filtration, have been shown to reduce DBP formation, T&O problems, and other issues associated with Delta water quality. Advanced treatment technologies are regarded by several agencies, especially those with smaller treatment plants, as too complex and costly to be integrated into their plant and consistently maintained. Additionally, agencies are interested in learning about methods for the removal of emerging contaminants using existing conventional processes (rather than looking at emerging technologies) prior to new regulations.

Some agencies indicated that reliable and accurate diagnostic tools for real-time, on-site TOC measurement would facilitate their ability to effectively adjust treatment processes to deal with highly variable Delta raw water. Treatment demonstration projects could include testing the capabilities of new analysis equipment.

Some agencies cited problems with treatment technologies recently installed at their treatment plants based on successful pilot scale studies. Information on the resolutions employed by these agencies would be valuable to other agencies contemplating similar upgrades and installations.

Future Coordination and Communication

Many agencies note that their interaction with other local and state-wide water agencies and with the WQP is currently limited. These agencies are enthusiastic about raising the level of communication. The majority of agencies support the establishment of a web-based forum to increase communication with other agencies using Delta water and to access a wide range of potentially useful sources of information from CALFED projects on water quality and treatment research. The content of such a forum could be based on the suggestions described by the agencies, but should not duplicate other existing efforts. Agencies stress that such a forum must be user friendly and available information must be easily accessible.

Workshops that are focused on water quality and treatment issues associated with Delta water would also benefit the agencies interviewed. Such workshops could occur within existing drinking water organizations' events, such as the California-Nevada Section of AWWA. While this would work for many agencies, attendance at many existing conferences and workshops is extremely difficult for some agencies because of tight schedules and funding. An effort could be made to make workshops more accessible and applicable to water treatment staff, particularly operators, and to focus specifically on issues relating to Delta water quality. The CALFED Science Conference should also include more drinking water quality presentations and/or separate seminars focused on the results obtained from CALFED-funded projects should be established.

4.2 Recommendations to the CALFED Water Quality Program

Based on the key recommendations above, Brown and Caldwell developed a number of recommendations for the continued efforts of the WQP. While some areas in which agencies recommend direct action are beyond the scope of the WQP, these issues could be addressed in regional plans where agencies have the opportunity to prioritize their concerns and investigate solutions. Recommendations are broken down into priority groups similar to Section 4.1 where agencies identified their concerns.

Source Water Quality Improvements

The WQP should address all constituents of concern. CALFED water quality improvement efforts should produce a comprehensive set of results, reflected in performance measures for drinking water quality. The WQP has funded projects that address water quality improvements and characterize contaminant discharges. To build on previous efforts, the WQP needs to communicate and compile initial project results as well as fund source water quality improvement projects:

- Characterize contaminant discharges and their impacts at Delta intakes.
- Reduce year round variability and high concentrations of identified constituents of concern.
- Coordinate and comprehensively understand results from CALFED-funded projects, such as through the development of program performance measures.

- Communicate progress and the results of efforts to water agencies.

Monitoring

Surface water is monitored by a wide variety of state programs, and often lacks dedicated funding. The WQP should determine the need for additional critical real-time monitoring stations, like those now in place at Vernalis, Hood, and Banks, to inform water quality.

Clifton Court Forebay

A number of actions in Clifton Court Forebay are described in the CALFED EIS/EIR[1], however, not the CALFED ROD, including the development and implementation of watershed management programs, implementation of algae control measures, and evaluation of wastewater discharge impacts. Remediation of Clifton Court Forebay could potentially be a critical factor in improving Delta water for agencies taking water from the Forebay. The WQP should evaluate the actions described in the CALFED EIS/EIR to improve conditions at Clifton Court Forebay, potentially through the development of Regional ELPH Plans.

Conveyance

The WQP should evaluate efforts that address water quality degradation in the conveyance channels:

- Identify potential sources of point and non-point source discharges into conveyance channels.

- Develop BMPs and evaluate potential relocation of discharges.

Treatment

As the WQP reviews its priorities and role in drinking water treatment technologies, there are a number of areas in treatment that the WQP should consider:

- Investigate expanding technology demonstrations to include conventional treatment and BATs.

- Investigate and address the barriers that prevent smaller agencies from utilizing advanced technologies.

- Evaluate the success of full scale process implementation for potential implementation at other WTPs.

- Review current research being conducted on the fate and transport of PPCPs (and other emerging contaminants, like endocrine disrupters) and the relationship of this research to Delta water as a source of drinking water.

[1] Available on the CALFED website at http://calwater.ca.gov/CALFEDDocuments/CALFEDDocuments.shtml.

- Review existing research on treatment of emerging contaminants and conduct further Delta specific evaluations, including percent removal using conventional treatment.

Communication

The WQP should increase outreach, communication, and dissemination of information among all the agencies throughout California, particularly those treating Delta water:

- Develop a web forum to provide interactive information associated with Delta water quality and water treatment, tailored to the agencies using Delta water.

- Coordinate with California-Nevada AWWA section meetings to include more Delta-related water quality and treatment-based content.

- Develop half-day workshops for operators on Delta-related issues.

- Develop CALFED teleconferences with water treatment staff on water quality and implications to treatment.

- Include more drinking water treatment related sessions at the CALFED Science Conference or establish separate workshops focused on drinking water treatment.

Regional Planning

As the WQP moves more towards a greater focus on Regional Planning, the WQP should encourage regions to further develop and evaluate:

- Storage and blending options and the potential of water storage and banking capabilities for agencies without these resources.

- Comprehensive local and regional watershed management programs to protect SWP conveyance channels and Delta water storage facilities.

- Contingency plans for dealing with catastrophic events and alternative raw water sources for agencies during emergency conditions.

4.3 CALFED Water Quality Program Performance Measures

The issues described by agencies using Delta water and presented in this report could be incorporated into the development and use of performance measures. These measures could take the form of realistic goals that are representative of both the multiple objectives of the WQP and the needs of drinking water agencies. Performance measures should assess the progress and ability of the WQP in the following three categories:

- Source Water Improvement
    - Source water improvements needed by agencies both in the Delta and in conveyance channels.
- Monitoring
    - Monitoring needed by agencies to increase predictability of water quality at their intakes.
- Best Available Technology Development
    - Availability of alternate treatment technologies to treat Delta water to meet current and future regulations.

Agencies rely heavily on the actions of CALFED and other state programs to help them manage actions beyond their control and in order to ensure drinking water quality for their consumers. Feedback from these agencies and their treatment staff will provide a highly resourceful tool in evaluating the progress of the WQP. Integration of these considerations will be a meaningful addition to WQP performance measures.