Summary of Key Issues and Controversies

Alternative Sources of a High Quality and Reliable Water Supply - Proponents of alternative sources of supply must anticipate and prepare effective responses for the review of any water exchange/transfer proposal. There are five broad categories of likely challenge:

- Changes to present water rights and impacts on other water users.
- Economic, environmental and socioeconomic impacts on water supplying area.
- Impacts on groundwater users.
- Potential changes to riparian or aquatic habitats.
- Conditions for use of existing federal, state, or local facilities.

Health Effects Research – Health effects concerns pivot around the carcinogenic and reproductive/developmental effects associated with DBPs in treated drinking water as well as concern over risk of infection from pathogens potentially present in sources of drinking water.

- Only half the total halogenated compounds formed during chlorination have been identified, and of these, only a few have been evaluated. Epidemiological studies focused on water treated with alternative disinfectants are lacking.
- Interpretation of toxicology studies is complicated by problems of extrapolating data from test animals to human populations. These complexities have helped to engender controversy over interpretation of what constitute safe levels of DBPs.
- The health effects of bromate, which are as yet insufficiently understood, have major implications for the choice of disinfection technologies, as ozone produces bromate in the presence of bromide.
- Stronger disinfection generally produces higher concentrations of DBPs. Therefore, there is tension between the need for adequate disinfection and the need to minimize DBP formation.

Monitoring and Assessment – Monitoring and assessment is important because it provides the ability to establish existing water quality conditions, to evaluate CALFED alternatives, to assess the effects of implementing CALFED alternatives, and to provide a mechanism for implementing CALFED's adaptive management approach.

- Pathogens monitoring is not reliable.
- Discharger data are lacking.
- Inability to directly measure Delta island drainage volume.
- Predictive tools require further development.
- Conclusions based on data may lack statistical certainty.
- Monitoring program databases are not comparable.

- Mass load data is inadequate.

- Monitoring and assessment of organic carbon is complex.

Regulatory Developments — The following issues and controversies stemming from the 1996 Amendments to the Safe Drinking Water Act and data-related considerations may have significant regulatory impact:

- Information on sensitive sub-populations is lacking.

- Must consider "risk-risk" tradeoffs when setting MCLs.

- Statutory deadlines for new drinking water regulations will pass prior to completion of EPA's research plan for microbes and DBPs.

- Must consider Delta hydrologic conditions when interpreting ICR data.

- What further improvements will be realized as utilities come into compliance with the currently promulgated Stage 1 DBP Rule?

- What further reductions of DBPs would be necessary under the Stage 2 DBP Rule?

- Will inactivation targets be established for *Cryptosporidium?*

- Incomplete health effects information ~~for all compounds of interest.~~

Source Control – The source control approach to water quality improvement involves the implementation of control measures at the pollutant source to reduce or eliminate the discharge of contaminants from both point and nonpoint sources. Source control approaches include treatment of waste discharges, implementation of management measures and best management practices, and implementation of watershed management programs.

- Need to better characterize sources and loads of drinking water contaminants.

- Seawater intrusion will be largely unaffected by source control actions.

- Feasibility and cost effectiveness of planned source control actions is unknown and must be determined early.

- Impacts on dischargers may occur.

- Must strike an appropriate balance between voluntary efforts and regulatory enforcement when implementing source control actions.

- Identifying the beneficiaries of source control actions (in order to assign funding responsibility) can be complex. There may be multiple beneficiaries of source control actions.

Storage, Conveyance, and Flexible Management of Water Operations – New storage and conveyance facilities and flexible management of water operations can provide ecosystem benefits and water supply reliability while simultaneously improving Delta source water quality.

Conveyance Improvements

- *South Delta Improvements (SDI) and Joint Point of Diversion (JPOD)* – Both SDI and JPOD would increase the operational flexibility of the CVP and SWP. This increase in flexibility would provide opportunities for the projects to improve water quality, water supply, and ecosystem protection. There is a need to further refine the relationship between increased export capacity, barrier operations, Delta stage, circulation, impacts to fish (including delta smelt) and water quality. Additionally, the need for and potential impacts of a third permanent barrier for flow and stage control on Grant Line Canal must be determined.

- *Hood-Mokelumne Diversion and Delta Cross Channel (DCC) Operation* - Further evaluation of the potential effects of the Hood facility on fisheries is needed. There is a perception that this facility would be the first phase of an isolated conveyance facility. Considerable uncertainty remains regarding the effectiveness of fish screen and screen bypass facilities to mitigate the potential blockage of upstream migrating fish. There is also uncertainty regarding the effectiveness of improved monitoring in directing DCC gate operations to protect fisheries while providing for export water quality.

- *Mokelumne River Channel Widening* - There is concern over a possible increase in organic carbon levels from proposed habitat improvements, and potential adverse effects on salmon entrainment, survival and upstream migration.

- *Relocation of North Bay Aqueduct Intake* – This conveyance improvement would require an evaluation of feasibility and cost effectiveness.

- *Isolated Facility* – There is concern of providing adequate assurances that such a facility would be operated appropriately to provide for in-Delta resource needs. Other issues include uncertainty regarding the effectiveness of fish screens and the potential adverse effect on salmon survival due to reduced flow below Hood.

- *Out-of-Delta Conveyance Improvements* – One concern is whether separating higher and lower quality flows would be feasible and cost-effective. Another concern is the increased salt loading to agriculture resulting from applying lower quality.

Storage and Operations

- Outflow and export management actions would entail water supply risk. However, the availability of new storage and conveyance facilities could reduce this risk. Water supply risk could also be mitigated through upstream water acquisitions. Shifting export pumping into the winter months could have negative impacts on some salmon runs and on Delta smelt.

- Real-time monitoring of fishery conditions could enhance operations, but the feasibility of the technology has not been fully demonstrated.

- Source/demand shifting concerns include how water users would be compensated for extra costs incurred by the shift and how increased water supply risk due to shifting would be allocated.

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- Concerns over new storage facilities include ecological and fishery issues, financing, and distribution of benefits. Furthermore, significant drinking water quality issues associated with in-Delta storage remain.

Treatment Technologies - Water treatment for drinking water purposes focuses on control of microbiological contamination, control of DBP formation, and aesthetics. Treatment is one facet of a multi-barrier approach to assuring safe drinking water. Treatment is effective only when watershed protection, source control, and distribution system protection and maintenance are included as elements of a comprehensive system to protect public health.

- Will inactivation targets be established for *Cryptosporidium*?
- Will the bromate standard decrease, increase or stay the same?
- How quickly will the feasibilty and cost effectiveness of UV treatment be determined?
- Need to characterize formation of DBP and microbial mixtures for each treatment technology, not just individual contaminants.

Glossary of Terms for Issue Papers

Carcinogenicity - Refers to the property of a substance or agent to produce cancer (malignant tumors) in experimental animals or is known or suspected to do so in humans.

Data Quality Assessment - This refers to the continuing evaluation of performance of a production system and the quality of the products (e.g., data) produced. Activities involved include checking on entry errors, transcription errors, accuracy and precision errors, and determining if the data meets the data quality objectives for the project.

Disinfection By-Products (DBPs) - Chemical disinfection of drinking water containing bromide and natural organic substances produces a number of by-products including the trihalomethanes; chloroform, bromodichloromethane, dibromochloromethane, and tribromomethane (bromoform), haloacetic acids, and bromate.

Distribution System - Refers to the system of water mains to deliver drinking water for domestic, commercial, industrial and fire fighting uses. A service connection to a residence includes a corporation stop tapped into the water main, a service line to a shutoff valve at the curb, and the owner's line into the dwelling which incorporates, commonly, a water meter and a pressure regulator or relief valve if necessary.

Enhanced Coagulation - Optimizing water treatment processes to aggregate small particles into filterable masses. The purpose of coagulation in water treatment is to destabilize suspended contaminants such that the particles contact and agglomerate, forming flocs that drop out of solution by sedimentation.

Granulated Activated Carbon (GAC) Treatment - Granular activated-carbon adsorption following filtration removes trace concentrations of a variety of nonpolar organic compounds.

Information Collection Rule (ICR) - The ICR required public water systems to collect data on DBPs and microorganisms (including viruses) for further development of the Enhanced Surface Water Treatment Rule and Stage 2 of the Disinfection/Disinfectant By-Product Rule. The final Rule was published in the May 14, 1996 Federal Register. Data are submitted to the U.S. Environmental Protection Agency.

Maximum Contaminant Levels (MCLs) - These are regulatory values set by the U.S. Environmental Protection Agency and each state that is delegated primacy for their enforcement. They are maximum permissible levels of contaminants in water which enter the distribution system for domestic water use. MCLs are derived by balancing the health risks with technological and economic impact. The state MCLs can be equal to or more stringent then the federal MCLs, but never more lenient.

Microbials - Commonly refers to microscopic pathogens, viruses and bacteria which appear in water, air and soil samples.

Microfiltration (MF) - Microfiltration membranes are absolute filters typically rated in the 0.1 to 2 micron range. Traditionally available in polymer or metal membrane discs or pleated cartridge filters, microfiltration is now also available in crossflow configurations. Operating pressures of 1 to 25 psig (0.07 to 1.7 bar) are typical.

Nanofiltration (NF) - Equipment removes organic compounds in the 300 to 1,000 molecular weight range, rejecting selected salts (typically divalent), and passing more water at lower pressure operations than RO systems. NF economically softens water without the pollution of salt-regenerated systems and provides unique organic desalting capabilities.

Ozone Treatment - Ozone (O_3) is a powerful disinfectant that is coming into greater use in the United States for disinfecting drinking water. It is particularly effective for destroying *Cryptosporidium*, a protozoan pathogen that has been responsible for recent disease outbreaks.

Precursors - Commonly referred to substances such as fulvic and humic acids that naturally occur or are enhanced by man-made activities which affect water. Both the quality and quantity of precursor material is important in the formation of Disinfection By-Products.

Quality Assurance - A system of activities whose purpose is to provide to the producer or user of a product or service the assurance that it meets quantitatively defined standards of quality. It consists of two separate but related activities, quality control and quality assessment.

Reverse Osmosis - Reverse osmosis is the forced passage of water through a membrane against the natural osmotic pressure to accomplish separation of water and ions. Reverse osmosis is one of the common methods for desalinization of sea water.

Risk Assessment - Risk assessment is the qualitative and quantitative evaluation performed in an effort to refine the risk posed to human health and/or the environment by the presence or potential presence and/or use of specific pollutants.

Sanitary Survey - Sanitary surveys, required every five years mandated by the 1962 U. S. Public Health Service Drinking Water Standards, consist of field work and laboratory analyses for the purpose of characterizing actual and potential contaminant sources. The next Sanitary Survey of the State Water Project is due 2001.

Sensitive Population - Also referred to as "sensitive pollutant receptors." These terms refer to the segment of the population which are more susceptible to effects of exposure to a pollutant. The sensitive segment of the human population can be the developing embryo, children, the elderly, the sick and those whose immune systems are challenged, e.g., HIV-positive.

Standardization - The process whereby the value of a potential standard is fixed by measurement with respect to a standard(s) of known value.

Toxicity - Defined as a quality, state, or degree of being poisonous. Toxicity can be acute (from a single dose of singular or multiple poisons) or chronic caused by repeated small doses over a considerable period. Effects may also be additive.

Ultrafiltration (UF) - Similar process to RO and NF, but is defined as a crossflow process that does not reject ions. UF rejects contaminants in the range of 1000 dalton (10 angstrom) to 0.1 micron particles. Because of the larger pore size in the membrane, UF requires a much lower operating pressure: 10 to 100 psig (0.7 to 6.9 bar). UF removes organics, bacteria, and pyrogens (fever causing agents) while allowing most ions and small organics, such as glucose, to permeate the porous structure.

Ultraviolet (UV) Treatment - Refers to a process involving exposure of water to the short wave length energy to destroy organisms by disrupting cellular processes.

E-033474

Alternative Sources of a High Quality and Reliable Water Supply

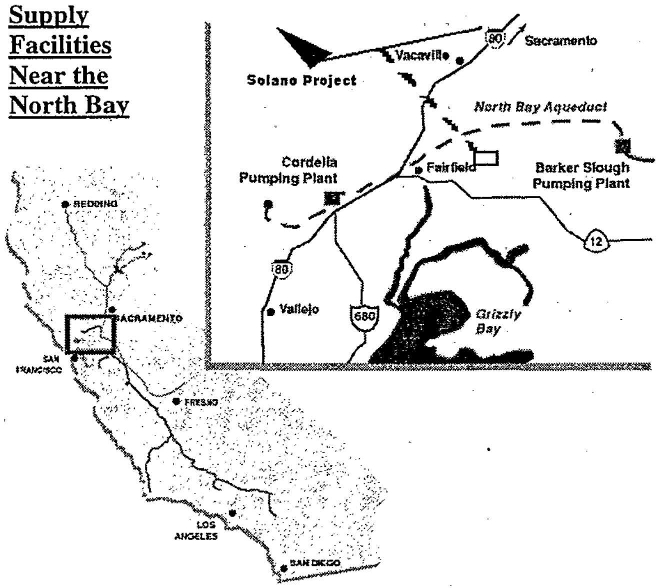
This issue paper explores opportunities to improve drinking water quality and reliability by substituting higher quality and/or more reliable sources of water for supplies currently being used to meet urban water needs. Following the Delta Drinking Water Council's consideration of this issue, an expanded analysis of potential actions to improve drinking water quality will be prepared.

Current Understanding

The quality of water delivered from the Delta is influenced by several sources of contaminants, including: seawater intrusion; agricultural drainage and runoff; livestock grazing and confined animal facilities; wastewater treatment plant discharges; urban runoff; and discharges from recreational boating activities. Seawater intrusion contains high concentrations of bromide that, when disinfected by ozone, produces bromate concentrations in excess of expected regulatory standards. Seawater intrusion also leads to production of brominated DBPs upon chlorination and high TDS levels that reduce the ability to effectively manage water supplies. Agricultural drainage and runoff contain seasonally high quantities of salts and DBP precursors.

Measures to address these sources of contaminants are covered in other issue papers and are beyond the coverage of this paper. However, there may be local opportunities to improve the quality of water supplied to Delta users through water exchanges and transfers. Each of the geographic areas of the state that receive water from the Delta has different possibilities for improving treated water quality. Several examples are illustrated in the following paragraphs. Additional examples will result from discussions with the Delta Drinking Water Council.

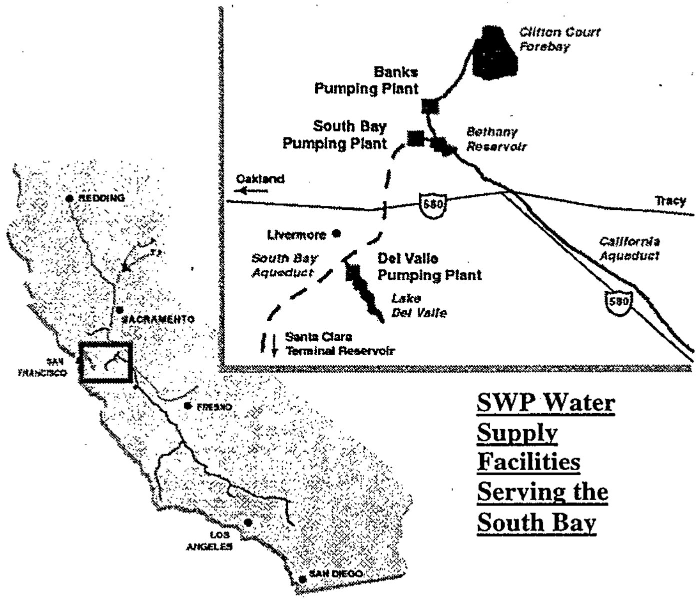
<u>Water Supply Facilities Near the North Bay</u>



<u>North Bay Area.</u> Water supplies for the area are derived from two major sources: the North Bay Aqueduct (supplied from Barker Slough) and the Solano Project (supplied from Lake Berryessa). The Barker Slough watershed contributes a significant amount of organic material to the North Bay Aqueduct. Solano County Water Agency is conducting a watershed management program to determine if BMPs can be implemented to improve water quality in Barker Slough. Two additional concepts for improving source water quality have been suggested:

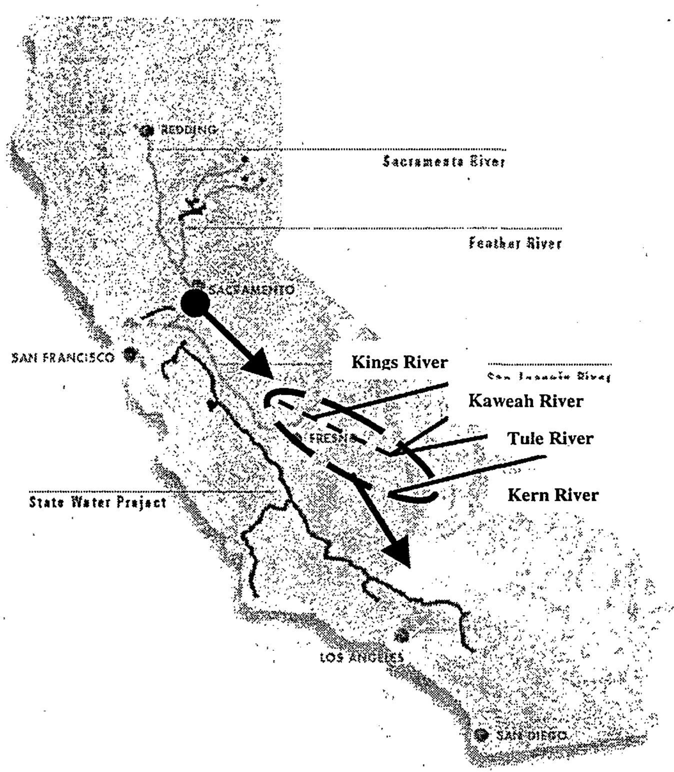
- Relocate the NBA diversion point to secure a better source water quality
- Exchange the higher quality Berryessa supply (principally an agricultural supply) with an NBA supply (chiefly an urban supply)

Bay Area. Several Bay Area agencies rely on the Delta as a water supply source. In addition to the SWP facilities shown to the right, an extensive network of local (San Francisco/EBMUD) and federal (CCWD/SCVWD) facilities provides opportunities to move supplies to areas of need. The region also includes two sources of high quality water imported from the Sierra. The combination of available facilities and available high quality sources may provide opportunities to improve water quality for agencies relying on the Delta and better reliability for agencies with sources impacted by drought conditions. Improved reliability and water quality may necessitate additional storage and conveyance facilities.



SWP Water Supply Facilities Serving the South Bay

Southern San Joaquin Valley. Another potential opportunity to improve source water quality through exchanges exists in the southern San Joaquin valley.



Water from the Kings, Kaweah, Tule, and Kern Rivers could be exchanged with water from the Delta. The higher quality Sierra sources would be conveyed to the California Aqueduct for delivery to Southern California urban users. The Delta supply would be provided to the agricultural users in the area south of Fresno.

Additional storage and conveyance facilities may be necessary to match water availability to urban and agricultural demand. Storage could be provided under a conjunctive use program in the valley. Careful integration of the Sierra sources with other Southern California supplies would be necessary to maximize the water quality benefit.

Following review of this issue paper with the Delta Drinking Water Council, it is expected that additional concepts will be developed.

Key Issues and Controversies

The infrastructure potentially needed to store and convey additional supplies of high quality water – whether from development of additional sources or water transfers/exchanges – will provide additional benefits of system redundancy. Added redundancy will improve system reliability during emergencies (such as source contamination), disasters (flooding, earthquakes), and droughts.

<u>Factors Affecting Proposals to Provide Alternative Sources of Water</u>

- Changes to present water rights and impacts on other water users
- Economic, environmental and socioeconomic impacts on water supplying area
- Impact on groundwater users
- Potential changes to riparian or aquatic habitats
- Conditions for use of federal, state, or local facilities

Proponents of alternative sources of supply must anticipate and prepare effective responses for the review of any water exchange/transfer proposal. There are five broad categories of likely challenge.

<u>Water Rights Requirements.</u> The State's permitting to appropriate water establishes the source, point of diversion, purpose of use/amount/season, place of use, and the facilities to be used. Either new or modified water rights would usually be needed to implement alternative source proposals. The process for seeking water rights may lead to conditions to address the concerns of interested parties and water users.

<u>Economic, Environmental and Socioeconomic Impacts.</u> Alternative supply plans could involve either a substitution of a higher-quality supply source for a lower-quality supply source of the same amount, or could be a simple transfer. The expected impacts of an exchange or a transfer would differ significantly. In general, an exchange would not have the same magnitude of impacts as a transfer on the source area. Citizens in the geographic area that contains the source of supply that is to be transferred under an alternative supply proposal can be expected to be concerned about the local impacts of the transfer. Issues that have been raised about transfers of surface water include effects on farm crop patterns (especially concerns about land fallowing), farm output, employment, and revenues; impact on communities; changes in county/local tax revenues; and impacts on local environmental conditions. Some, or all, of these concerns would be eliminated if the alternative supply proposal substituted a like quantity of lower-quality water to a source area for its higher-quality supply.

<u>Groundwater Impacts.</u> Proposal that would transfer a source area's surface water and substitute groundwater for the local supply have evoked some of the most serious, vocal, and potentially divisive challenges. Concerns have included increased pumping costs, the potential for overdrafting local groundwater basins, land subsidence, changes to groundwater quality, and effects on local groundwater users. Groundwater impacts could also occur from exchanges of a like amount of water if the exchange supply provided to the source area contained significantly higher concentrations of constituents such as TDS.

<u>Change in Extent of Riparian and/or Aquatic Habitat.</u> Although many water transfers could have positive environmental effects, any proposal to change how water is currently used must address the impact of the change on riparian and aquatic habitat. Additionally, possible changes in species diversity and population viability must be identified and mitigated.

<u>Use of Existing Facilities to Store and Deliver Water.</u> Facilities needed to convey the alternative source of supply may or may not be available. If existing facilities are part of the water exchange/transfer program, the owner of the facilities would control how and when any excess

capacity might be used. Specific procedural steps have been established for use of the federal and state systems to transport non-project water. The basic tenet for use of existing systems is protection of existing users of the system. New storage and conveyance facilities may be needed to facilitate water exchanges and transfers.

Proposals to develop new ways of providing high quality and reliable sources of drinking water face one additional practicality – the passage of time. As new drinking water regulations are issued, water providers will encounter increased pressure to apply all available means to achieve compliance. If water demands grow over time, existing storage and conveyance capacity for exchanges and transfers would diminish accordingly. The inability to secure a higher-quality source will push more water purveyors to rely on more expensive treatment to try to compensate for a lower-quality source. Once the water purveyor has expended resources for additional treatment, capital resources are reduced for other projects.

Ongoing and Near-Term Activities

On November 16, 1999 CALFED staff met with representatives from Bay Area urban water suppliers to develop a proposal for investigating the potential for regional water exchanges to improve source water quality. The initial phase of work would focus on two technical tasks: (1) quantitatively assess individual agency needs for higher quality source water; and (2) assess the ability of existing facilities to convey the needed quantities assuming the water is available. An additional phase identifying specific sources of higher quality supply would be undertaken if warranted by the results of the initial phase.

Additional Reading

Pacific Institute, 1998, *California Water Transfers: An Evaluation of the Economic Framework and A Spatial Analysis of the Potential Impacts.*

The National Heritage Institute, October 1998, *An Environmentally Optimal Alternative.*

CALFED, June 1999, *Water Quality Program Plan*

Health Effects Research

Current Understanding

Health effect concerns pivot around the carcinogenic and reproductive/developmental effects associated with disinfection by-products (DBPs) in drinking water as well as concern over risk of infection from pathogens potentially present in sources of drinking water. Brominated DBPs, such as bromodichloromethane (a trihalomethane species) as well as bromate may be of particular concern. EPA is considering further DBP regulation and more stringent disinfection regulations (e.g. Cyptosporidium inactivation) which could further influence changes in disinfection practice and create a potential conflict between minimizing chemical and microbial risk. See the "Regulatory Developments" and "Treatment Technologies" issue papers for more information.

There are primarily two ways to assess health effects. Epidemiology is a science that considers disease incidences of a human population exposed to constituents of interest at the actual levels of exposure. Toxicology is a science that involves studies of individual contaminants in carefully controlled laboratory conditions at levels much higher than anticipated human exposure. The principal findings of health effects studies include:

Cancer. In a number of epidemiological studies involving exposure to chlorinated water, bladder risks are low but consistent; colorectal also shows up, but less frequently. These studies are indicative of some hazard associated with chlorinated drinking water, but no dose-response can be inferred.

Reproductive-Developmental Effects. A number of studies provide inconsistent results, but if aggregated, begin to be suggestive of a low-level risk. One study on miscarriage and THMs (Waller et al, 1998) indicate higher risks in bromide containing waters that were chlorinated. This study, however, had some exposure assessment limitations and is being re-evaluated (reconstructing the actual exposures) and will be repeated elsewhere.

Specific Compounds. Brominated organic compounds, in general, seem more significant than chlorinated compounds. For example, bromodichloromethane, bromochloroacetic acid, dichloroacetic acid, and bromodichloroacetic acid, all formed by chlorination, are biologically active compounds. Bromate, resulting from ozone and a minor contaminant in hypochlorite, is also significant. Chlorite, a chlorine dioxide by-product, has activity suggesting it may result in endocrine disruption.

Microbials. A number of organisms present in surface waters can be of health concern. Pathogenic organisms, such as *Cryptosporidium* are of public health concern. Recent outbreaks of cryptosporidiosis have highlighted the need for more effective disinfection of drinking water. In April 1993, about 400,000 persons in Milwaukee, Wisconsin became ill of cryptosporidiosis. Approximately 100 deaths resulted from this outbreak. While the significance of water in transmitting disease is not well understood, there are some general health trends of importance. First, the incidence of cryptosporidiosis in the HIV-positive population has decreased, as have other opportunistic pathogens potentially associated with water distribution systems (e.g., *Mycobacterium avium* complex and *Legionella*). Second, variations in infectivity of *Cryptosporidium* have been observed with different *Cryptosporidium* species.

Key Issues and Controversies

Sparse Data. Only half the total halogenated compounds formed during chlorination have been identified (see Figure 1). Of these identified DBP compounds, only a few have been evaluated (see Figure 2). Most of these are addressed individually and yet they occur as part of a complex mixture. Epidemiological studies have only focused on chlorinated water, not water treated with alternative disinfectants.

Interpretation of Toxicology Studies. The two principal problems are extrapolation from the high doses used in the rodent studies to the low doses to which individuals are exposed and the extrapolation from the test animals to humans. Toxicologists have sought to lessen the uncertainty by studies focused on understanding which mechanisms would be relevant at low doses in humans. With additional studies, however, controversy over interpretation of what constitute safe levels remains. As an example, such a controversy continues to exist nearly 30 years after chloroform was regulated as a carcinogen under the 1981 trihalomethane rule. The CALFED Bromide Panel advised CALFED to follow and support ongoing/planned research that focuses on health effects and mechanisms which induce toxicological or carcinogenic responses from exposure to brominated and chlorinated by-products.

Significance of Bromate for Technology Selection. While ozone is the major viable alternative and confers a number of benefits for Delta water (e.g., improved disinfection, reduction of tastes and odors, greater filtration stability, reduction of most DBPs), it does produce bromate which produces tumors at three sites in rats (kidney, thyroid, and mesothelium), but has never been evaluated for human exposure (i.e., epidemiological) for either cancer or reproductive effects. On the other hand, the miscarriage study (Waller et al, 1998) showed a strong association of bromodichloromethane (and perhaps other bromochloro disinfection by-products) with spontaneous abortions prompting questions about the hazards associated with chlorination of bromide-containing waters. Toxicology data on many of the brominated DBPs formed by chlorine are unavailable.

Protection Against Pathogenic Organisms While Minimizing the Formation of DBPs. The simultaneous public health threats of pathogenic organisms and DBPs pose a big challenge to water utilities in providing safe drinking water to consumers. Refer to the "Regulatory Developments" issue paper for additional information.

Ongoing and Near-Term Activities

Mixture Evaluation—Chemical Reactivity/Toxicological Expert Technology Evaluation

Objective: As either a complement to the toxicological testing (if determined feasible), or as an alternative, compare technology alternatives with available toxicology data, making inferences based on chemical reactivity for compounds lacking toxicological data.

Rationale: Some toxicological characterization of the various technologies is needed, particularly in understanding the impact of various levels of bromine substitution on the health effects of the complete mixture.

Elements:

- Develop profiles of compounds and anticipated concentrations for technologies under consideration (e.g., ozone, GAC, chlorine dioxide, UV, membranes) for various Delta water quality scenarios.
- Evaluate available health effects data for compound classes of interest.
- Determine chemical characteristics that may modulate potency.
- Identify ranking/scoring method for determining relative potency for various endpoints.
- Conduct mixture evaluation and sensitivity analysis.

Potential Longer-Term Activities

During the CALFED planning process, agencies, stakeholders and an expert panel on bromide advised CALFED with respect to health effects associated with DBPs. There are several actions proposed for Stage 1 (first seven years of implementation after the Record of Decision on the Programmatic EIR/S):

- Programmatic EIR/S Water Quality Program Implementation Strategy, Action #12 - Perform public health effects studies, as needed, to more specifically identify the potential health effects of bromide-related DBPs.
- Bromide Panel recommendations: (1) Define co-occurrence of bromide and organic carbon, (2) develop models of DBP formation to assess treatment options, (3) define short and long term strategies for regulatory compliance, and (4) support health effects research.

Additional Reading

Summary of EPA Health Effects Symposium, February 10 – 12, 1999, Washington, D.C.

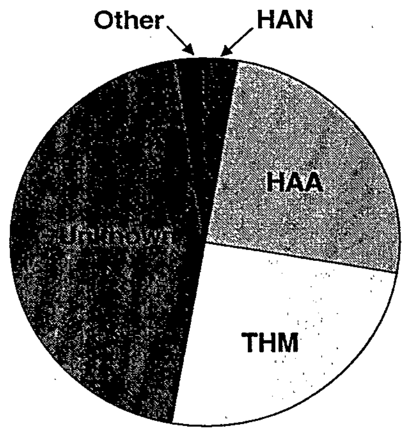


Figure 1
A Fraction of TOX Remains Unidentified

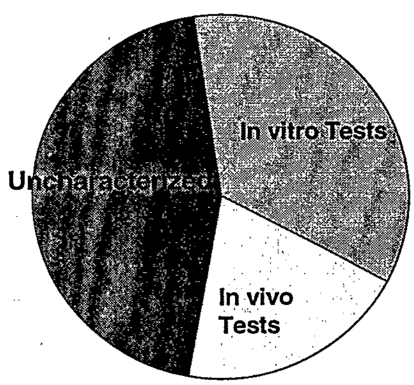


Figure 2
Toxicological Characterization of Known DBPs Limited

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Monitoring and Assessment

Current Understanding

The key drinking water constituents of concern for the production of safe and potable drinking water from Delta sources are tabulated below:

Monitoring Parameter	Significance to Drinking Water Quality
Total Organic Carbon (TOC)	Formation of disinfection byproducts (DBP Precursor)
Bromide	Formation of brominated disinfection byproducts (DBP Precursor)
Pathogenic Organisms	Waterborne diseases
Chemical Contaminants	Regulated drinking water quality constituents
Total Dissolved Solids (TDS) or Salinity	Taste and odor problems (salty taste), corrosion of infrastructure and appliances, and impacts on wastewater reclamation programs, groundwater conjunctive use programs, and blending projects
Nutrients	Taste and odor problems (algae – geosmin and 2-methylisoborneol), impacts on filtration (algae)
Turbidity	Impacts on filtration and disinfection

All of the above constituents are naturally occurring, to one degree or another, and some are magnified by human activities. Most of these constituents are routinely monitored by the Department of Water Resources. More recently some constituents have been monitored through the Sacramento River Watershed Program.

Monitoring and assessment is important to the CALFED Drinking Water Quality Program because it provides the ability to establish existing water quality conditions, to evaluate CALFED alternatives, to assess the effects of implementing CALFED alternatives, and to provide a mechanism for implementing CALFED's adaptive management approach.

Monitoring and assessment of drinking water constituents generally involves the development of a field sampling program, transport of the samples to the laboratory, storage of samples, analysis by the laboratory, and finally recording, interpreting, and presenting the results in a format which can be used for decision-making. Water quality data may be assessed by relating the data to flow regimes, land and water use patterns, and demographic and geographic information. Statistical and graphical tools are often employed to enable relationships to be identified. The credibility of water quality data, expressed in terms such as accuracy, precision, completeness, and chain-of-custody, must be assessed as a critical part of the data evaluation process. Collectively, the tools used to assess the credibility of data fall within the category of quality assurance/quality control.

The degree of quality assurance/quality control applied to the data collection and evaluation process, the frequency of sampling, the number of samples collected and the sensitivity required to detect constituents at levels of concern generally drives the costs of monitoring and assessment programs.

Regulations are instrumental in driving the content of monitoring and assessment programs. The California Department of Health Services (under the California Safe Drinking Water Quality Act) and the United States Environmental Protection Agency (under the federal Clean Water Act and Safe Drinking Water Act) are the agencies having authority to regulate drinking water. These agencies have promulgated Maximum Contaminant Levels (MCLs) for drinking water that directly require monitoring, and that provide impetus to related monitoring and assessment activities. The Central Valley Regional Water Quality Control Board (under authority of the federal Clean Water Act and the California Porter-Cologne Act) is in the process of developing a drinking water policy for their Basin Plan update which will address the need for establishing water quality objectives and implementation plans to control sources of drinking water constituents of concern in the Delta. This process may lead to the need for additional monitoring and assessment activity. Regulatory development issues related to drinking water are discussed in the "Regulatory Developments" issue paper.

Key Issues and Controversies

Pathogens Monitoring Not Reliable. Currently, there are two methods for detecting the presence of pathogens in source waters: EPA Method 1623 and the Information Collection Rule Method. Both methods have been proven to have problems with recoveries and variability of results. Method 1623 appears to be a modest improvement over the ICR with respect to the filter used and the elimination of a concentration step.

Discharger Data are Lacking. Historically, there has been reluctance on the part of dischargers to monitor their discharges for constituents of drinking water concern beyond the specific requirements of their discharge permits. Efforts are underway to develop a drinking water strategy for the Central Valley Regional Water Quality Control Basin Plan that would enable improved coordination of discharge requirements with needs for drinking water protection. This effort requires support.

Inability to Directly Measure Delta Island Drainage Volume. Approximately 260 agricultural drains discharge into the Delta. Considerable water quality monitoring data exist that characterize the discharges, but adequate flow data are not available to accurately quantify the loads of drinking water contaminants discharged to Delta channels, or to enable detailed evaluation of source control approaches.

Predictive Tools Require Further Development. Current models and other tools to assess and predict the effects of CALFED actions on concentrations of DBP precursors, pathogens, and other drinking water constituents of concern require further development. For example, existing constituent transport tools are generally based on conservative constituents (e.g. salts) when in fact some constituents undergo transformation during transport, combine with other constituents present in Delta waters, or are subject to change by factors unrelated to salinity. New analytical tools and approaches are required to answer questions being raised by the CALFED process.

Conclusions Based on Data May Lack Statistical Certainty. In order to use monitoring data for decision making, one must be confident that differences depicted in data are real, rather than artifacts of the process. Fully conclusive monitoring results must generally be based on a large number of samples that are often beyond the financial and physical means of the data collector. Therefore, from a practical standpoint, it is necessary to balance the need to develop strong conclusions with limitations on available resources for the data collection effort. To best achieve the needed balance, good statistical design should be incorporated to the monitoring plan at the outset. And, because there must be tradeoffs that are not strictly technical, the choices should be discussed and agreed upon by the CALFED participants.

Databases are Not Comparable. Monitoring programs from different agencies and within agencies employ variable approaches to sampling and analysis, and different data management formats result from the peculiar needs of individual programs. These differences often frustrate the ability to perform broad-based interpretations of the information, and these problems have historically militated against larger scale integration of monitoring and assessment efforts. As the CALFED program relies upon region-wide watershed approaches to resolving the problems of the Bay-Delta, there is a great need to overcome data compatibility problems in order to cost-effectively interpret data produced by different participating entities. Standardized sampling and analysis methods, standardized data storage formats, and a standardized quality assurance program are greatly needed to effectively manage the CALFED Program.

Mass Load Data is Inadequate. The loads of drinking water constituents of concern need to be quantified to effectively manage contributions of pollutants from various sources.

Monitoring and Assessment of Organic Carbon is Complex. Two issues are of particular significance:

- TOC and dissolved organic carbon (DOC) vary qualitatively among sources. The CALFED Organic Carbon Workshop findings indicate that the quality of TOC is as important as the quantity in affecting trihalomethane formation potential (THMFP). Because the quality of TOC and DOC varies considerably, current surrogate measures of THMFP may be of limited value.

- Formation potential of other DBPs such as haloacetic acids and bromate are not measured by current screening methods. Screening methods that are not sensitive to these DBPs may not reveal the full significance of organic carbon in the Delta system. This suggests the need for new methods to evaluate the capacity of source waters to produce DBPs in drinking water.

Ongoing and Near-Term Activities

Currently, there are two key monitoring and assessment programs directed toward constituents in Delta water supplies that affect its use as a drinking water supply. Both of these programs exist within the California Department of Water Resources. The Municipal Water Quality Investigation (MWQI) Program is responsible for monitoring a number of key sampling sites, including Delta channels, island drainages, and tributaries. The municipalities purveying drinking water to consumers are required by the State Department of Health Services to conduct sanitary surveys of the State Water Project to identify potential sources of source water quality degradation and to enable corrective measures to be taken where feasible. The last SWP Sanitary Survey update was performed in 1996, and will be repeated in 2001. The work will be performed MWQI on behalf of the SWP contracting agencies. DWR's Division of Operations and Maintenance monitors key locations within the reservoirs and aqueducts of the SWP. The program includes sampling for a number of drinking water contaminants. Also, the Division maintains a number of continuous water quality monitoring recorders at various locations within SWP facilities.

The Sacramento River Watershed Program also monitors for drinking water contaminants, including TDS, nutrients, general minerals and pathogens at 12 sampling sites on the Sacramento River and major tributaries. In addition, CALFED is funding research on organic carbon by the United States Geological Survey.

CALFED staff is recommending several early implementation actions for possible implmentation before the Record of Decision. At least two of these early implementation actions involve monitoring and assessment and are in the process of being refined through the input of participating agencies and stakeholders:

- Veale/Byron Tract Drainage Management Project. This action focuses on a bundle of measures designed to improve both the quantity and quality of drainage discharges from Veale and Byron Tracts and to improve the drinking water sources at south Delta drinking water intakes. The action would have multiple benefits in that the solution options may include wetlands, detention basins and other activities for flood management. Monitoring and assessment of data associated with this project would help to provide baseline conditions and guidance on the effectiveness of solution option choices.

- Assessment of Sources and Magnitudes of Loads of Drinking Water Constituents of Concern. The purpose of this action is to evaluate existing monitoring data to determine baseline conditions under various hydrologic conditions and operational scenarios. The information from this action will be used to determine the adequacy of current information and to identify monitoring and research gaps. The second purpose of this action is to implement a monitoring and research program so that changes in Delta water quality resulting from CALFED's actions and the effectiveness of drinking water quality actions can be evaluated.

Potential Longer-Term Activities

Through a series of stakeholder meetings over the course of three years, CALFED has identified a number of longer-term actions specific to drinking water improvements to be conducted during Stage 1. These actions will involve project specific monitoring and assessment programs:

- Control of TOC contribution through control of algae, aquatic weeks, agricultural runoff, and watershed improvement.

- Study brominated and chlorinated DBP operational controls at water treatment plants and implement incremental improvements as warranted.

- Control pathogens through control of cattle, urban stormwater, sewage, boat discharge, and possibly recreational swimming.

- Study impacts from recreational swimming and impacts from wild animals.

- Relocate Barker Slough intake.

- Reduce methyl tert-butyl ether (MTBE) in various areas.

- Address water quality problems in terminal reservoirs.

- Perform public health effects studies to more specifically identify the potential health effects of bromide-related DBPs

- Investigate alternative sources and means of providing high-quality water supply for urban users of Delta water.

- Investigate combinations of new supplies and technologies that can minimize salt content of urban water supplies and provide greater public health protection.

- Develop a plan sufficient to meet forthcoming United States Environmental Protection Agency and Department of Health Services standards for brominated DBPs.

In addition, the CALFED Comprehensive Monitoring, Assessment and Research Program through stakeholder and agency input have recommended the following actions which will have monitoring and assessment components:

- Determine loadings of organic carbon from agricultural operations in the Delta through the measurement of concentrations and flows from agricultural drainage discharges.
- Establish real-time TOC/DOC monitoring network at critical locations in the Delta.
- Determine how CALFED programs such as Ecosystem Restoration will affect the loading of DBP precursors and other drinking water constituents of concern.
- Determine the effect of operational changes (such as reservoir reoperations, flow barriers, exports) on delivered water quality.
- Develop models to assess and predict the effects of CALFED programs on concentrations of DBP precursors and other drinking water constituents of concern.
- Develop accurate predictive models for transport and fate of pathogens, DBP precursors, and other drinking water constituents of concern.
- Identify methods for accurate quantitative determination of pathogens.
- Identify source control measures for pathogens, DBP precursors, and other drinking water constituents of concern
- Perform and evaluate pilot scale implementation or feasibility studies of source control measures
- Identify short and long term monitoring and assessment needs

Additional Reading

DWR, December 1999, *Municipal Water Quality Investigations Program Annual Report – October 1995*
CALFED, October 1999, *Organic Carbon Drinking Water Quality Workshop Proceedings*, Draft.
Sacramento River Watershed Program Annual Monitoring Report: 1998 – 1999.
M. Jung and Q. Tran, 1999, *Delta Island Drainage Volume Estimates – 1954-55 versus 1995-96*
CUWA, April 1993, *Study of Drinking Water in Delta Tributaries*
CUWA, May 1995, *Study of Drinking Water in Delta Tributaries*
DWR, *State Water Project Monitoring Report*
CALFED, June 1999, *Revised Programmatic EIR/S*
Sanitary Survey of the State Water Project 1996
CUWA, June 1998, *Bay-Delta Water Quality Evaluation – Draft Final Report*

Regulatory Developments

This issue paper summarizes drinking water regulations of importance, some of the key issues that will influence the course of future regulations, and some studies that would enhance regulatory decision making on issues relevant to CALFED.

Current Understanding

Of primary importance for water utilities treating Delta water are regulations governing microbes and disinfection by-products (DBP). There are several current regulations, and anticipated future water quality regulations that will affect and determine the required treatment processes for Delta water. The primary constituents that will affect the treatment of Delta water include *Giardia*, Virus, *Cryptosporidium*, Trihalomethanes (THMs), Haloacids (HAAs), Bromate, Total Organic Carbon (TOC).

The process of developing the regulations governing microbes and disinfectants/DBP (D/DBP) as summarized by EPA is presented on the next page. Some of the key points include:

Stage 1 and the IESWTR. Development of Stage 1 of the D/DBP Rule and the Interim Enhanced Surface Water Treatment Rule (IESWTR) represented a major departure from previous drinking water regulatory efforts, in that it was a negotiated rulemaking that involved various people representing interested parties. While the initial health effects issues of concern were cancer and reproductive/developmental health effects, the occurrence of a disease outbreak in Milwaukee brought keen attention to *Cryptosporidium*, the causative agent in the Milwaukee incident. The focus of treatment discussions was on removing precursors of DBP (i.e., total organic carbon), regulating additional DBP, limiting the amount of disinfectant that could be added to treated water, and optimization of treatment for *Cryptosporidium*. Rather than making dramatic changes requiring major capital expenditures based on incomplete occurrence data and limited health effects information (especially on reproductive/developmental effects), an incremental approach was adopted. As the 1994 Negotiated Rulemaking Agreement noted: "...Each party also agrees that additional research, particularly on health effects, is needed to develop sound regulations for disinfectants and disinfection by-products in public drinking water."

The intent was for EPA to conduct the relevant research so as to provide a stronger scientific basis for developing a more comprehensive and more protective public health regulation. In order to effect some interim measure of added microbial protection prior to promulgation of the IESWTR, EPA developed a voluntary program (i.e., the Partnership for Safe Water) for accrediting plants with a focus on treatment optimization for reducing microbial risks. For obtaining better information on occurrence of microbes and DBPs, the Information Collection Rule was promulgated, requiring major water systems to conduct 18 months of water quality monitoring. Table 1 indicates the contaminant levels for Stage 1 Disinfectant/DBP Rule and the IESWTR.

Stage 2 and the ESWTR. Through the Federal Advisory Committee Act (FACA) a formal advisory committee was convened on March 30, 1999 to develop the Stage 2 D/DBP Rule and the Enhanced Surface Water Treatment Rule (ESWTR). Similar to Stage 1, this committee consists of individuals representing the most significant interest groups (see Table 2). Underlying the deliberations is consideration of data collected under the Information Collection Rule and the health effects data developed since 1994. The committee will meet until April 2000 at which time, if a consensus is reached, an agreement in principle will be signed. A proposed rule is anticipated in November 2001 with a final rule anticipated in May 2002.

Microbial/Disinfectants and Disinfection Byproducts Rules Strategic Plan

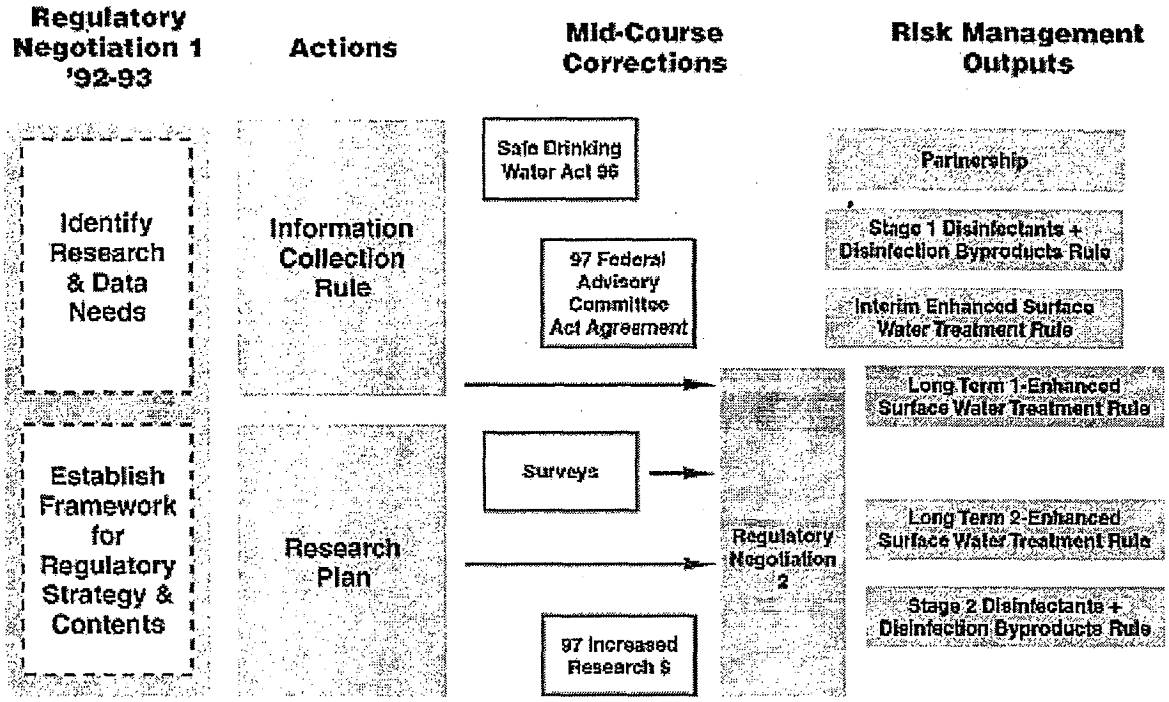

Table 1
Water Quality Constituents
And Current Standards

Constituent	***Current Standard***
Giardia	3 log[1] (99.9%)
Virus	4 log[1] (99.99%)
Cryptosporidium	2 log (removal only)
Trihalomethanes	80 μg/l[2]
Haloacids	60 μg/l[2]
Bromate	10 μg/l[2]
TOC	35% reduction[2]

(1) Inactivation and/or removal.
(2) Disinfectant/Disinfection By-Product Rule (D/DBP) - Stage 1 and IESWTR November 1998 levels assumed.

Based on current understanding of the direction of health effects research, alternative Stage 2 regulatory scenarios and their implications have been identified in Table 3. The alternate scenarios identified here do not necessarily comprise the complete range of possibilities, as regulatory developments will follow future findings of fact that are not fully predictable. Also, the projected treatment implications assume ozone and membrane filtration would be the primary advanced treatment technologies used to meet future requirements. Other technologies, including ultraviolet irradiation, are being evaluated and, if technically feasible and cost effective, may alter the treatment implications connected with different regulatory scenarios and, indeed, could affect source water quality requirements.

Table 2 *M/DBP FACA Members*	
Member	***Affiliation***
Michael A. Dimitirou	International Ozone Association
Cynthia C. Dougherty	US Environmental Protection Agency
David Esparza	Pueblo Office of Environmental Protection
Cathey Falvo	Physicians for Social Responsibility
Peggy Nilsson Greimer	Chlorine Chemistry Council
Jeffrey K. Griffiths	National Association of People with AIDS
Richard L. Haberman	Association of State Drinking Water Administrators
Barker G. Hamill	Environmental Council of States
Christine Hoover	National Association of State Utility Consumer Advocates
Rosemary Menard	Unfiltered Surface Water Systems
Richard Moser	National Association of Water Companies
Erik D. Olson	Natural Resources Defense Council
David Ozonoff	Conservation Law Foundation
David Paris	AWWA
Brian L. Ramaley	Association of Metropolitan Water Agencies
Charles R. Reading Jr.	Water and Wastewater Equipment Manufacturers Association
Bruce H. Tobey	National League of Cities
Rodney M. Tart	National Rural Water Association
Chris J. Wiant	National Environmental Health Association and National Association of County and City Health Officials
John D. Williams	National Association of Regulatory Utility Commissioners
Marguerite Young	Clean Water Action

Key Issues and Controversies

A number of key issues and controversies stem from the 1996 Amendments to the Safe Drinking Water Act and data-related considerations.

1996 Amendments. There are three concepts that may have significant regulatory impact:

- Sensitive Sub-Populations – The Amendments require that consideration be given to identify groups within the general population that may be at greater risk to exposure to drinking water contaminants. Studies will focus on evaluating sensitivity in infants, children, pregnant women, the elderly, individuals with a history of serious illness, or other sub-populations that can be identified and characterized are likely to experience elevated health risks. It now appears that genetic variability may be a greater driver of sensitivities than children and the elderly (Bull, 1999). In the absence of data on sensitivity for children, for example, a safety factor of 10 is to be used for standard setting. In addition, endocrine disruptors are an emerging issue that is to be evaluated and considered by EPA.

Table 3
***Stage 2 D/DBP Rule Regulatory Possibilities*[1]**

No.	Scenario	Driving Factors	Treatment Implications[2]
1	Individual DBP species regulated.	More studies are now pointing to toxicological significance of brominated compounds. Approach already recommended by Science Advisory Board. Bromodichloromethane, dichloroacetic acid, bromodichloroacetic acid, and MX are candidates.	Reduced free chlorine contact time or residual when bromide levels are elevated. Depending on where levels are set, may require either ozone for primary disinfection or membrane filtration with very little or no free chlorine contact time.
2	Instantaneous levels.	Reproductive health effect concerns. Toxicological studies and epidemiological studies (DHS THM Study) both suggest bromochloro compounds of concern.	May require greater TOC removal and stricter process control when TOC levels are high. Lower tolerances for source water changes if water is high in precursors that cannot be removed. With ozone or membrane filtration, minimal chlorine contact time should keep instantaneous levels consistently low.
3	Default values THMs 40 ug/l, HAA5 30 ug/l, and Bromate 5 ug/l.	Without health effects data to the contrary, no basis for refuting.	Current THM and HAA levels of most Delta plants exceed the Stage 2 default levels. Requires either ozone for primary disinfection or membrane filtration with very little free chlorine contact time to meet THM and HAA MCLs. Significant operating constraints on ozone with elevated bromide levels.
4	No change from Stage 1.	Concern of reduced disinfection with chlorine. Research findings indicate reduced health concerns associated with DBP. High cost for alternative technologies (ozone, membranes, GAC).	In general, Stage 1 THM and HAA limits are currently being met. Ozone or membranes would not be required. Bromate not an issue unless ozone is implemented for reasons other than THM/HAA control (e.g., tastes or *Cryptosporidium).*
5	Additional DBPs regulated.	Research may yield findings about other compounds, particularly brominated species. Statutory requirements for regulating new chemicals every 3 years.	Steps taken to reduce THM and HAA levels (e.g. ozone or membrane filtration) should also reduce levels of other chlorinated by-products. Some ozone by-products could be regulated but levels of known by-products can be reduced through biological filtration.
6	Mixtures of compounds and synergistic effects would be regulated.	Appealing because of the natural mixture of compounds that occur in chlorinated drinking water. Little research to date on synergistic effects of combinations of DBPs.	May require either ozone or membrane filtration coupled with little free chlorine contact time. Depends on mixtures and levels. Bromide levels may be critical.
7	More stringent limits than default levels.	Requires definitive health effects data demonstrating increased health concerns. Significant cost implications and reduced operational flexibility.	Requires either ozone for primary disinfection or membrane filtration with very little or no free chlorine contact time.

1. These options will be influenced by decision on a Cryptosporidium inactivation target (if any), that might be embodied in a future Cryptosporidium Rule.
2. UV light may be used in lieu or in concert with ozone, pending further research and regulatory approval.

- Risk-Risk Considerations – Explicit consideration must be given to "risk-risk" tradeoffs when setting an MCL. For example, if the technology to meet the MCL either (i) increases concentration of other contaminants in drinking water, or (ii) interferes with treatment used to comply with other primary drinking water regulations), then a level other than the feasible level may be set. The intent is for EPA to minimize overall risk by balancing both the risk reductions from treating the individual contaminant with possible side-effects of such treatment on concentrations of other contaminants. The Amendments also note that these considerations are consistent with the process used to set DBP Stage 1 and Stage 2 standards. This consideration is critical in selection of Delta water treatment technologies. Overall, DBP production is much lower with ozone-chloramine than chlorine-chloramine. Ozone is a superior disinfectant. But ozone forms small concentrations of bromate, and chlorine preferentially produces brominated DBP. Brominated species pose a countervailing risk to bromate. Since there is clearly a risk-risk trade-off, it is crucial to identify how the risk of the brominated compounds compare to that of bromate since this analysis may lead to a different standard for bromate.

- Statutory Deadlines – The Safe Drinking Water Act Amendments of 1996 set an aggressive schedule by which regulations must be set, including: (a) August 2000 -- Final Rule Filter Backwash Recycling Rule, (b) November 2000 -- Final Rule Long Term 1 Enhanced Surface Water Treatment Rule & Ground Water Rule, and (c) May 2002 -- Final Rule Stage 2 Disinfection Byproduct Rule & Long Term 2 Enhanced Surface Water Treatment Rule. Of considerable significance is that decisions will be made prior to EPA's completion of their research plan for microbes and DBPs.

- Interpretation of ICR Data - How will data be interpreted relative to protozoan occurrence? What impacts will the high quality Delta water treated during this period of testing (i.e., low bromide) impact regulatory options? What further improvements will be realized as utilities come into compliance with the currently promulgated Stage 1 DBP Rule? What further reductions would be necessary under Stage 2?

- Cryptosporidium - Will inactivation targets be established? Is this dependent on technical feasibility (e.g., UV), occurrence, and/or disease incidence (which has dropped over the last 5 years)?

- Incomplete Health Effects Information - Occurrence data are not available for all the compounds of interest. In addition, the health effects of all DBPs have not been studied, nor has the toxicology of DBP mixtures been adequately investigated. Furthermore, expert opinion can vary widely in the interpretation of toxicology data. The epidemiological studies are generally difficult to interpret for regulatory decision-making due to the difficulty of making accurate exposure assessments.

Ongoing and Near-Term Activities

The CALFED Water Quality Program Plan contains a number of proposed early implementation actions directed at improving the safety of drinking water taken from the Delta. However, none of these proposed actions are specifically directed toward regulatory development. The Delta Drinking Water Council and its technical support team, the Drinking Water Constituents Work Group, have responsibility for the continuing evolution and development of the Drinking Water Quality Program. The following actions have been developed and proposed by the Work Group to augment the actions proposed in the Water Quality Program Plan.

<u>Enhanced Pathogen Risk Assessment</u>

Objective: Supplement the Bay-Delta water quality database with more comprehensive and sensitive determinations of *Giardia* and *Cryptosporidium.*

Rationale: Data collected using the EPA-specified method did not have a high degree of sensitivity. Method 1623 is far more sensitive. Developing data for the occurrence of *Giardia* and *Cryptosporidium* in the Delta compared to other sources would aid determinations as to the level of inactivation appropriate for Delta users.

Elements:

- Develop coordinated monitoring program with other US sources
- Perform comparison based on new data and other, traditional indicators
- Summarize results

Bromate Risk Assessment Sensitivity Analysis

Objective: Determine the impact of different outcomes of ongoing toxicological evaluations.

Rationale: Several studies are currently being conducted that may impact the bromate risk assessment. It is important to identify which outcomes would materially impact the risk assessment both to inform the FACA process and to suggest the need for EPA to accelerate the peer review process if such results are encountered.

Elements:

- Discuss potential outcomes of bromate research by 2000 and 2002 with researchers
- Summarize results scenarios
- Interview prominent toxicologists for their risk assessment inferences
- Identify which results would change the risk assessment and by how much
- Query individuals as to what research might resolve uncertainties and identify time frame/resource requirements

Potential Longer-Term Activities

CALFED should closely follow state and federal drinking water regulation development processes and participate in these processes through the technical expertise of the Drinking Water Constituents Work Group. The Work Group should be responsible for identifying opportunities for CALFED support of regulation setting activities that lead to solutions of the drinking water problems associated with Delta water supplies, and should advise the Delta Drinking Water Council of the need to formulate recommendations for CALFED Policy Group approval.

Additional Reading

www.epa.gov – regulations and legislation

Source Control

The CALFED Water Quality Program Plan, a technical appendix to the June 1999 Revised Draft Programmatic EIS/EIR, identifies bromide, natural organic matter (measured as total organic carbon or TOC), salinity (measured as total dissolved solids or TDS), pathogens, turbidity and nutrients as contaminants of concern for drinking water supplies obtained from the Delta. The Drinking Water chapter of the Water Quality Program Plan contains primarily source control actions as the means to reduce levels of these contaminants in Delta water supplies. In addition, the CALFED Drinking Water Quality Improvement Strategy, proposed in the June 1999 Revised Phase II Report, includes source control actions as an element of the strategy.

Current Understanding

The source control approach to water quality improvement involves the implementation of control measures at the pollutant source to reduce or eliminate the discharge of contaminants from both point and nonpoint sources. Source control approaches include treatment of waste discharges, implementation of management measures and best management practices, and implementation of watershed management programs. Some sources of drinking water contaminants are more amenable to source control than others. For example, source control actions are more readily implemented for agricultural drainage and wastewater treatment plant discharges that have collection and discharge facilities, as opposed to diffuse sources of pollutants such as watershed runoff and seawater intrusion.

The Water Quality Program Plan includes potential actions that address the following sources of contaminants: agricultural drainage and runoff; livestock grazing and confined animal facilities; wastewater treatment plant discharges; urban runoff; and discharges from recreational boating activities. Actions are proposed to control the discharge of contaminants to the Delta and its tributary watersheds, and to protect water quality in the conveyance facilities and reservoirs that transport and receive Delta water supplies. The source control actions proposed for early implementation primarily address organic carbon and salinity. Many of the CALFED source control actions rely on an incentive-based approach, rather than a regulatory approach.

Our understanding regarding the feasibility and cost-effectiveness for many of the CALFED source control actions is limited. The recommendations for CALFED source control actions are based on professional judgement, available water quality data concerning sources of drinking water contaminants, seriousness of the water quality problem, information for previously implemented source control projects, and information concerning the treatment technologies available to remove contaminants from wastewater.

Key Issues and Controversies

Sources of Drinking Water Contaminants. Successful implementation of source control actions requires sufficient knowledge regarding the sources and loads of drinking water contaminants, to focus actions on those sources of greatest concern. For example, available water quality data collected by the Municipal Water Quality Investigations (MWQI) Program at DWR indicates that Delta island drainage contributes a significant load of organic carbon to the Delta at certain times of the year. This information has led to further studies and proposed source control actions addressing organic carbon discharges from Delta agricultural drains. For pathogens, our understanding of sources is limited due to the lack of reliable monitoring methods, and as a result, further studies are needed before specific source control actions can be implemented. As CALFED moves forward with implementation of a source control program, studies are needed to better characterize the sources and loads of drinking water contaminants.

Seawater Intrusion. Seawater intrusion into the Delta is the major source of bromide for Delta drinking water supplies, and also contributes a significant portion of the salinity in the Delta. These contaminants cannot be controlled or reduced using the source control approach. As a result, other elements of the Drinking Water Quality Improvement Strategy must be utilized to reduce bromide and salinity levels at the drinking water intakes. Refer to "Conveyance" and "Storage and Operations" issue papers.

Feasibility and Effectiveness of Source Control Actions. The priority for implementation of source control actions will be determined based on feasibility, costs and timing issues. In addition, CALFED will need to compare the cost-effectiveness of source control actions to other approaches for Delta water quality improvement. As CALFED moves forward with implementation of a source control program, studies are needed to determine the feasibility and cost-effectiveness of source control actions.

Impacts on Dischargers. Since source control focuses on pollutant sources, these actions may adversely affect entities that discharge drinking water contaminants to the Bay-Delta watershed. If the source control actions are threatening to discharger entities and do not adequately account for impacts to dischargers, the ability to implement source control actions may be limited. Development of a successful source control program must involve the participation of the discharging entities to ensure cooperation and consideration of their needs. This will require substantial outreach to the discharger community, beyond what has occurred to date as part of the CALFED process.

Incentives vs. Regulatory Requirements. CALFED's approach for implementing source control is based primarily on providing incentives rather than implementation through regulatory actions. Some participants in the CALFED process question the ability to implement successful source control programs without additional or more stringent regulatory requirements.

Beneficiaries of Source Control Actions. Because the feasibility and cost-effectiveness for many of the CALFED source control actions are unknown, it may be difficult to identify beneficiaries of source control actions that would be expected to pay for implementation of the actions.

Potential Multiple Benefits of Source Control Actions. The implementation of CALFED source control actions may also result in water quality benefits for other beneficial uses. For example, agricultural water users, as well as drinking water agencies, would benefit from reduced salinity levels in the Delta. Source control actions that reduce nutrient levels could potentially benefit fisheries in some areas by reducing levels of compounds that contribute to low dissolved oxygen conditions. Also, actions to reduce discharges of pathogens would benefit recreational beneficial uses.

Some drinking water contaminants may be more cost-effectively controlled at the source rather than through treatment at the drinking water treatment plant. If CALFED source control actions are effective in reducing levels of drinking water contaminants in Delta water supplies, it may reduce the need for future investments in advanced treatment technologies.

Ongoing and Near-Term Activities

Watershed protection and source control have been components of the overall strategy to provide safe drinking water for a number of years. Drinking water agencies conduct sanitary surveys of the watersheds from which they derive surface waters every five years. The sanitary surveys identify the key contaminant sources in the watersheds and strategies for protecting drinking water supplies. Water agencies that derive their supply from small watersheds where they own or control the majority of the property in the watershed have been the most successful in protecting their sources. The water agencies diverting water from the Delta have worked with DWR to protect the major conveyance and storage facilities for the State Water Project. These agencies have, in many cases, developed watershed protection strategies for local storage reservoirs (e.g. CCWD's Los Vaqueros Reservoir and Metropolitan Water District's Lake Mathews and Eastside Reservoirs).

Agencies that derive water from the Delta have virtually no control over the numerous activities in the Sacramento and San Joaquin basins. They must rely on the regulatory programs of the State Water Resources Control Board and the California Environmental Quality Act to protect their water supplies. Although great strides have been taken in protecting California's waterways through these programs, little attention has been paid to the contaminants of most concern to drinking water agencies. The California Regional Water Quality Control Board (RWQCB), Central Valley Region is initiating technical work for the development of a drinking water policy for the Central Valley Regional Water Quality Control Plan (Basin Plan). Development of the drinking water policy is expected to be a multi-year effort. The policy will address long-term source water protection needs for drinking water through the establishment of water quality objectives and implementation plans to control sources of drinking water contaminants. The CALFED source control program should be closely linked to the development of this policy.

The MWQI Program is currently conducting an agricultural drainage reduction project, which should provide useful information for further development of Delta agricultural drainage source control actions. This project entails evaluating the potential benefits and costs of treating agricultural drainage to remove organic carbon for the purpose of reducing the load of organic carbon reaching the drinking water intakes in the Delta.

Stakeholders participating in CALFED's Water Quality Technical Group identified several source control early implementation actions for addressing drinking water contaminants of concern for Delta water supplies. These actions, summarized below and described in more detail in the CALFED Water Quality Program Plan, are based on best professional judgement rather than a scientific understanding of the sources and loads of constituents of concern. Additional monitoring and pilot/feasibility studies are needed to quantify the potential improvement in water quality resulting from the early implementation source control actions.

<u>Assessment of Sources and Magnitudes of Loadings of Constituents of Concern for Drinking Water.</u> As discussed above, there are varying levels of understanding of the sources and loads of the constituents of concern to drinking water supplies. Prior to implementing costly source control projects, a better understanding of the sources and seasonal loads of the drinking water constituents is needed. The Drinking Water Constituents Work Group is currently designing a study and preparing a proposal for CALFED funding to obtain this needed information.

<u>Management of Agricultural Drainage from Veale and Byron Tracts.</u> There is evidence that agricultural drainage from Veale and Byron Tracts may be partially responsible for elevated salinity levels at Contra Costa Water District's (CCWD) Rock Slough and Los Vaqueros intakes. The Veale/Byron Tract Work Group has been formed to determine the impact of these drains on CCWD's water quality and to evaluate alternatives for managing the drainage.

<u>Barker Slough Watershed Management Program.</u> The North Bay Aqueduct Contractors obtained a $580,000 grant from the Delta Tributary Watershed Program to determine the sources of key constituents of concern in their source waters (Barker Slough) and to evaluate best management practices for controlling those sources. This study is underway and being funded by Solano County Water Agency and DWR's MWQI Program while awaiting the release of grant funds.

<u>Reduction of Discharges of Human Waste from Watercraft in the Delta.</u> The Delta is used heavily for recreation, particularly boating and fishing. Although the impact of discharges of human waste from boats on the pathogen levels in the Delta is unknown, basic public health protection should dictate that the

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existing prohibition on discharge of vessel waste be rigorously enforced. A stakeholder process is proposed to evaluate additional educational and regulatory needs. This action is not currently being addressed.

Agricultural Drainage Management Pilot Study. A number of potential actions have been considered to control or manage Delta agricultural drainage and reduce the associated water quality impacts at Delta pumping plants. These include treating agricultural drainage, relocating drains away from drinking water intakes, storing drainage on islands for release on the ebb tide, and implementing land management practices that would reduce the amount of drainage and/or improve the quality of the drainage. A feasibility study is needed to identify alternative practices for further study at the pilot scale level. Modeling studies are needed to understand the impacts of these alternatives on TOC concentrations at the Delta pumping plants. This action is under the purview of the Drinking Water Constituents Work Group but is not currently being addressed.

Management of Drainage from the San Joaquin Basin. The potential to time releases of agricultural drainage and wetlands drainage from the west side of the San Joaquin Valley to coincide with periods of high flow and greater assimilative capacity in the river will be investigated to determine if water quality improvement in the Delta can be achieved. This action is being addressed by the CALFED Salinity and Selenium Work Group.

Potential Longer-Term Activities

Stakeholders participating in CALFED's Water Quality Technical Group identified a number of research programs and source control actions to improve drinking water quality in the Delta during Stage 1 of the CALFED Program (first seven years). Actions were identified for specific components of the watersheds and conveyance facilities (e.g., Sacramento River Basin, North Bay Aqueduct). Many of these actions depend upon the results of monitoring and pilot studies to be conducted during the early implementation phase of the CALFED Program. The Stage 1 actions fall into the following categories.

- Agricultural Drainage – Treat drainage, relocate discharge points, implement best management practices (BMPs), and modify management practices to reduce TDS, nutrient, and TOC loads.
- Animal Enclosures – Implement BMPs to reduce discharge of fecal matter and associated TOC, nutrients, and pathogens into Delta drinking water sources.
- Wastewater Discharges – Improve treatment, relocate outfalls, and encourage a watershed-based approach to permitting that evaluates cumulative impacts of pollutants that affect drinking water quality, such as TOC, TDS, pathogens, and nutrients.
- Urban Runoff – Treat storm water runoff, implement source control BMPs, relocate outfalls, and encourage a watershed-based approach to permitting that evaluates cumulative impacts of pollutants that affect drinking water quality, such as TOC, TDS, pathogens, and nutrients.
- Algae Control – Treatment to kill or remove algae, reduce nutrient sources, and evaluate operational measures.
- Boating Control – Develop and implement educational programs and support enforcement programs to reduce discharges of human wastes.
- Local Watershed Management – Support community-based watershed management efforts.

Specific action plans for these activities will be developed as the program progresses, with considerable assistance and guidance from the Delta Drinking Water Council. Although these Stage 1 actions are scheduled to be implemented during the first seven years of the CALFED Program, it is extremely likely that many of these actions will be implemented over a much longer time frame. In addition, some of these actions may prove to be infeasible or unnecessary after further evaluation.

Effectiveness of Source Control Actions

As described previously, the effectiveness of the proposed actions in improving Delta drinking water quality is unknown at this time. Until a better understanding of the sources and loads of key drinking water constituents is developed, it is not possible to identify the highest priority actions or quantify their impacts on Delta water quality. Another factor to keep in mind in evaluating the source control actions is that the Central Valley's population is growing at a rapid rate. As the population grows, the loads of drinking water contaminants from wastewater and urban runoff sources will increase unless source control measures are implemented. It is possible that the source control actions contemplated by the CALFED Program may not improve water quality but only maintain existing loads and ambient water quality conditions as the population of the Central Valley increases.

The source control actions developed by the Water Quality Technical Group will not reduce the loads and concentrations of bromide at the Delta diversion locations. Bromide enters the Delta by mixing of waters of San Francisco Bay with Sacramento and San Joaquin River water in the Delta. Although there are minor sources of bromide in the watersheds of the rivers, the only method of controlling the bromide concentrations at the Delta pumping plants is to limit the mixing of seawater with the drinking water supply. Source control actions in the watersheds will have no significant impact on the bromide concentrations in drinking water supplies diverted from the Delta.

Pathogens present another challenge with respect to improving drinking water quality through source control. The methods for detecting pathogens in source waters have not been perfected to the point where pathogens can be reliably detected and quantified. It is difficult to quantify the loads of pathogens from various sources and to evaluate actions to reduce pathogen loads. Until these methods are improved, qualitative assessments of pathogen presence/absence and concentrations of non-pathogenic bacteria must be used to evaluate improvements in water quality.

In summary, the CALFED Water Quality Program Plan includes potential methods for improving Delta water quality through source control actions. The feasibility and cost-effectiveness of these actions are largely unknown. A good understanding of the sources and loads of drinking water constituents is needed to identify the high priority actions and to evaluate the effectiveness of those actions in improving drinking water quality in the Delta. Additionally, pilot studies are needed to investigate the feasibility and costs associated with some of the proposed actions. Source control actions will not be able to significantly improve bromide concentrations in the Delta and may only be able to help maintain existing water quality conditions with the considerable growth in population of the Central Valley that is projected.

Additional Reading

The following documents contain information on the source control element of the CALFED Drinking Water Quality Improvement Strategy:

CALFED, June 1999, *Water Quality Program Plan*, Chapter 3 – Drinking Water.
CALFED, June 1999, *Water Quality Program Plan*, Chapter 12 – Implementation Strategy
CALFED, June 1999, Water Quality Program Plan, *Appendix E -- Bay-Delta Drinking Water Quality: Bromide Ion (Br$^-$) and Formation of Brominated Disinfection By-products (DBPs).*
CALFED, June 1999, *Revised Phase II Report*, pp. 40-48.
CALFED, October 9, 1999, *Organic Carbon Drinking Water Quality Workshop Proceedings*, Draft.

Storage, Conveyance, and Flexible Management of Water Operations

New storage and conveyance facilities and flexible management of water operations can provide ecosystem benefits and water supply reliability while simultaneously improving Delta source water quality.

Current Understanding

Tidal dispersion mixes seawater and fresh water inflow within the Delta. Seawater is the primary source of salinity and bromide in the Delta although fresh water inflows also contribute to the salt load. As discussed in the "Source Control" issue paper, a diffused source such as seawater intrusion is not amenable to source control actions. And as discussed in the "Treatment Technologies" issue paper, technologies that effectively remove bromide and other salts are limited and expensive.

Bromide and salinity export loads are related to project operations (e.g. outflow and export management) and can be reduced through new storage and conveyance facilities and flexible management of water operations. Such an approach could strategically increase outflow, shift exports to periods of better water quality, increase the percentage of high quality water reaching Delta drinking water diversions, and maintain better separation of sources of differing quality.

High total organic carbon (TOC) concentrations in Delta drinking water diversions correspond with the collective operations of agricultural drains rather than with water project operations. Peak TOC concentrations regularly occur in the Delta in winter from agricultural drainage. Considering this predictability, management of TOC export loads could be accomplished through flexible management of water operations as well as through source control measures.

Contra Costa Water District's Los Vaqueros Reservoir is an example of a storage facility that was constructed to enhance drinking water quality in an environmentally friendly manner. The reservoir is operated in coordination with the District's other Delta diversions to selectively fill during periods of relatively low Delta bromide and salinity concentrations.

Key Issues and Controversies

<u>Conveyance Improvements.</u> The following are general descriptions of potential conveyance improvements for enhancing source water quality at Delta drinking water diversions. Key issues and potential conflicts are discussed for each.

- South Delta Improvements (SDI) and Joint Point of Diversion (JPOD) - The SDI Program includes a number of coordinated actions to address long-standing concerns with respect to water quality, fisheries, and water supply availability. Proposed facilities include a new screened intake to the SWP Clifton Court Forebay, a permanent fish barrier at the head of Old River, permanent flow and stage control barriers on Middle River and Old River, dredging of Old River and other south Delta channels, and extension and screening of agricultural intakes. The head of Old River fish barrier would prevent out-migrating San Joaquin River salmon from entering the south Delta and improve survival. The flow barriers, in concert with channel dredging and agricultural intake extensions, would help to control the flows and stages in the south Delta and maintain accessibility to water supplies for agricultural and other beneficial uses – especially when export rates are high. It is anticipated that implementation of SDI would result in an increase in permitted export pumping rates.

JPOD would allow the federal CVP to use pumping capacity at the SWP Banks Pumping Plant, or, conversely, would allow the SWP to use pumping capacity at the federal Tracy pumping plant. The State Water Resources Control Board recently approved a phased and widened use of JPOD.

Both SDI and JPOD will increase the operational flexibility of the CVP and SWP. This increase in flexibility would provide opportunities for the projects to improve water quality, water supply, and ecosystem protection. Additional export capacity could be used to pump additional water supplies during times of better Delta water quality and forego pumping of supplies during times of reduced water quality. JPOD would provide the additional flexibility of dual points of intake from the Delta, allowing pumping from the intake with the better water quality during times of lower rates of export.

There are a number of implementation issues associated with SDI and JPOD. These include a need to further refine the relationship between increased export capacity, barrier operations, Delta stage, circulation, impacts to fish (including delta smelt) and water quality. Improved monitoring will aid in these evaluations. Additionally, the need for and potential impacts of a third permanent barrier for flow and stage control on Grant Line Canal must be determined.

- Hood-Mokelumne Diversion and Delta Cross Channel (DCC) Operation - Actions to better protect migrating Sacramento River salmon may involve more frequent closure of the DCC gates. Increased closure of the gates could negatively impact export water quality because of the reduced through-Delta flow reaching the south Delta intakes. The proposed Hood-Mokelumne screened diversion of up to 4,000 cfs would help to offset the negative water quality impact due to the DCC gate closure. Further evaluation of the potential effects of this facility on fisheries would be required prior to implementation.

  Major issues associated with a Hood-Mokelumne diversion include the perception that this facility would be the first phase of an isolated conveyance facility. Considerable uncertainty remains regarding the effectiveness of fish screen and screen bypass facilities to mitigate the potential blockage of upstream migrating fish. There is also uncertainty regarding the effectiveness of improved monitoring in directing DCC gate operations to protect fisheries while providing for export water quality.

- Mokelumne River Channel Widening - Widening the Mokelumne River channel could improve the conveyance capacity of north to south central Delta flow. Setback levees on the Mokelumne River would also improve fishery habitat and reduce flood potential. These channel modifications could be coupled with a Hood-Mokelumne diversion to further improve conveyance of high quality water to the south Delta. Issues associated with Mokelumne River channel widening and through-Delta conveyance of export water supplies include the possible increase in organic carbon levels from proposed habitat improvements, potential adverse effect on salmon entrainment, survival, and upstream migration.

- Relocation of North Bay Aqueduct (NBA) Intake – The Barker Slough watershed contributes a significant amount of organic material to the NBA. Solano County Water Agency is conducting a watershed management program to determine if BMPs can be implemented to improve water quality in Barker Slough. Conveyance improvements could also provide improved water quality in the NBA. CALFED identified relocation of the Barker Slough intake as a Stage 1 Action in its June 1999 Water Quality Program Plan. Such an action would require an evaluation of feasibility and cost effectiveness. As discussed in the "Alternative Sources of a High Quality and Reliable Water Supply" issue paper, a regional exchange with Solano Project water users is an alternative approach to improving source water quality for NBA water users.

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- Isolated Conveyance Facilities - An isolated conveyance facility would provide direct access to better source water for the SWP and CVP. As considered by CALFED, this facility would include an isolated canal around the eastern Delta directly connecting the export facilities to the Sacramento River at Hood. The Hood intake would be screened to reduce the potential impacts to fish. The quality of the diverted water arriving at the Clifton Court Forebay would be expected to approximate that at the Hood intake (about 100 mg/l TDS and about 20 µg/l bromide). Diversions at Hood would be supplemented by diversions in the south Delta. The quantity of south Delta diversions and the extent to which they can be isolated from the Hood diversions would substantially affect delivered water quality. Average Delta quality contains about 250 mg/L TDS and 280 ug/L bromide, although in extended dry periods these concentrations are significantly higher. Numerous isolated facility studies have been conducted by CALFED with capacities ranging from 5,000 cfs to 15,000 cfs. Operation rules have also been varied in an effort to minimize the impact on south Delta water quality and to fisheries.

  The benefits and impacts of an isolated facility depend on the size and the associated operation rules. A larger capacity facility could provide significant improvements to export water quality, but could pose a risk to south Delta water quality and to migrating Sacramento River salmon. Alternatively, a smaller facility could provide lesser water quality benefits, but risk to south Delta water quality and to fisheries would be diminished.

  Significant issues affect the implementability of an isolated facility. Of primary importance is the difficulty in providing adequate assurances that such a facility would be operated appropriately to provide for in-Delta resource needs. Other issues include uncertainty regarding the effectiveness of fish screens and the potential adverse effect on salmon survival due to reduced flow below Hood.

- Out-of-Delta Improvements - Out-of-Delta conveyance improvements that can improve drinking water quality include construction of additional conveyance facilities to segregate the transfer of water for urban and agricultural uses (e.g. O'Neill bypass) and additional conveyance facilities which could allow high-quality water exchanges for urban use. Construction of an O'Neill bypass could improve water quality for some contractors by selectively routing higher quality source water into the joint reach of the California Aqueduct. However, when demands are high in the California Aqueduct, selective routing is limited because both Delta exports and releases from San Luis Reservoir are required to meet demand. Preliminary study results indicate that if ideal routing is assumed through the O'Neill Forebay, average salinity reduction is about 5 to10 percent. Most of this salinity reduction is caused by direct routing of Delta exports to the joint reach when demands are relatively low and Delta water quality is substantially better than supplies previously stored in San Luis Reservoir.

  Other conveyance facilities, such as a Mid-Valley Canal or enlarged Friant-Kern and Cross Valley Canal could provide for exchanges of water supplies that would allow higher-quality water for urban uses. A significant issue with this type of exchange would be the increased salt loading resulting from applying poorer quality water for agricultural use. Many other issues typically associated with water transfers, impacts to water rights, access to conveyance facilities, and mitigation for third party impacts, would also affect the implementability of regional water quality exchanges and are discussed in the "Alternative Sources of a High Quality and Reliable Water Supply" issue paper.

<u>Storage and Operations.</u> Typically, the months of April through July are most favorable with respect to the Delta as a source of drinking water. Outflow from natural runoff is usually high enough during this period to push seawater out of the Delta. This period is also outside the period of peak TOC loading from agricultural drainage. Water supply needs are greatest in these months because of direct demand requirements (which are supplemented by San Luis Reservoir releases). However, fishery concerns have

resulted in a shift in exports from these higher-quality spring months to lower-quality fall months, with a corresponding degradation in delivered water quality. In particular, May and June have proven in recent years to be sensitive Delta smelt months with elevated take at the export pumps. Given these special circumstances, several operational strategies could be adopted to improve water quality delivered from the Delta for drinking water purposes. These strategies include outflow management, export management, real time evaluation of fishery conditions, and source/demand shifting. The effectiveness of these strategies could be enhanced through the construction of additional storage facilities.

- Outflow Management – Increasing Delta outflow in fall months through reservoir releases could reduce peak bromide and salinity concentrations in south Delta drinking water diversions. (Delta outflow has less of an influence on water quality at the North Bay Aqueduct's Barker Slough intake.) Preliminary modeling studies conducted by CALFED suggest that, depending on the amount of outflow enhancement and assuming some Delta conveyance improvements, peak reduction of bromide and salinity in the south Delta in fall months could be in the range of 20 to 30 percent. Such an operation would entail a water supply risk, as the filling of San Luis Reservoir would be delayed. However, the availability of conveyance improvements (i.e. SDI and JPOD) along with the ability to recover some storage losses through runoff capture could significantly reduce water supply losses. Water supply risk could be reduced further if new storage were developed to supply the additional fall outflow. Water supply risk could also be mitigated through upstream water acquisitions. With additional storage facilities north or south of the Delta, peak fall bromide concentrations could be lowered by as much as 30 to 50 percent in many years, including the driest ones. Migrating salmon may benefit from higher fall Delta outflow, although shifting export pumping into the winter months could have negative impacts on other salmon runs and Delta smelt.

- Export Management – Quality of delivered and stored water south of the Delta could be improved by shifting diversions to periods with better Delta water quality. When operating to meet water supply reliability and ecosystem objectives, the least risky operation is to begin filling San Luis Reservoir as soon as water and export capacity are available. This typically occurs in the fall of most years. However, if outflow has been low throughout the summer and fall months, seawater intrusion will occur in the south Delta and bromide and salinity concentrations will be elevated. If hydrologic conditions improve as the water year develops, outflows will increase and salinity will be pushed out of the Delta. Under these hydrologic conditions, it would be beneficial to postpone exports to fill San Luis Reservoir until Delta water quality has improved. However, there is no guarantee that fish conditions will be favorable and that surplus water will be available in the Delta for export.

  Conveyance improvements such as SDI and JPOD could offset the risk associated with selectively filling San Luis Reservoir. Additional storage south of the Delta could also offset the risk associated with selectively filling San Luis Reservoir. Preliminary modeling studies conducted by CALFED suggest that the most efficient role of additional south of Delta storage for drinking water quality purposes would be to make releases for direct delivery when foregone exports in the Delta are not recovered later in the winter. Filling of south of Delta storage would be restricted to the periods when conveyance and pumping capacity were available and water quality in the Delta was relatively good. These conditions would likely overlap in the late winter and spring.

  While the preceding discussion has focused on export management for bromide and salinity reduction, export management strategies could also be implemented to reduce organic carbon loads in drinking water diversions. Export reductions during periods of peak organic carbon loading (typically in February and March) would benefit Delta fisheries in most years as was shown in recent CALFED Environmental Water Account gaming studies. Risk to water supply reliability would depend on which assets are available for supply recovery.

Some stakeholders have suggested that export water quality could be improved through demand reduction in the CALFED study area. Demand reduction, implemented through increased investment in conservation and recycling measures, could result in lower Delta exports and higher Delta outflows. If conserved water was banked in a storage facility, this export management strategy could provide benefit in drier years when the Delta is supply limited.

- Real Time Evaluation of Fishery Conditions – The 1995 Water Quality Control Plan and related Endangered Species Act biological opinions all provide for the flexible application of the "export-inflow (E/I) ratio" based on real time evaluation of fishery conditions. Minor temporary adjustments to the E/I ratio requirements could yield significant water quality benefits without adversely affecting environmental protection.

- Source/Demand Shifting – CALFED water management agencies have found that voluntary shifts by water users in the timetable for water deliveries during the year, or temporary shifts by water users to non-project sources of supply, have been extremely valuable in dealing with short term fluctuations in water supply availability. These approaches have been especially useful in addressing the so-called "low point" problem in the San Luis Reservoir (where reduced Delta pumping and increased demands combine to lower reservoir levels to a point where water quality problems occur). These management techniques could also be of value in dealing with short term fluctuations in Delta water quality. Issues associated with these "shifting" management techniques include compensating water users for extra costs incurred by the shift and allocating any increased risk caused by shifting.

- Additional Storage – As discussed above, the effectiveness of outflow and export management could be enhanced with additional storage facilities. New storage could also provide additional flexibility towards improvement in water supply reliability and ecosystem health. New storage north of Delta could be utilized to enhance Delta outflow in the fall. South of Delta storage could be utilized to offset potential water supply risks resulting from selective export and reservoir filling strategies. In-Delta storage could also provide additional flexibility in meeting water quality, water supply reliability, and ecosystem goals. Flexibility would increase if diverted water to island storage could be directly exported instead of being released back into the Delta. Significant areas of conflict are associated with additional storage, including but not limited to ecological and fishery issues, financing, and distribution of benefits. Furthermore, significant drinking water quality issues associated with in-Delta storage remain.

Ongoing and Near-Term Activities

CALFED's Water Management Strategy (WMS) will evaluate and compare many tools and approaches for addressing the issue of water supply reliability in the Bay-Delta system. The WMS has three broad purposes: (1) develop a menu of water management tools that can be used to attain CALFED's water supply reliability goals, (2) identify specific water management tools from this menu that will be implemented in Stage 1 of the CALFED Bay-Delta Program, and (3) provide a long-term decision making framework for evaluating the success of implementation efforts and for selecting additional tools needed to achieve CALFED's objectives. CALFED has implemented a number of activities to help refine the WMS. These activities are summarized below:

<u>Water Management Development Team.</u> To address the near-term implementation of the WMS, CALFED has established a Water Management Development Team. This team, consisting of CALFED agency and stakeholder representatives, is evaluating the performance of a number of water management

tools that might be implemented in Stage 1. The team will advise CALFED policy makers on the value of these water management tools, and how the benefits of these tools might be shared to meet the multiple objectives of the Program, including drinking water quality.

Integrated Storage Investigation. The primary objectives of the Integrated Storage Investigation are to (1) provide information to help determine the appropriate role of storage in CALFED's WMS and (2) coordinate and facilitate longer-term evaluations of specific storage opportunities underway by CALFED agencies. Studies that have been conducted as part of CALFED's WMS refinement process include an Economic Evaluation of Water Management Alternatives, a Riverine Processes Study, a Drinking Water Quality Operations Study, a Hydroelectric Facilities Re-operation Investigation, and a preliminary investigation of groundwater conjunctive use opportunities. Longer-term evaluations of storage facilities are also underway. DWR is currently conducting a North of Delta Offstream Storage Investigation and has recently initiated appraisal studies of in-Delta and off-Aqueduct storage opportunities. DWR is also discussing possible cooperative studies of groundwater conjunctive use opportunities with a number of local water agencies and elected officials throughout California. USBR has completed an appraisal study assessing the potential for enlarging Shasta Dam and is developing a workplan for a feasibility study of a 6.5-foot dam raise.

WMS Evaluation Framework. To help address long-term implementation of the WMS, CALFED is developing a WMS Evaluation Framework. Through a series of facilitated workshops and interviews with stakeholders and agency representatives, CALFED will attempt to better define specific WMS objectives. The Evaluation Framework will also include performance measures to help gage progress towards the identified objectives. A series of three workshops along with individual interviews have been completed to aid in this effort.

WMS Comprehensive Evaluation. To help illustrate the relative effectiveness of alternative water management strategies in light of the identified objectives and performance measures, CALFED is conducting a comprehensive evaluation of alternative water management strategies. The alternative strategies will reflect emphasis on a variety of water management tools. The comprehensive evaluation will include hydrologic and economic analyses and assessment of environmental and social impacts to evaluate performance measures under the alternative strategies. To help illustrate the evaluation process and provide preliminary findings, a limited number of alternative strategies will be defined and evaluated by early January 2000. If warranted, additional evaluations will be completed in early 2000.

Additional Reading

CALFED, June 1998, *Diversion Effects on Fish – Issues and Impacts*

CALFED, June 1999, *Water Quality Program Plan*

CALFED, November 8, 1999, *Studies for the Water Management Strategy Comprehensive Evaluation*, technical memorandum from the Drinking Water Quality Operations Workgroup, DRAFT.

Treatment Technologies

This issue paper explores opportunities to improve drinking water quality from Delta source water through treatment technologies.

Current Understanding

Water treatment for drinking water purposes focuses on control of microbiological contamination, control of disinfection by-product formation, and aesthetics.

- Microbiological Control - The focus for disinfection and microbial control currently pivots around the removal and inactivation of the protozoan pathogens *Giardia* and *Cryptosporidium* (viruses and bacteria are typically controlled when these organisms are removed and/or inactivated). Currently, 3-log (99.9 percent) removal and inactivation of *Giardia* is required in the Surface Water Treatment Rule (SWTR). (The Interim Enhanced SWTR, which is currently in effect, requires a 2-log removal of *Cryptosprodium* for systems that filter and which serve 10,000 or more people.) The Enhanced SWTR (ESWTR), currently under development, would also address the removal/inactivation of *Cryptosporidium*, through either removal or inactivation. In addition, concern is intensifying over bacterial pathogens that may grow in distribution systems.

- Disinfection By-Product Control - The disinfectant residual concentration and the organic and inorganic compounds formed by the disinfection process (termed disinfection by-products or DBPs) are currently regulated under the Disinfectants/Disinfection By-Products (D/DBP) Rule. These levels are currently being re-evaluated and may be further lowered.

- Aesthetics - Reduction and/or elimination of unpleasant flavors and odors is critical for ensuring consumer acceptance, and is a priority for Delta water users.

While the focus of this issue paper is on treatment technology, there is growing appreciation of the need to develop a comprehensive drinking water management strategy that also considers source water and distribution system issues. Therefore, in considering this paper the reader should be reminded that treatment is one facet of a multi-barrier approach to assuring safe drinking water. Treatment is effective only when watershed protection, source control, and distribution system protection and maintenance are included as elements of a comprehensive system to protect the health of consumers.

Water treatment technologies are classified into two major areas for purposes of discussion in this issue paper: conventional processes and membrane processes.

<u>Conventional Processes With Modifications.</u> Conventional treatment processes utilize chlorine for disinfection. The following outlines modifications to conventional treatment processes for DBP precursor removal and alternate forms of disinfection.

- DBP Precursor Removal

  - ♦ Enhanced coagulation – Changing the coagulant, the dose, or the pH can increase removal of TOC. Increased costs are associated with coagulants, and corrosion inhibition, and solids handling.
  - ♦ Granular Activated Carbon (GAC) filter media – While easy to retrofit into existing filters its effectiveness for removing TOC is limited. It is most often used for reducing tastes and odors.

- GAC post-filter adsorbers – A costly technology, removal of TOC is initially high but rapidly decreases. Once the capacity to remove TOC is exhausted, it must be regenerated, a process that is energy intensive, costly, and that has air quality implications.
- Other
  - Ion exchange
  - Iron oxide coated media – While promising in lab studies, it has not yet been implemented at full-scale
  - Nanofiltration (TOC and limited bromide or bromate) – See below.
  - Reverse osmosis (TOC and bromide) – See below.

- Alternate Disinfection

  - Chlorine dioxide – While limited by production of chlorite (a potentially harmful chemical byproduct), it is a strong disinfectant that does not react with bromide. Inactivation of *Cryptosporidium* is possible, though the requirement for concentration and contact time (CT) values is so high (>200 mg/l-min) that it is not feasible given chlorite constraints.
  - Ozone -- With bromate the most significant by-product formed, ozone is the strongest disinfectant used in water treatment. Recent studies have developed CT values for 1-log inactivation of *Cryptosporidium* of about 7 mg/l-min (at 10 degrees C). Ozone also can remove taste and odor causing compounds. The bromate control strategy for a given inactivation requirement is two-fold: a) source water controls of bromide and TOC; and b) treatment optimization. Ozone treatment can be optimized to reduce bromate formation by:
    - Reducing the natural organic matter (or TOC) prior to ozonation (i.e. applying ozone to the settled or filtered water – a feature of the North Bay Regional, Martinez, Randall-Bold, and Bollman treatment plants, among others)
    - Decreasing the pH prior to ozonation (i.e. through addition of acid or additional coagulant for non-raw water ozone applications)
    - Other refinements (e.g. tapering the ozone dose, adding ammonia, adding peroxide, adding ferrous salts, etc.) may be used. GAC produces inconsistent results in bromate reduction.
  - UV – Based on recent research on *Cryptosporidium* inactivation, UV has re-emerged as a candidate for primary disinfection. Costs appear to be lower than for ozone. While it is a highly promising technology, it is not yet mature. The effectiveness of UV for destroying virus has not been adequately established, nor does UV treatment protect against organism regrowth in drinking water distribution systems. There are, therefore, substantive questions concerning the need to employ another disinfection technology in conjunction with UV to adequately disinfect the water. Irradiation intensity – contact time (IT) tables have not yet been developed, measurement of dose continues to be problematic, reactor design for larger-scale applications has not been addressed, and the magnitude of safety factors that will be applied in developing IT tables and engineering design (and which will influence cost) have not yet been determined. Despite these questions, industry and regulatory interest in this promising technology is propelling its rapid development.

Membrane Processes. Instead of the ozone optimization approaches, membranes of various configuration could be used in-lieu, or in conjunction with the existing treatment processes. The primary membrane filtration technologies, in order of increasing filtration capability (decreasing pore size) are:

- Microfiltration (MF)
- Ultrafiltration (UF)
- Nanofiltration (NF)

- Reverse Osmosis (RO)

In general, the cost of membrane filtration increases as filtration capability increases (and pore size decreases). Table 1 indicates the treatment processes that could be used to effectively remove and/or inactivate the constituents.

Table 1
Constituents and Treatment Processes

Constituent	***Treatment Process Effectively Removes/Inactivates Constituent?***				
	Ozone	***MF***	***UF***	***NF***	***RO***
Giardia	Some	Yes	Yes	Yes	Yes
Cryptosporidium - Inactivation - Removal	 Some No	 No Yes	 No Yes	 No Yes	 No Yes
Virus	Some	Some	Some	Some	Some
Trihalomethanes	Some	No	No	Yes	Yes
Haloacids	Some	No	No	Yes	Yes
Bromate	Increases	No	No	Depends	Yes
TOC	Yes	No	No	Yes	Yes
Total Dissolved Solids	No	No	No	No	Yes

For purposes of comparison, UV treatment technology appears to offer the possibility of adequate destruction of Giardia and Crytposporidium, some inactivation of virus, effective prevention of trihalomethane, haloacid, and bromate formation, potential reduction of TOC and no effect on TDS.

Based on the constituents of concern, and the ability of the different membrane treatment processes to reduce and/or remove these constituents, reverse osmosis is the most reliable process to meet all of the current and potential future water quality standards for Delta water.

- Microfiltration - The microfiltration process could be used in-lieu of the existing treatment processes at the water treatment plant. This treatment process would result in a minimum of 3-logs (99.9%) of *Giardia/Cryptosporidium* removal credit. However, it would not reduce the bromide levels, TOC or the total dissolved solids (TDS). 2-log (99%) virus reduction could be accomplished via a short free chlorine contact time (before ammonia addition for conversion to chloramine). Chemical cleaning will be required to reduce fouling of the membranes.

- Ultrafiltration - As with microfiltration, the ultrafiltration process could be used in-lieu of an existing plant. This treatment process would also result in a minimum of 3-logs of *Giardia/Cryptosporidium* removal credit and 1.5 logs of virus reduction (this is a conservative assumption -- demonstration is required and could be greater). However, it would not reduce the bromide, TOC or TDS levels. Disinfection for virus would be accomplished via a short free chlorine contact time followed by ammonia addition to minimize DBP formation. The cost of ultrafiltration equipment is very similar to that for microfiltration for clean or filtered water.

However, due to potential fouling of the filters with unfiltered Delta water, the flux rate through the ultrafiltration equipment is 1/3rd that for microfiltration. This results in higher capital costs. An alternative is to add powdered activated carbon (PAC) to increase flux. However, this will increase operating costs and its long-term impact on membranes has not yet been determined. The power, chemical, and membrane replacement operating costs are higher than for microfiltration. The Alameda County Water District is evaluating ultrafiltration preceded by coagulation and clarification (for removal of turbidity and TOC).

- Nanofiltration - Nanofiltration is a specialized version of the reverse osmosis membrane process designed basically for softening, or removal of large organic molecules such as those associated with color found in drinking water. Nanofiltration will be higher in cost than both microfiltration and ultrafiltration. It can achieve some bromate reduction (in a post-ozone application), but may not be sufficient to meet anticipated water quality goals. Nanofiltration may or may not achieve the desired bromate reduction even if the entire flow is treated by the nanofiltration system, if the influent bromate is high. This alternative may not provide any significant benefits over the other technologies, and has a significantly higher cost. Nanofiltration would be more cost effective for a less stringent bromate standard.

- Reverse Osmosis - Standard reverse osmosis could be installed downstream of ozone and filtration. It will remove bromate, and at the anticipated rejection rate of 98 percent for bromate, the treated water can be blended with a portion of the untreated water to reduce overall costs. With an admittedly conservative membrane influent of 15 μg/l of bromate, the blended concentration would be approximately 5 μg/l. For a given design flow, approximately ⅓rd the flow would be bypassed around the RO units and the remainder would be product water to blend with the bypass stream. However, the RO process will develop a waste stream of up to 12 percent of the total plant flow.

The membrane treatment technologies discussed here can present problems with disposal of the materials rejected by the filters. Generally, these problems will increase as filtration capability increases (pore size decreases). As reverse osmosis is the most rigorous of the filtration methods being considered, disposal problems for this technology will be greater, overall, than for the other technologies. The following discussion of the waste management problems associated with reverse osmosis may, to some lesser degree, be experienced with the other technologies.

The reverse osmosis waste stream is not recoverable due to the high TDS level, and will require special disposal. It is uncertain whether the sanitary agencies will accept these flows. One alternative could be river discharge. However, this could be costly and difficult to obtain the necessary permits. Due to the waste stream, a larger source water supply is required to produce the same treated water flow. Depending on the blend required to reach the bromate goal, the source water supply might need to be increased by as much as 20 percent. The cost for reverse osmosis would be highest in terms of capital and operations costs.

Key Issues and Controversies

The following are key issues and controversies associated with treatment technologies:

- *Cryptosporidium* inactivation – Will there be any requirements for plants treating Delta water?
- Bromate – Will the standard decrease, increase or stay the same?
- Regulatory approvals – How quickly will outstanding issues be resolved for UV?

- Characterization of mixtures rather than individual contaminants – Since each technology creates its own particular mixture of DBPs and microbes, will that become a basis for selection the most appropriate alternative?

In an attempt to organize the issues, a risk tradeoff analysis framework is presented in Table 2.

Table 2
Risk Trade-Off Analysis

Target Risk	*Target Population*	*Technology*	*Countervailing Risk*	*Affected Population*
Cryptosporidium	Immunocompromised, infants, elderly persons	Ozone	Bromate	General?
		UV	Unknown	Unknown
		Membranes	Br-DBP	Pregnant women
Brominated DBP	Pregnant women	Ozone	Bromate	General?
		Chlorine dioxide	Chlorite	Reproductive?
			Cryptosporidium	Immunocompromised
Taste & Odor	General population	Ozone	Bromate	General?
		GAC	Brominated DBP	Pregnant women

Each technology introduces a countervailing risk. The challenge is weigh the countervailing risks against the target risks along with the cost component.

Ongoing and Near-Term Activities

The CALFED Water Quality Program Plan contains a number of proposed early implementation actions directed at improving the safety of drinking water taken from the Delta. However, none of these proposed actions are specifically directed toward treatment technologies. The Delta Drinking Water Council and its technical support team, the Drinking Water Constituents Work Group, have responsibility for the continuing the evolution and development of the Drinking Water Quality Program. The following actions have been developed and proposed by the Work Group to augment the actions proposed in the Water Quality Program Plan.

Currently, a number of Delta water agencies are operating ozone plants (CCWD, ACWD, Martinez, Fairfield), evaluating membranes (ACWD, Zone 7), and studying other alternatives (SCVWD, MWD). Two studies that may be useful for evaluating alternative technologies in the near-term are described below.

UV Treatment Feasibility Assessment

Objective: Assure development and evaluation of UV treatment technology is accomplished in a timely manner, and that issues affecting the use of UV technology to treat Delta water are addressed in the evaluation process.

Rationale: Ultraviolet irradiation has apparent potential to greatly reduce concerns over the presence of organic carbon and bromide in drinking water sources, as this technology does not allow organic carbon and bromide to react and produce chemical disinfection byproducts. This technology may have great significance for Delta water supplies that have high bromide concentrations, and could affect overall decisions on the future of the Delta. It is very much in the interest of the CALFED program that this technology be rapidly and thoroughly explored for its applicability to treatment of Delta waters.

Elements: CALFED should track the progress of existing research and development efforts to explore and refine UV treatment technology, and support extended efforts where appropriate to the CALFED mission, in the following areas:

- Evaluate the potential of UV to inactivate or destroy virus
- Evaluate UV in combination with other disinfection technologies with regard to adequacy of disinfection and minimization of DBP formation.
- Develop irradiation intensity – contact time (IT) tables
- Develop means of measuring UV treatment dosage
- Evaluate reactor designs for larger-scale applications
- Establish the magnitude of safety factors to be applied to developing IT tables and engineering design

<u>Mixture Studies - Technology Evaluation</u>

Objective: If determined feasible, compare technology alternatives with short-term toxicology tests.

Rationale: A concurrent toxicological evaluation of the various technologies will enable better understanding of the importance of source water quality conditions for each alternative on the entire mixture of constituents that can be anticipated in Delta water after various treatment techniques.

Elements:

- Identify technologies to be evaluated (e.g., ozone, GAC, chlorine dioxide, UV, membranes).
- Develop experimental plan.
- Organize a panel of independent scientific experts in health effects.
- Conduct evaluation, with oversight of the Drinking Water Constituents Work Group and scientific panel.
- Prepare peer reviewed scientific report.

Potential Longer-Term Activities

The Water Quality Program Plan includes an action to be taken in the first seven years of the CALFED program implementation (Stage I action) directed at investigating and optimizing operational controls to reduce brominated and chlorinated disinfection byproducts. The Delta Drinking Water Council and the Drinking Water Constituents Work Group should help to organize the efforts of drinking water purveyors using Delta waters to cooperatively and systematically identify and fully evaluate a comprehensive range of operational capabilities for treating Delta water to minimize DBP formation.

The American Waterworks Association Research Foundation (AWWARF) is presently undertaking research into low level bromate concentrations produced in drinking water treatment processes. CALFED should maintain awareness of the progress of this research and support extension of this research as appropriate to meet the CALFED objective of protecting the health of persons consuming drinking water from the Delta.

Additional Reading

CUWA Expert Panel Report, 1998, *Bay-Delta Water Quality Criteria*
ACWD Membrane Study, 1999, AWWA Membrane Technology Conference Proceedings