Comments on the CALFED WQTG Drinking Water Issues Report
Drinking Water Quality Control Strategy

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via email

Paul Marshall
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CALFED WQTG

Dear Paul:

I have reviewed the drinking water strategy draft report that you emailed yesterday and find that, in general, it provides good coverage of many of the Delta-exported water domestic water supply water quality topic areas. I have made comments directly in the draft in italics. There are several places where there are some significant technical issues that need to be corrected, such as the role of phosphorus in supporting algal growth under a nitrogen-limited situations and the role of algae as a THM precursor. These are areas in which I have worked for many years and have published extensively on them. I have previously brought these issues to the attention of CALFED WQTG management. Evidently that material was not passed on to the group that developed this report.

There are also some problems with wording, where there is need to clarify certain issues. These are noted in italics in the text.

From an overall perspective, I feel that the writeup needs to be focused on the development of a specific strategy for CALFED WQTG. At this time it is largely a collection of problem areas with discussion of some of the issues that need to be addressed. At several places I have questioned whether the recommended approach is appropriate for CALFED to address. In many instances, these are local problems that need to be addressed by the utility impacted. They are not Delta or Delta watershed problems. While there might be some justification for using CALFED funds for helping the utility address the local problems, since it could relieve pressure on the need to control the larger watershed sources of the same constituents, certainly before CALFED funds are used to address these issues, the utility should be funding a substantial part of the investigative/control program as its own responsibility.

Some of the key areas that are recommended for control, such as nutrients, TOC, and TDS in the greater watershed, need additional discussion before a control strategy can be developed. One of the issues that I have raised which is not mentioned but which must be mentioned, is the relative cost of controlling TOC or TDS problems or the impact of nutrients in the watershed as a whole, versus control by additional treatment at the treatment plant. While typically water utilities claim that it is too expensive to remove TOC at the treatment plant through activated carbon, etc., these costs are on the order of 10 to 15 cents per person per day more than is being paid now by the utilities consumers. Is that really too expensive, compared to the cost of treating all of the ag drains within the Delta and the watershed to remove TOC?

Similarly, with respect to nutrient problems and the associated tastes and odors, shortened filter runs, and THM precursors under certain conditions, the costs of controlling nutrients in the watershed will certainly be far greater than the cost of controlling the algal tastes and odors at the treatment works.

It is my reading of the situation that the water exporters will not gain much sympathy or support for increased monitoring or control programs within the greater Sacramento and San Joaquin River watersheds for the control of constituents that do not impact the people within these watersheds. I am sure that there is going to be a general attitude that if the exporters want the water, they are going to have to take the nutrients, TOC, and TDS with it. The control of these problems will be done at the expense of the exporters. The exporters should not delude themselves into thinking that the control programs for these constituents will be implementable at the cost of the stakeholders within the watersheds.

While there is an attempt in this writeup to claim that City of Sacramento water plants are having water quality problems similar to those that are being experienced by the water exporters, such claims are not in accord with the conclusions reached by the Sacramento River Watershed Toxics Subcommittee, which has recently concluded that nutrients/algae are not a problem for the City of Sacramento. This conclusion was reached based on information provided by City of Sacramento representatives. This kind of discrepancy between what is said in this draft report and what has been found in the Sacramento River watershed program needs to be reconciled.

With respect to the use of CALFED funds for these control programs, again there will likely be some opposition by the watershed stakeholders, unless the needs for CALFED funds of the watershed stakeholders are fully met. Again, there is going to be a significant problem between the exporters and the watershed stakeholders, where the stakeholders will look on the export of the water as a major cause of some of their resource problems within the watershed and Delta that need to be addressed.

Overall, the report, when corrected for technical errors and clarity of presentation, is a good starting point for developing a CALFED WQTG strategy for managing exported water domestic water supply water quality. It still needs substantial work, however, to formulate a credible strategy that should serve as a basis for CALFED support. If there are questions on these comments, please contact me.

G. Fred Lee

G. Fred Lee Revised DRAFT 7/24/98 prepared 7/25/98 (changes are shown in italics)

CALFED WATER QUALITY PROGRAM

WATER QUALITY ISSUES AND CORE PROGRAM ACTION ITEMS FOR PROVISION OF DRINKING WATER

SUMMARY

Drinking water is a product derived from raw water sources and treated to remove pathogens and other contaminants of health *and aesthetic* concern, comply with regulatory standards and meet consumer demands. Several raw water constituents are problematical for the production of drinking water from Delta sources. These include bromide, natural organic matter (NOM), microbial pathogens, nutrients, total dissolved solids, salinity and turbidity. Except for pathogens, their impacts are largely a result of the water treatment process used by a given utility. *This statement is not true. Algal taste and odors are generally not the result of treatment processes. This section needs to be rewritten to clarify.*

The CALFED water quality core program activities are expected to be undertaken regardless of the choice of storage and conveyance alternative. Because utilities will be expected to meet more stringent regulatory requirements many years before any large-scale improvements in water quality are available from the proposed CALFED storage and conveyance alternatives, core program efforts to improve drinking water quality should plausibly focus on activities that reduce loadings of constituents of concern, improve consistency and enhance treatment flexibility. We determined that water quality problems around the aqueducts, storage reservoirs and intakes were most open to this approach. *I do not understand this statement, it needs to be rewritten.*

Bromide is problematical primarily when it is oxidized to bromate during disinfection with ozone and when it reacts during chlorination to form brominated organic compounds (disinfection byproducts), which will be more-stringently regulated in the next several years. It primarily enters the Delta from seawater intrusion and from agricultural returns to the San Joaquin River. Bromide levels in the Delta are substantially higher than the national average. Meaningful approaches to reducing bromide within the context of the CALFED water quality core program were not found.

NOM (as total organic carbon, TOC) is problematical when oxidized and/or halogenated to form disinfection byproducts, some of which will be stringently regulated in the immediate future. Additionally, the use of ozone may increase the availability of organic carbon as a nutrient *(carbon)* source. It results largely from degradation of peat soils and agricultural material and enters Delta waters from agricultural operations and runoff. *I have seen no reliable information on the actual sources of TOC in the Sacramento River as it enters the Delta. About half of the TOC exported from the Delta is from upstream of the Delta sources.* TOC levels in the Delta are typical of surface waters around the U.S. Some opportunities were found to reroute or treat individual agricultural drains adjacent to intakes. Collaborative management of activities in the watersheds around intakes also appears promising. There is concern that some planned CALFED

mitigation activities to create wetland habitats may have adverse consequences for drinking water quality.

Nutrients (nitrate, ammonia, phosphate) are problematical primarily by supporting algal growth. Algae, in turn, pose treatment difficulties for their removal and from production of unpleasant flavors and odors. Nutrients come from fertilizers, animal husbandry and urban runoff. Effects are largely seen in storage reservoirs and in the aqueducts themselves. Several watershed management approaches to control agricultural runoff and drainage appear promising. *(See write up on Nutrients issues (see attached) developed by GFL to better define this issue. The Nutrients writeup is still marked "draft", since one of those who had promised to provide references on ecological issues has not done so. The water supply aspects of this writeup are final from the author's perspective)*

Total dissolved solids, salinity and turbidity adversely impact consumer acceptance and treatment plant operations. These results from seawater intrusion, agricultural drainage and surface runoff. Some approaches to local control of agricultural drainage around intakes and storage reservoirs appear promising.

PURPOSE OF THIS DOCUMENT

The CALFED Water Quality Program has several elements, including development of core activities to improve water quality that are independent of the several storage and conveyance alternatives under consideration. This document on possible CALFED drinking water core activities is part of a broader effort to better characterize the water quality problems in the Bay Delta and to propose appropriate and feasible activities to further describe these problems as necessary and minimize their adverse impacts. Its purpose is to identify the issues for the production of drinking water that arise from the qualities of Delta waters as sources, to develop and evaluate activities appropriate to the core program that can minimize these impacts, to identify opportunities for implementation of these activities, and to determine data gaps and necessary data-gathering activities. Therefore, no attempt was made in this document to evaluate the possible impacts of the general, large-scale CALFED storage and conveyance alternatives. Because of the growing consideration that CALFED alternatives will be decided upon in a phased approach over several years and because drinking water regulations that pose problems for treatment will be implemented prior to these decisions or any resulting water quality improvements, this document emphasizes activities likely to result in mitigation of adverse impacts in the next several years. In addition, some ideas for research, demonstration, pilot and longer-term projects were discussed and developed. A general approach to reduce loadings of constituents of concern was used, rather than reliance on source replacement with higher quality waters or relocation of intakes to higher quality waters. However, these were discussed and developed as appropriate. Activities for monitoring and assessment were developed for inclusion in the CALFED CMARP.

PROBLEM STATEMENT

What problems need to be solved?

Bay Delta waters are used to produce drinking water for a substantial number of people in California. Utilities divert water at several points within the Delta with distinct water qualities. These waters are subsequently treated by a variety of means to control pathogens and other contaminants of concern and to meet Federal and State regulatory requirements. Depending on the specific water quality at the intakes, existing treatment plant configurations, attendant operational constraints, and regulatory requirements, utilities may have difficulty in simultaneously providing adequately safe drinking water, providing water that meets customer requirements for taste and odor, and staying in regulatory compliance. Therefore, there are three inter-related concerns arising from source water quality: 1) The treated water may not be adequately safe to consumers. 2) The treated water may not meet regulatory criteria. 3) The treated water may not be aesthetically acceptable to the consumers. While drinking water regulations are designed to adequately protect public health, they are constantly evolving as new information becomes available. In some cases, utilities would like to provide additional protection in advance of or beyond regulatory requirements. In addition, aesthetic acceptance of drinking water by the public is not a primary goal of these regulations and must be dealt with on a site-specific, community basis. Because treated water quality is a product of source water quality and treatment, the end result is that as the regulatory and consumer requirements become more stringent, the possible combinations of source water qualities and treatment options become restricted.

On a site-specific basis, utilities will have baseline limits on the type and degree of treatment approaches available to meet these requirements within plausible costs to consumers. Some of these limits result from law, some by location or size of the facility, some by costs. Therefore, to the extent possible, given competing and potentially conflicting non-drinking water needs, the highest quality and most consistent source waters are desirable. These will maximize drinking water utilities' flexibility. The overall problem to be solved is to provide source waters at the various reference points of concern of sufficient quality to allow treatment to comply with drinking water regulations and to meet consumer requirements. At a minimum, the CALFED water quality program core components should result in substantial and meaningful improvements to water quality factors that pose treatment problems to utilities. The following discussions describe the contaminants considered to be of primary concern and how they cause problems for water treatment.

One of the issues that must be addressed by the Drinking Water Group is the relative overall cost to control constituents at their source versus control at the treatment plant. It will likely be far cheaper to treat at the plant than control at the source. This issue becomes especially important if the costs of control are borne by the people in the Sacramento and San Joaquin River watersheds and the benefits are primarily to those who export water to the south and west. Unless the exporters are willing to pay for the cost of the source control programs in the watersheds of the Delta and within the Delta, there will likely be little sympathy and support from the "watershed" stakeholders to cooperate in source control programs. If the exporters have to pay the cost of source control, they may find that it is cheaper to practice advanced treatment at the treatment works.

**Contamination impacts on human health,
regulatory compliance and consumer acceptance**

The constituents in Delta waters identified as of most concern with respect to production of drinking water include microbial pathogens, bromide, natural organic matter, dissolved solids, salinity, turbidity and nutrients. Some other contaminants of Delta waters, including pesticides, metals and methyl tertiary butyl ether (MTBE) were evaluated and considered to be relative unimportant at this time. Information is generally available *(for what purpose)* for natural organic matter (measured as total organic carbon (TOC), bromide (directly, or calculated from chloride), microbial pathogens (specifically Giardia, Cryptosporidium, coliform bacteria and viruses), total dissolved solids (TDS) (directly, or calculated from salinity or electrical conductivity (EC)), nutrients (specifically, nitrate, nitrite, ammonia and phosphate) and turbidity. (Needs to be rewritten)

Microbial pathogens are of direct health concern. The other major constituents of concern have no direct health effects at the concentrations found in Delta surface waters, but affect consumer acceptance and treatability of the water to meet requirements for pathogens and disinfection byproducts. *(This does not apply to algal taste and odors)* Under the 1989 Surface Water Treatment Rule, surface water must be treated by filtration and/or disinfection to minimize disease risks from microbes. In addition, turbidity, which can compromise disinfection, must be removed. SWTR turbidity requirements for the finished water serve to indicate treatment effectiveness. Emphasis in this rule was on reducing risks from Giardia, Legionella and viruses. The focus on Giardia was as an indicator organism to ensure adequate filtration and disinfection treatment. Subsequent concerns have arisen for Cryptosporidium, an organism more difficult to disinfect than Giardia. Because of this, additional requirements for systems serving more than 10,000 customers have been proposed by US EPA as the Interim Enhanced Surface Water Treatment Rule (IESWTR), expected to be promulgated in November 1998 and enforced beginning 2001-2003. These will, among other things, establish more stringent filtration and turbidity requirements. As discussed below, these requirements will limit to varying degrees the flexibility of utilities to select among treatment approaches. Additional regulations for control of filter backwash and for filtration of smaller systems serving 10,000 or fewer customers (Longer-term 1 ESWTR) will be promulgated and enforced beginning 2004. US EPA is obligated to consider additional pathogen control requirements (Longer-term 2 ESWTR) based on the results of the ongoing Information Collection Rule, which would tentatively be enforceable beginning 2005-2007. ICR data include information on levels of Giardia, Cryptosporidium, bacteria and viruses in source waters, other water quality factors, and water treatment effectiveness. The nature of these regulations is unknowable at this time, but could include disinfection requirements for Cryptosporidium, if such technologies are cost-effective.

An unfortunate side effect of oxidative disinfection is formation of unwanted chemical byproducts, some of which have adverse health impacts. Additionally, some have objectionable taste and odor characteristics that affect consumer acceptance. Different oxidants and different water qualities yield different types and concentrations of byproducts. A current maximum contaminant level (MCL) exists for total trihalomethanes (TTHMs, including chloroform, bromodichloromethane, chlorodibromomethane and bromoform) at 100 ug/L. US EPA has proposed a Stage 1 Disinfectants and Disinfection Byproducts Rule (D/DBPR) that will lower this MCL to 80 μg/L and additionally establish MCLs for haloacetic acids (HAAs) at 60 μg/L and for bromate at 10 μg/L.

An action level will be established for TOC that will trigger treatment requirements for enhanced coagulation and/or other approaches to minimize byproduct precursors. Limits on chlorine, chloramine and chlorine dioxide residuals in the distribution systems will also be established. These are expected to be promulgated November 1998 and enforced beginning 2001-2003. As discussed below, these requirements will limit to varying degrees the flexibility of utilities to select treatment approaches given current Delta water qualities. US EPA is obligated to consider additional controls of disinfectants and byproducts as a Stage 2 D/DBPR that would be promulgated in 2002 and enforced beginning 2005-2007. This regulation will be considered together with the LT2 ESWTR in open public discussion during 1999-2000 using ICR data, recent health effects studies and other current information. In this respect, ICR data on water treatment effectiveness and production of byproducts will be significant. While the nature of these regulations is unknowable at this time, placeholder MCL values have been brought forward for TTHMs at 40 μg/L and HAAs at 30 Ug/L. There is some concern that the bromate MCL might be lowered below 10 μg/L. However, the feasibility and cost-effectiveness of possible MCLs will be closely considered. If promulgated, these would likely yield further restrictions on treatment choices and/or source water qualities.

Consumer acceptance of drinking water is of major concern. Consumers want water that is both safe and pleasant to drink. Adverse taste, odor and appearance problems come from both raw water and the effects of treatment. Waters with naturally high TDS or salinity taste salty or are unacceptably hard. *(What is acceptable respect to hardness depends on what available, ie, see the Davis CA situation.)* Turbidity from suspended sediments and other material can yield cloudiness or precipitates in the glass. Waters high in nutrients such as nitrate, ammonia or phosphate may support growth of algae and other organisms. Algal blooms are common in the Delta, *(this statement is not true.)* in the aqueducts and especially in storage reservoirs. The majority of algae are non-toxic; a few species are toxic or produce algal toxins. While algae are expected to be removed by treatment, chlorination of algae frequently results in objectionable odors and flavors in finished water, such as geosmin or methylisoborneol (MIB). Algae also cause operational problems for filtration. California Department of Health Services (CA DHS) has authority to regulate tastes and odors under existing secondary drinking water standards, but for practical purposes, consumer acceptance drives utilities' efforts to minimize aesthetic problems.

Contamination impacts on water treatment

Among the most important objectives of treating drinking water are inactivation and removal from the water such infective agents as bacteria, protozoa and viruses. Source waters taken from the Delta are subjected to treatment which includes removal of dissolved and particulate matter and disinfection. The processes are closely linked because particle removal through filtration and associated practices greatly increases the effectiveness of disinfection, as well as directly removing many microbial contaminants. The process of treating surface waters generally involves mixing coagulant chemicals with the source water, which causes some dissolved organic material and many of the particulates to aggregate and to settle out. The settled water is then filtered, usually through beds of special sand and anthracite mixtures, removing many more microbial contaminants. At one or more points in the process, oxidative disinfectant chemicals are applied for specified contact times. Water that flows from the treatment facility into the pipes that distribute the water to homes and businesses must additionally contain a sufficient disinfectant residual (usually chlorine or chloramine) to prevent growth of harmful bacteria or other organisms in the distribution system, up to the taps of customers. The site-specific choices of treatment approaches and treatment plant configurations are a function of history, the sequential nature of regulations, local land uses and zoning, physical site limitations, politics, economics, water sources and water quality, system management, idiosyncrasies of designers and reviewers, public will and other factors. That is to say, each situation is unique.

Application of these processes to treat waters from the Sacramento-San Joaquin Delta has generally resulted in safe and acceptable drinking water that meets all currently applicable drinking water standards. However, depending on periodic and/or episodic water quality changes resulting from drought, seasonal effects or land use, some utilities have had difficulty meeting current standards or consumer water quality demands at certain times.

Physical removal processes, including coagulation, flocculation, sedimentation and filtration. As noted above, compliance with current and pending requirements for removal of microbial pathogens may be adversely affected by water quality. The major factors affecting physical removal processes for Delta waters in warm months are the presence and types of algae and water temperature. The presence of nutrients, higher light levels and warmer waters enhance algal growth, often explosively. Algae may cause physical clogging of filters and air binding, decreasing filter runs, increasing filter backwashing and decreasing overall plant *finished water production rate*. The presence of algae in the raw water supply can cause large pH swings that can adversely affect coagulation, flocculation and sedimentation. Warm and diel varying water temperatures can cause temperature inversions in upflow clarifiers that can cause large daily swings in settled water turbidities.

During the winter months, high turbidities from storm-related events may necessitate reducing filtration rates to prevent filter breakthrough. Fluctuations in source water turbidity and in the specific components of turbidity over time require close attention to coagulant doses and proper filter operation. In addition, colder water temperatures reduce coagulation effectiveness and the ability to achieve a filterable floc is made more difficult.

TOC in and of itself does not affect the physical removal process, but levels affect the degree of coagulation, flocculation and sedimentation required. For example, increases in TOC increase the coagulant demand of the water, thus requiring more coagulant in order to effectively remove the turbidity. If TOC exceeds specific regulatory action levels, enhanced coagulation or other requirements may apply.

Disinfection. Disinfection is required for all drinking water from surface sources. Levels of microbial pathogens in Delta waters do not specifically influence the degree of disinfection, since current regulations are based on uniform treatment requirements. However, future regulations may require treatment to be proportional to pathogen levels in source waters. As noted below, Delta levels for pathogens appear to be lower than national averages. Primary disinfection by utilities using Delta sources is usually accomplished with chlorine in the form of gas or hypochlorite. Some utilities use ozone or a combination of disinfectants.

Chlorine has been used as a primary disinfectant for drinking water for decades. It is effective for bacteria, viruses and Giardia at reasonably feasible concentrations and contact times. It is well-understood, relatively simple and inexpensive. Because of this, US EPA continues to support its use. However, it does not appear to be adequately effective for disinfection of Cryptosporidium. If future regulations were to require disinfection of Cryptosporidium, alternative disinfectants will have to be available and of similar utility.

Ozone is a strong oxidant that is effective for inactivation of most pathogenic microorganisms, including Cryptosporidium. While the November 1997 Notice of Data Availability for the proposed IESWTR indicates that US EPA would allow a 2-log physical removal credit for Cryptosporidium to water systems that optimize their filtration and related treatment processes, additional measures to protect against Cryptosporidium may be desirable. Even optimized filtration is not completely effective to remove all Cryptosporidium from drinking water, and chlorinated disinfectants are relatively ineffective to kill or inactivate it. For this and other reasons, some California water systems are considering converting to ozone for their primary disinfection, as one centralized treatment method now available that appears to be adequately effective against Cryptosporidium. Ozone also is effective in controlling adverse tastes and odors that are frequently associated with algae in source waters. Several utilities have explored or installed ozone treatment specifically to combat algal taste and odor problems.

Several constituents of Delta water complicate attainment of strong disinfection. Turbidity and natural organic matter, occurring primarily from stormwater runoff and agricultural activities, provide a disinfectant demand that can require higher applied disinfectant doses and/or longer contact times. These materials can also sequester pathogens and protect them from disinfection. Bromide is present in Delta water supplies because of seawater intrusion into the Delta and from agricultural return flows into the San Joaquin River. TOC, primarily from peat soils of Delta islands and from agriculture, results from natural decomposition of plant materials. Together, bromide and TOC react with disinfectant chemicals to produce a broad range of chemical disinfection byproducts. In addition, nutrients affect disinfection treatment indirectly by supporting growth of algae and other organisms. These have different effects depending on the disinfectant employed.

As noted above, chlorine reacts with TOC to produce halogenated organic compounds of public health and regulatory interest. Additionally, the presence of bromide in source waters shifts the proportion of bromine-containing byproducts to higher levels. Because of the higher molecular weight of brominated versus chlorinated byproducts, it becomes more difficult for utilities to meet MCLs which are based on weight/volume. Moreover, recent health effects studies suggest that the brominated byproducts may be more problematical than chloroform. Chlorination of natural organic material, particularly algae, can produce disagreeable tastes and odors that are difficult to remove. These can occur as a result of primary disinfection or from reactions in the distribution system.

Ozone does not produce halogenated byproducts such as chloroform and the other chloro-bromo-THMs. Therefore, ozone use should enable utilities to more easily meet lower TTHM standards. However, ozonation is more complex and expensive than chlorination. Ozonation of natural organic matter generates higher levels of assimilable organic carbon that can support bacterial regrowth. In addition, it does not produce a persistent disinfection residual, so other disinfectants, generally chloramines, must be used to protect distribution systems from bacterial regrowth and to minimize TTHM formation in the distribution system. Perhaps more importantly, ozone produces chemical byproducts of its own. In the presence of bromide, ozone produces bromate. As noted above, bromate will be regulated at 10 µg/L under the Stage 1 D/DBPR because it appears to have a significant cancer causing potential of its own. Apart from bromate, ozone has the capacity to produce a number of other oxidized organic byproducts, many of which are of unknown toxicity. The presence in the source water of bromide additionally enhances the number of chemical byproducts that could be produced by use of ozone. For these reasons, the research for the Stage 2 D/DBP/microbial rules is exploring the potential for other treatments which are equally effective against Cryptosporidium, but may not produce potentially harmful byproducts.

Treatment control of disinfection byproducts. Some utilities employ treatment trains that include pre-chlorination treatment for TOC removal and/or post-chlorination treatment to remove disinfection byproducts. Treatment processes are available that can adequately remove the majority of organic precursors and disinfection byproducts. These include use of granular activated carbon (GAC), nanofiltration or reverse osmosis. However, GAC and nanofiltration are not effective for bromide and bromate removal. Such processes are relatively expensive. In addition, these technologies may not be technically feasible as a modification to an existing treatment plant and may create other environmentally undesirable impacts. *(Such as?)*

Taken together, the presence in Delta exports of bromide and TOC required most purveyors of drinking water from the Delta to modify their treatment practices to meet existing SWTR and TTHM requirements. Some drinking water utilities now using Delta water report general success in compliance with the anticipated provisions of the proposed Stage 1 D/DBPR; others will have to undertake substantial treatment modifications to meet these requirements.

Other operational issues. Some TDS (salinity) is a critical drinking water quality issue for a number of reasons. TDS is regulated by DHS as an aesthetic standard, but increases in TDS can have significant economic costs due to more rapid corrosion of infrastructure and appliances. Elevated TDS can severely affect wastewater reclamation programs, groundwater conjunctive use programs, and blending projects.

What is the nature of the occurrence of contaminants affecting drinking water?

Sources of these contaminants to Delta waters are both point and non-point sources and occur throughout the Delta, the aqueduct and associated reservoirs. Pathogens largely come from sewage treatment plants, urban stormwater runoff, animal feeding operations and recreational users on the Delta and in storage reservoirs. Sources of TOC include natural organic matter runoff from peat soils, from agricultural drains and other agricultural activities, from tidal wetlands, from algae and from wastewater treatment plants and urban stormwater outflows. Bromide results from seawater intrusion, from natural leaching of soils and from agricultural drainage of connate groundwater and leachate. TDS comes from seawater intrusion, natural leaching of soils, agricultural drainage and stormwater runoff. Turbidity results from storm events, all types of runoff and resuspended sediments. Nutrients result largely from agricultural runoff, sewage treatment plants, animal feeding operations and urban stormwater runoff.

Sacramento River. The Sacramento River and its tributaries are the sources of drinking water for residents of Sacramento, West Sacramento, Roseville, and a number of smaller communities. In addition, water is pumped from Barker Slough, a tributary to the Sacramento River, into the North Bay Aqueduct to provide drinking water to communities in the North Bay Area (discussed below). The Sacramento River provides about 76% of the inflow to the Delta. The Sierra tributaries to the Sacramento River provide high quality drinking water sources that have low levels of most drinking water contaminants of concern. As the water flows out of the foothills and into the valley, contaminants from a variety of urban, industrial, and agricultural sources degrade the quality of the Sacramento River.

Sources of organic carbon in the Sacramento River watershed include wastewater discharges, agricultural runoff, and urban stormwater runoff. DOC levels usually double during the wet, rainy season from surface runoff and drainage. Major storms can increase DOC even more during peak runoff periods. We have been unable to quantify the loadings of organic carbon to the river. TOC concentrations in the effluent of the Sacramento Regional Wastewater Treatment Plant were generally between 10 and 20 mg/L and concentrations in the Natomas East Main Drainage Canal were generally between 3 and 9 mg/L. Recent data on Sacramento urban runoff show TOC concentrations of about 10 mg/L. The Department of Water Resources (DWR) Municipal Water Quality Investigations (MWQI) Program has monitored the Delta and its tributaries for parameters of interest to drinking water suppliers. DOC concentrations range from 1.4 to 7.7 mg/L with a median of 2.1 mg/L in the Sacramento River at Greene's Landing, downstream of the urban Sacramento area. Concentrations in the American River range from 1.4 to 4.3 mg/L with a median of 1.9 mg/L at the Fairbairn Water Treatment Plant which is located downstream of a significant portion of the Sacramento urban area.

Bromide is not a problem in the Sacramento River watershed. The concentrations in the Sacramento River at Greene's Landing range from not detected (<1ug/L) to 80 μg/L with a median of 20 μg/L.

Potential sources of TDS in the Sacramento River Basin are agricultural drainage, urban runoff, and municipal and industrial wastewater discharges. Approximately 60 to 70 percent of the load to the Sacramento River at Greene's Landing comes from unidentified sources with about 26 to 33 percent coming from the Colusa Basin Drain and Sacramento Slough.TDS concentrations in the Sacramento River at Greene's Landing range from 39 to 132 mg/L This is considered high quality drinking water. These concentrations are likely to increase as the population of the Sacramento Valley increases.

The Colusa Basin Drain may be an area where nutrients are a problem. A turbidity plume usually extends downstream in the Sacramento River from where the CBD enters. The turbidity is caused by suspended sediments, organic compounds and phytoplankton. High nutrients levels in CBD contribute to the algal growth.(where?)

Turbidity concentrations fluctuate in the Sacramento River with the highest concentrations occurring during and immediately after major storm events. Turbidity levels in the Sacramento River at Greene's Landing range from 4 to 70 NTU.

The DWR MWQI Program is currently conducting a pathogen monitoring program throughout the State Water Project system. The results of that study are not yet available. Metropolitan Water District conducted a study that included the Sacramento River at Greene's Landing in 1992 and 1993. Giardia was detected in 42 percent of the samples at levels up to 82 cysts per 100 L. Cryptosporidium was detected in 50 percent of the samples at levels up to 132 cysts per 100 L.

San Joaquin River. The major tributaries of the San Joaquin River provide drinking water to residents of the East Bay Area, San Francisco, and communities in the San Joaquin Valley. The San Joaquin River proper is not a source of drinking water for any large communities. The San Joaquin provides about 15% of the inflow to the Delta. The Sierra tributaries to the San Joaquin River provide high quality drinking water sources that have low levels of most drinking water contaminants of concern. As the water flows out of the foothills and into the valley, contaminants from a variety of urban, industrial, and agricultural sources degrade the quality of the San Joaquin River.

Sources of organic carbon in the San Joaquin watershed include natural organic matter from soils and vegetation and wastewater, urban, and agricultural discharges. Water that is high in organic carbon is pumped from the Delta at the Tracy Pumping Plant and used to irrigate cropland along the westside of the San Joaquin Valley. Some of this water is then recirculated in the San Joaquin River. Based on fairly limited data, Mud and Salt Sloughs were found to contribute about 30 percent of the organic carbon load to the San Joaquin River. This was prior to construction of the Grasslands Bypass Project so the contribution from this area may have changed. Most of the load to the San Joaquin River was unidentified. DOC concentrations in the San Joaquin River at Vernalis range from 2.2 to 11.4 mg/L with a median concentration of 3.4 mg/L. TOC concentrations in Mud and Salt Sloughs are 5.5 to 31 mg/l. Data on the concentrations of organic carbon in the tributaries to the San Joaquin River are available in a USGS Open-File report (88-479) for March 1985 to March 1987.

The sources of bromide in the San Joaquin River include the drainage from areas of ancient marine deposits in the San Joaquin Valley and the Delta water that is diverted for irrigation and recirculated through the San Joaquin River system. Bromide concentrations in the San Joaquin River at Vernalis range from 40 to 650 µg/L with a median concentration of 370 µg/L.

The sources of TDS in the San Joaquin River are agricultural drainage, urban runoff,(not likely to be important) municipal and industrial wastewater discharges, discharges from dairies and confined animal facilities, and Delta water that is diverted for irrigation and recirculated through the San Joaquin River system. The Regional Board is conducting studies on the loadings of TDS to the San Joaquin River. TDS concentrations in the San Joaquin River range from 143 to 768 mg/L.

Potential sources of pathogens in the San Joaquin watershed include urban runoff, wastewater discharges, dairies, and other confined animal facilities. The DWR MWQI Program is currently monitoring pathogens in the San Joaquin River at Vernalis and downstream of the Stockton wastewater treatment plant discharge. The results of that study are not yet available.

Turbidity concentrations fluctuate in the San Joaquin River with the highest concentrations occurring during and immediately after major storm events. The DWR MWQI Program has measured turbidity in the San Joaquin River at Vernalis ranging from 8 to 68 NTU.

Delta Agricultural Drainage. Approximately 260 agricultural drainage pump stations are dispersed among 60 Delta islands and tracts. The pumps discharge a combination of seepage, surface runoff, and irrigation return water into the adjacent channels. Drain water is high in mineral salts and organic matter. Drainage volumes have not been measured in the Delta, although DWR and USGS estimated drainage volumes from PG&E electrical usage records. The volume and water quality of drain water that is discharged into the channels correlate with the seasonal farming activities and regional soils. There are two periods when drainage volumes are highest. In the late fall and early winter, the fields are flooded to leach out salt accumulations from the soil. This results in short periods of high drainage volume and high TOC concentrations in the drainage, especially from organic soil areas during December and January. High organic carbon levels are associated with the organic content of the drained soils. The highest concentrations are typically found in drains located on peat organic soil areas and the lowest from mineral-type soil areas. In January 1989, for example, the DOC concentration was 119 mg/L in the drainage from Empire Tract. The second peak drainage season occurs during the summer (June, July, August) when irrigation is increased. Organic carbon levels are relatively lower than when the fields are leached in the late fall and early winter. For example, in June through August 1989, the DOC concentrations in agricultural drainage from Empire Tract ranged from 16 to 42 mg/L. Because agricultural drainage TOC has higher humics than river TOC, disinfection byproduct formation potential is greater. These drains represent the greatest individual source of organic carbon loading to the Delta. Living crop biomass is not thought to be a significant contributor of TOC relative to island soils. However, crop residues such as stalks and leaves are a source of humus as this material dies and decays. The decomposing crop residue is relatively small in volume and depth (inches) compared to the underlying peat soil depth (several feet). Therefore carbon from peat decomposition in the underlying soil is the expected major contributor of organic carbon. Based on past drainage volume estimates (1954-55) and more recent water quality monitoring, the increases in organic carbon concentrations in the Delta channel waters are mostly from drainage discharges. Other activities and processes also increase organic carbon but they are relatively smaller than from drainage discharges.

(An issues that is not generally discussed or realized is that about half of the TOC that comes off of Delta islands is from taken from the Delta channels to the islands. Through evapo concentration, the TOC increases in this water. Added to this TOC is leaching of the peat soils. Both are important.)

Wastewater treatment plants. Wastewater treatment plants are sources of pathogens, nutrients, TOC, TDS and other drinking water contaminants. In general, the permitting activities for these plants do not fully address drinking water contaminant loadings. Frequently, increases in loadings are allowed without analysis of impacts. Concerns for existing wastewater treatment plants and for those associated with planned developments such as Mountain House *(what is this - a new development-where?)* need to be addressed. *(Increased use of wetland treatment systems is an additional source of TOC.)*

Recreational boaters. Recreational boating activities in the Delta and storage reservoirs can result in contamination of these water bodies with, among other things, microbial pathogens and nutrients *(not likely significant)* from waste discharges. Thousands of boats and millions of people use these waters, thus the impact, while of unknown magnitude, may be substantial.

Adverse impacts from other CALFED core activities, including mitigation. Among the various activities under consideration for CALFED are mitgations that involve creation of new wetlands for habitat. There is concern that such flooding will release organic carbon from the peat soils covering many of the Delta islands, resulting in drainage water containing elevated concentrations of problematic organic carbon fractions and other disinfection by-product precursors.

Although the concentration of DOC is a strong determinant in predicting the formation of THMs in treated drinking waters, the more important factor is the "quality" of the DOC. By quality, we mean the intrinsic chemical composition of the DOC, and in particular the small fraction of the DOC that are precursors for THMs. Research into the formation of THM from DOC recognized that compounds with different chemical compositions reacted with chlorine at different rates. These rates varied by over 100-fold. Recent studies within the Sacramento-San Joaquin Delta found that the propensity of DOC to form THMs varied from about 2-16. This is independent of concentration. Thus, at any given concentration of DOC, the most reactive DOC would form perhaps eight-times the amount of THM as the least reactive DOC. It is the products of the decomposition of the peat soils rather than the peat soils themselves that compose the DOC fractions of concern.

This variation in THM formation is related to a variety of environmental factors, many of which may apparently be managed to reduce DOC reactivity. For example, preliminary data suggest that the most reactive DOC is formed when plant-derived organic matter is degraded without oxygen, conditions that would be common in marshes and flooded islands. Management alternatives may include the reduction of wetlands and flooded areas, or placement of drinking water intakes to avoid waters of this type. Another example, based on preliminary data, is that different plants release DOC of different reactivity when they are degraded. Agricultural activities or ecosystems could be managed to favor those plant communities that result in the release of more benign DOC.

CALFED plans call for extensive restoration of wetlands within the Sacramento-San Joaquin Delta. It is currently thought that significant acreage will be retired from agricultural production and constructed as tidal marsh to provide habitat for waterfowl and fish. There are currently ~500,000 acres in agricultural production within the Delta. These restorations may potentially provide a large source of DOC to Delta waters with a chemical composition much different than agricultural drainage water. Thus, these wetland conversions may ultimately impact the quality of Delta waters as a source for drinking waters.

The USGS and the DWR MWQI Program evaluated the release of DOC and associated trihalomethane formation potentials (THMFP) over one year from three types of wetland habitats in peat soil: continuously, shallow flooded to about 1-ft deep; an open water, spring fed pond about 3-ft deep; and a reverse-flooded treatment that was intentionally flooded from early spring to midsummer. Analyses indicate that (1) the reverse-flooded treatment had the highest DOC (median of 164 mg/L) and THMFP (median of 19,000 µg/L), (2) the open-water treatment had the lowest DOC (median of 8.4 mg/L) and THMFP (median of 1,384 µg/L), and (3) the continuously-flooded treatment had intermediate DOC (median of 67 mg/L) and THMFP (7,430 µg/L). Although loads from these wetland treatments were not determined, the concentrations of DOC and THM precursors released are of significant concern.

Although definitive studies are lacking for the Delta, some simple estimates may be made using existing data. First, the production of organic carbon by wetlands is quite high, between 1.5 and >3 times that of corresponding agricultural lands on an areal basis. It is reasonable to expect that DOC release is proportional to organic carbon production, so the total amount of DOC released will potentially increase by an amount corresponding to increased production.

Also, preliminary data suggest that the quality of DOC released by wetlands forms more THM than that released in agricultural operations. Comparison of DOC in waters draining a corn field on Twitchell Island to nearby flooded experimental ponds reveals that the DOC released into pond waters forms up to 60% more THM than DOC in the agricultural waters.

These restorations will also have an impact on the physical mixing of Delta water with San Francisco Bay water, and in combination with enhanced water removal from the Sacramento River by the chosen storage and conveyance alternative, could possibly increase the amount of bromide intrusion into Delta waters.

Increased mixing with Bay waters is a potential result of opening a greater amount of the Delta to tidal exchange, but depends on the location of the new tidal marshes and modifications to Delta channels. Mixing during tidal exchange is the dominant means by which seawater is transported into the Delta. Opening large areas of wetlands to tidal mixing may increase the volume of water exchanged during each tidal cycle, and thus may increase the landward extent of seawater bromide transport. It is not clear, however, that any increase in seawater intrusion will result from increasing the area of wetlands within the Delta. Any change in tidal mixing strongly depends on the location of the new wetlands and physical changes to Delta channels. Some analyses suggest that tidal mixing may be lowered under certain developmental and operational scenarios, while others suggest the opposite.

(Another issues that needs to be watched is the use of marine dredged sediments for Delta levee and shallow water habitat development. These sediment are high in TDS and bromide which will leach out of the deposited sediments.)

Water quality at specific points of concern

Because treatment is necessary to remove pathogens and to produce adverse disinfection byproducts, the points where water quality is of concern are primarily associated with the intakes and storage reservoirs for the various water treatment facilities, which are not necessarily located within the Delta proper. While most of the TOC, bromide, salinity and TDS in Delta waters are in the original exports, it is also recognized that degradation of water quality can occur during transport through the aqueducts and in the storage reservoirs, as a consequence of influent water quality (e.g., nutrient contribution to algal growth), drainage or runoff into the aqueducts, or from operations at the reservoirs (e.g., pathogen loading from swimming). For the CALFED discussion, the following reference points were chosen for more detailed analysis:

North Bay Aqueduct users (Benicia, Fairfield, Vallejo, Vacaville, Napa, American Canyon): Barker Slough intake

South Bay Aqueduct users (Alameda County Flood Control and Water Conservation District (Zone 7), Alameda County WD, Santa Clara Valley WD): Clifton Court Forebay, Del Valle Reservoir, Bethany Reservoir, South Bay Aqueduct

Contra Costa Canal users (Contra Costa WD, Pittsburg, Martinez, Bay Point): Rock Slough, Mallard Slough and Old River intakes, Los Vasqueros Reservoir

City of Sacramento: Sacramento River intake

EBMUD: American River intake (proposed), Upper San Leandro Reservoir

Tracy WD: Delta Mendota Canal intake

Metropolitan WD of Southern California: southern portion of CA Aqueduct, San Luis Reservoir, Pyramid and Castaic Lakes, Silverwood Lake and Lake Perris

Santa Clara Valley WD: San Luis Reservoir, South Bay Aqueduct

Hollister, Gilroy and two small systems: San Luis Reservoir

Santa Nella County WD and campground: O'Neill Forebay

Westlands WD, Tehachapi Cummings WD and associated systems: CA Aqueduct

CA Aqueduct East Branch users (Antelope Valley/East Kern WA, Palmdale WD, Crestline-Lake Arrowhead WA, San Gabriel Valley MWD)

Castaic Lake WA: CA Aqueduct West Branch

Central Coast WA: CA Aqueduct Coastal Branch

Kern County WA, East Niles Community Services District: CA Aqueduct via Cross Valley Canal

We also noted some planned or future developments that will use Delta waters:

Mountain House- Delta Mendota Canal, San Joaquin River
Gold Rush City- San Joaquin River
City of Stockton- Calaveras River/ Stanislas River

North Bay Aqueduct/Barker Slough Watershed

The Barker slough watershed is located in the larger Sacramento River watershed. The lower reaches of Barker Slough are within the northwest section of the Sacramento-San Joaquin Delta. The area of the watershed is about 14.6 square miles (9,340 acres). It is this watershed that drains directly into Barker Slough, the location of the Barker Slough Pumping Plant (BSPP), which feeds the North Bay Aqueduct. The BSPP draws water from Barker Slough, Lindsey Slough, and Calhoun Cut in different proportions depending upon local hydrology and seasonal runoff. The NBA is a 72-inch diameter pressurized pipeline that supplies water to the cities of Fairfield, Vacaville, Napa, Suisun, Vallejo, Benicia, and Travis Air force Base. Over 400,000 people receive treated NBA water. Land use activities in the Barker Slough watershed include grazing of sheep and cattle, row crop farming, and recreational/preserve uses. Approximately 70 percent of the watershed is used for pasture and 22 percent is devoted to row crops such as alfalfa, corn, and safflower. The remaining 8 percent of the watershed is devoted to recreational activities and the Jepson Prairie Reserve. The upper watershed also receives drainage from a new housing development and a golf course.

The NBA water periodically contains very high concentrations of organic carbon, bromide, coliform bacteria, metals, and turbidity and low levels of alkalinity and pH. The State Water Contractors conducted the first sanitary survey of the SWP watershed in 1990 and updated the sanitary survey in 1996. The initial survey identified the NBA as having the poorest water quality in the entire SWP system. The follow-up survey included a more focused evaluation of the Barker Slough watershed and recommended that a study be conducted to evaluate the source of water quality contaminants in the NBA system.

A water quality monitoring program, conducted by DWR's MWQI Program has shown that runoff from the local Barker Slough watershed greatly degrades the quality of raw water at the BSPP. Organic carbon concentrations average 8 mg/L and reach 25 mg/L during storm events. The average turbidity of 54 NTU exceeds the CALFED goal of 50 NTU and storm season turbidities (200-800 NTU) greatly exceed the goal.

North Bay Aqueduct at Barker Slough Pumping Plant:

	88/89 (dry year)			96/97 (wet year)		
Parameter	min	max	median	min	max	median
Dissolved Organic Carbon (mg/L)	N/A	N/A	N/A	3.4	13.1	5.5
Bromide (mg/L)	N/A	N/A	N/A	0.01	0.08	0.05
Chloride (mg/L)	15	77	24	12	16	14
Total Coliform Bacteria (MPN)	N/A	N/A	N/A	6.4	5,600	113.7
Total dissolved solids (mg/L)	362	189		142	180	154
Electrical conductivity (S/cm)	236	626	316	122	521	345
Turbidity (NTU)	12	39	23	19	218	49

The results of the historical BSPP data study and the MWQI Phase I study show distinct seasonal (wet and dry) differences in water quality at all of the sampling sites. Most of the concentrations of contaminants increased during wet seasons and decreased during dry seasons, though organic carbon levels remain high throughout the year compared to other waters of the Delta.

Phase I results show that land uses in the Barker Slough watershed influence the water quality at the BSPP, primarily during the wet season. Storms producing 1 inch of rainfall over a 24-hour period after initial soil saturation have the ability to raise most concentrations of contaminants at the BSPP. High runoff events also show dramatic fluctuations and increases in turbidity and a reduction in alkalinity, which creates treatment plant problems in terms of flocculation and sedimentation. The fluctuations and increases in dissolved organic carbon and coliforms cause treatment plant problems in terms of disinfection and in meeting the drinking water standards for disinfection by-products.

During the dry season, water quality is more consistent, but still poor in terms of organic carbon. The pumping plant is located in the heavily vegetated Lower Barker Slough and near Calhoun Cut. Cattle are often seen grazing in the Slough itself. Organic carbon sources may include the extensive riparian plant vegetation and filamentous algae growth. Additional studies of nutrient loading and algae production will be made as part of a companion algae study.

In summary, the water quality of the NBA is greatly affected by the land uses immediately located upstream in the Barker Slough Watershed. Seasonal runoff creates increases and fluctuations of organic carbon, turbidity, and coliform bacteria. Episodic runoff also decreases alkalinity, creating additional problems at the treatment plant. Dry season organic carbon levels are still much higher than other Delta diversion sites, and this may be attributable to vegetation and algae within the immediate hydrological area.

South Bay Aqueduct/ Clifton Court Forebay Data

The South Bay Aqueduct (SBA) provides Delta water to three State Water Project (SWP) contractors. These are the Alameda County Water District, Santa Clara Valley Water District and Zone 7 of Alameda County Flood Control and Water Conservation District. Together, these three agencies provide drinking water to 1.8 million people in Alameda and Santa Clara Counties.

A sanitary survey for the SWP was completed in October 1990. An update was completed in May 1996. These documents examined potential sources of contamination from watersheds affecting the various components of the SWP. In addition, the 1996 update characterized the major areas of concern by the 29 SWP contractors regarding water treatment problems. Water quality and treatment concerns of the three SBA contractors related to regulatory compliance (current and future), treatability and consumer acceptance issues. These concerns vary both seasonally and between drought periods and wet periods.

During periods of high runoff into the Delta and also into Lake Del Valle (a 40,000 acre-foot operational reservoir tied into the SBA), high turbidity is a treatability concern. Coagulant dosages must be adjusted and filter rates lowered so as to prevent filter breakthrough and maintain optimum filtered water quality. In the multiple-barrier approach to water protection, filtration is a key barrier.

In dry periods, both during seasonal variations and during extended drought periods (e.g., 1987-1992), the major concerns relate to total dissolved solids (TDS), chlorides, bromides, total organic carbon (TOC), and algae (from nutrient loadings). In addition, even though their levels are consistently below the current MCLs, there is concern about levels of pesticides and herbicides in the Delta supply that come from agricultural drainage.

High TDS/chlorides and algae cause problems primarily from a consumer acceptance standpoint (taste and odor). In addition, source water with significant concentration of certain kinds of algae can cause major treatment problems through large diurnal pH swings (e.g., between 6.5 and 9.0 in a 24-hour period), causing major coagulant control problems and clogging and air-binding of filters.

High levels of bromides and TOC can cause problems meeting current (e.g., total trihalomethanes) regulations, and will be especially problematic to SBA contractors trying to meet future disinfectants/ disinfection byproducts regulations.

Data from Banks pumping station, 1990-1995

Parameter	Minimum	Maximum	Median
Total Organic Carbon (mg/L)	2.5	9.6	4.0
Nitrate (mg/L) N or NO3-	0.2	13	2.6
Bromide (mg/L)	0.04	0.53	0.22
Chloride (mg/L)	14	175	84
Electrical Conductivity (umhos/cm)	162	840	515
TDS (mg/L)	94	466	286

(The same units for specific conductance be used through this report)

Rock Slough Intake Data (Contra Costa WD)

The Rock Slough Intake is located in the west-central Delta in the vicinity of Knightsen in eastern Contra Costa County. The land surrounding Rock Slough is used primarily for agriculture. Residences are scattered in the vicinity of the intake but are ancillary to agricultural operations.

Water levels in Rock Slough are subject to tidal variations, with a typical variation of about 3.5 feet. Rock Slough salinity is high when there is seawater intrusion from San Pablo Bay during periods of low Delta outflow, or when agricultural drainage discharges for the Delta and upstream San Joaquin River are high (in both volume and salinity, typically during leaching in wet periods when Delta outflow is high.). Drainage from Veal Tract has historically increased the salinity at the intake during wet winters by up to 130 mg/L chloride. Seawater intrusion typically occurs during the summer months in dry years and fall months in most years. The main impact of agricultural drainage during wet winters is to increase dissolved solids, TOC and possibly pathogens. Listed below are the minimum, maximum and median levels of pertinent water quality parameters at Rock Slough Intake from 1/93 through 4/98.

Parameter	Minimum	Maximum	Median
Bromide (mg/L)	<0.1	0.81	<0.1
TDS (mg/L)	70	489	210
TOC (mg/L)	<0.1	40	4.1
Turbidity (NTU)	4.75	34	7.2
Nitrate (mg/L) *units?*	0.17	18	1.85

Phosphate (mg/L)	<0.2	0.4	0.24
Giardia (cysts/100L)	ND	ND	ND
Cryptosporidium (oocysts/100L)	ND	ND	ND

Mallard Slough Intake Data (Contra Costa WD)

The Mallard Slough Intake is located in the west end of the Delta on the Sacramento River across from Chipps Island off Suisun Bay. The slough is shallow, tidal and approximately 400 feet long. It is surrounded by Delta marshlands. The intake pumps are located at the far end of the slough, away from the main Sacramento River channel.

Mallard Slough is affected predominantly by salt water intrusion during dry seasons and under drought conditions. It is not influenced by agricultural drainage. Salinity in Mallard Slough is not suitable for drinking water use except at times of high Delta outflow. Water quality at Mallard Slough is comparable to Rock Slough only in the early spring during high runoff years. Contra Costa WD halts diversions from Mallard Slough when the chloride content of the San Joaquin River exceeds 100mg/L. Listed below are the minimum, maximum and median levels of pertinent water quality parameters at Mallard Slough Intake from 1/93 through 4/98.

Parameter	Minimum	Maximum	Median
Bromide (mg/L)	<0.1	13	3.3
TDS (mg/L)	80	5850	1428
TOC (mg/L)	(one data point: 5.7)		
Turbidity (NTU)	5.75	36	16
Nitrate (mg/L) *units?*	0.32	3.7	1.65
Phosphate *units?*	<0.2	4.1	0.385
Giardia (cysts/100L)	NA	NA	NA
Cryptosporidium (oocysts/100L)	NA	NA	NA

Old River Intake Data (Contra Costa WD)

The Old River Intake is situated in the south-west Delta between the Clifton Court Forebay and State Route 4 in the Byron Tract. The land use adjacent to the Old River Intake is mostly agricultural. However, the town of Discovery Bay is located within three miles of the pumping facility and is expanding. The outfall for the Discovery Bay wastewater treatment plant is within a few hundred yards of the intake.

The water level in Old River is subject to tidal fluctuations and varies by about 3-4 feet, but is six miles south of Rock Slough and is subject to less salt water intrusion. The intake is primarily affected by agricultural drainage flushed out of the fields in the winter months. The main impact of this drainage to water quality is increased dissolved solids, TOC and possibly pathogens. High nutrient levels in the slough may be from wastewater discharges and/or agricultural activities. Listed below are the minimum, maximum and median levels of pertinent water quality parameters at Old River Intake from 8/95 through 4/98.

Parameter	Minimum	Maximum	Median
Bromide (mg/L)	<0.1	0.65	<0.27
TDS (mg/L)	60	388	180
TOC (mg/L)	1.1	370	3.8
Turbidity (NTU)	5.4	50	14.7
Nitrate (mg/L) *units?*	0.12	18	1.85
Phosphate *units?*	<0.2	8.9	1.75
Giardia (cysts/100L)	NA	NA	NA
Cryptosporidium (oocysts/100L)	NA	NA	NA

Delta Mendota Canal Data

This presents a brief discussion of the results of monitoring at the Delta Mendota Canal intake by the Department of Water Resources. Although there are data available since 1983 for most water quality constituents, two water years are presented here, the 1988/89 (dry year) and 1996/97 (wet year). There is a difference in water quality dry year to wet year. There are other variables that also effect water quality. These include seasonality, stormwater runoff, dam releases and irrigation practices.

	88/89 (dry year)			96/97 (wet year)		
Parameter	min	max	median	min	max	median
Dissolved Organic Carbon (mg/L)	2.1	5	3.5	2.7	4.4	3.1
Bromide (mg/L)	-	-	-	0.01	0.24	0.13
Chloride (mg/L)	18	198	124	12	69	46
Total Coliform Bacteria (MPN)	-	-	-	8.7	782	22.2

Total dissolved solids (mg/L)	330	349	330	97	367	224
Electrical conductivity	7.3	897	634	153	586	399
Ammonia (mg/l) *units?*	-	-	-	0.05	0.2	0.08
Turbidity (NTU)	7	28	13	8.5	110	27.2
THM formation potential (ug/l)	250	730	485	306	467	407

San Joaquin River at Vernalis Data

This presents a brief discussion of the results of monitoring of the San Joaquin River near Vernalis by the Department of Water Resources. Although there are data available since 1983 for most water quality constituents, two water years are presented here, the 1988/89 (dry year) and 1996/97 (wet year). There is a difference in water quality dry year to wet year. There are other variables that also effect water quality. These include stormwater runoff, dam releases and irrigation practices.

	88/89 (dry year)			96/97 (wet year)		
Parameter	min	max	median	min	max	median
Dissolved Organic Carbon (mg/L)	2.8	6.5	3.4	2.4	8.1	3.2
Bromide (mg/L)	-	-	-	0.02	0.29	0.21
Chloride (mg/L)	83	206	134	7	98	66
Total Coliform Bacteria (MPN)	-	-	-	69.7	3440	196
Total dissolved solids (mg/L)	381	897	514	92	449	321
Electrical conductivity	7.7	1460	846	120	800	562
Ammonia (mg/l) *units?*	-	-	-	0	0.47	0.05
Turbidity (NTU)	8	46	15	22.2	96	31.7
THM formation potential (ug/l)	250	730	530	309	699	422

San Luis Reservoir Data

This presents a brief discussion of the results of monitoring by the Santa Clara Valley Water District for selected water quality parameters in the San Luis Reservoir (San Luis). San Luis receives Central Valley Project water transported from the Delta by the Delta-Mendota Canal, plus Delta water from H.O. Banks.

Due to its large size and residence time, San Luis generally allows for natural settling of particles and dampens water quality fluctuations in Delta water. Direct reservoir monitoring data is available for all of the parameters of interest below except Cryptosporidium and Giardia. Santa Teresa Water Treatment Plant (STWTP) influent, during months when San Luis was that plant's sole raw water source, was used to represent San Luis water for pathogens. STWTP influent data was also used for 1990 and months during 1991 when San Luis data is unavailable. Reservoir monitoring data prior to 1991 are being retrieved from archived files and may be summarized at a later date.

TOC concentrations have ranged from 1.96 to 6.9 mg/l, averaging about 3.4 mg/l. This is based on San Luis sampling data from August 1991 to the present and STWTP influent data from 1990 and 1991. During this time period, TOC concentrations were generally higher from 1990 to 1992 than from 1992 to the present; the highest values were recorded during early 1992 and mid-1993. The peaks in TOC values were likely due to drought conditions affecting Delta water quality.

Bromide concentrations have ranged from non-detectable to 0.53 mg/l, averaging about 0.25 mg/l. This is based on San Luis sampling data from October 1991 to the present and STWTP influent data from 1990 and 1991. During this time period, bromide concentrations were generally higher from 1990 to 1992 than from 1992 to the present and appear to peak during the summer of 1991. This is likely due to drought conditions affecting Delta water quality. The timing of the highest bromide concentrations is somewhat earlier than the timing of the high TOC concentrations mentioned above.

Nitrate concentrations (expressed as N) have ranged from non-detectable to 4.6 mg/l, averaging about 2.1 mg/l. This is based on San Luis sampling data from January 1991 to the present. During this time period, nitrate concentrations were highest during mid-1991, generally 1 mg/l or less until mid-1995, and generally between 2 and 4 mg/l until the present. Available ammonia concentrations (expressed as N) from December 1991 through November 1994 range from non-detectable to 0.14 mg/l.

Phosphate concentrations (expressed as PO4) have varied from 0.05 mg/l to 1.05 mg/l, averaging about .25 mg/l. This is based on San Luis sampling data from October 1994 to the present. During this time period, phosphate concentrations were generally at their highest during the first half of 1996 and early 1998.

District treatment plant influent and effluent samples have been analyzed for Cryptosporidium and Giardia regularly since June of 1991. Cryptosporidium has been detected six times in samples representing San Luis water. The highest concentration reported was 3.5 oocysts per 100 liters. Giardia has not been detected in samples representing only San Luis water. Giardia has been detected only once during District monitoring, in a July 1995 sample representing a blend of San Luis and South Bay Aqueduct water.

MWDSC Storage Lakes and Reservoirs

Summarized below are water quality results for the influents of our treatment plants that receive exclusively SPW.

Metropolitan's Jensen plant (750 mgd) receives West Branch SPW through Castaic Lake, and Metropolitan's Mills plant (326 mgd) receives East Branch SPW through Silverwood Lake (via Devil Canyon). However, the Jensen plant can at times receive Los Angeles Aqueduct water, whereas the East Branch can at times include water from the Kern River or Santa Ana River. Because we are using nonparametric analyses (percentiles) for the representation of the data, the non-SPW sources will not effect the median and interquartile (25th to 75th percentile) statistics, and most likely represent outliers in the database (<<10 percent of the data).

Metropolitan's major water quality concerns in our SPW supplies are disinfection by-product (DBP) precursors, pathogens, salinity, and taste-and-odor problems. Results of the chemical analyses represent just over a ten-year period (1987-1998) and include both wet and dry year data (Table 1 and attached figures). Although the microbiological data only cover a few years, they do include specialized monitoring of storm water runoff into the source water lakes.

The median and 90th percentile values of bromide in West Branch SPW were 0.22 and 0.34 mg/L, respectively, whereas the median and 90th percentile concentrations in East Branch SPW were 0.20 and 0.39 mg/L, respectively. The highest bromide levels were observed between 1989 and 1993 owing to drought conditions. Bromide concentrations fluctuate more frequently in East Branch SPW than in West Branch SPW because the average detention time in Silverwood Lake (0.2-year) is much shorter than in the Pyramid/Castaic Lake system (~2.1 years).

Metropolitan is also concerned about levels of TDS in our SPW supplies, which comes primarily from seawater intrusion and secondarily from agricultural drainage in the San Joaquin River Basin. In addition, TDS can be introduced into the California Aqueduct during groundwater pump-in programs. Moreover, the TDS of treated waters can be significantly increased--by the addition of large amounts of acid and base--when ozonating high-bromide waters at a reduced pH level to minimize bromate formation, or during enhanced coagulation at an acidic pH in order to remove total organic carbon (TOC). High TDS levels have a significant impact on groundwater recharge and waste water recycling programs.

The median and 90th percentile values of TDS in West Branch SPW were 349 and 407 mg/L, respectively, whereas the median and 90th percentile concentrations in East Branch SPW were 298 and 391 mg/L, respectively. Similar to the bromide values, higher TDS levels have been observed in drought years. In addition, TDS fluctuates more frequently in the East Branch SPW because of the shorter detention time in Silverwood Lake.

The median and 90th percentile values of TOC in West Branch SPW were 2.7 and 3.1 mg/L, respectively, whereas the median and 90th percentile concentrations in East Branch SPW were 2.9 and 3.8 mg/L, respectively. As with bromide and TDS--contaminants that originate in the Delta--TOC fluctuates more frequently in the East Branch SPW because of the shorter detention time in Silverwood Lake.

We *(who is "We"?)* are also concerned about nitrate and nitrite, as these represent nutrients that can stimulate algae growth. Algae growth occurs in the Delta, in the California Aqueduct, and in the SPW reservoirs. Algae create taste-and-odor problems, and certain blue-green algae also produce algal toxins (hepato- and neurotoxins). Algal matter may be a source of DBP precursors. In particular, amino acids from algae have been shown to be precursors for certain nitrogen-containing DBPs (e.g., cyanogen chloride, haloacetonitriles). To date, Metropolitan's primary concerns with algae are the production of the off-flavor compounds geosmin and 2-methylisoborneol in the water. These malodorant compounds cannot be removed by conventional treatment and are objectionable to water consumers at part per trillion levels in the water.

The median and 90th percentile values of nitrate in West Branch SPW were 2.2 and 2.7 mg/L as N, respectively, whereas the median and 90th percentile concentrations in East Branch SPW were 2.4 and 3.4 mg/L as N, respectively. The median and 90th percentile values of nitrite in West Branch SPW were "not detected" (ND, with a detection limit of 0.005 mg/L as N) and 0.005 mg/L as N, respectively, whereas the median and 90th percentile concentrations in East Branch SPW were 0.006 and 0.020 mg/L as N, respectively. There appears to be little change in the median concentrations of nitrate over the past ten years. The nitrite levels were significantly higher in East Branch SPW, with almost no nitrite detected in West Branch SPW as measured in the Jensen plant influent.

We are also concerned over phosphate, as this also represents a nutrient that can stimulate algae growth. The median and 90th percentile values of phosphate *(Total or Soluble O-P?)* in West Branch SPW were 0.049 and 0.083 mg/L as P, respectively, whereas the median and 90th percentile concentrations in East Branch SPW were 0.080 and 0.10 mg/L as P, respectively. Since phosphorus *(only some forms of phosphorus are bioavailable)* is biologically available, these phosphate values represent only a small fraction of the total phosphorus in the systems. These phosphorus levels are considered to be excessive, resulting in increased biological productivity. *(Not true, if the algal growth is limited by nitrogen, the amount of algal available P is of no consequence in developing algae. This section needs to be rewritten to discuss the relationship between N and P compounds and algae.)* This increased productivity adds to the TOC loading *(Not true- as discussed in my "Nutrients" write up algae only increase TOC under certain conditions.)*, has led to treatment plant problems, and contributes to increased frequency and intensity of taste and odor episodes. As was the case for nitrate, phosphate levels were higher in the East Branch than the West Branch SPW.

Pathogens are in Delta waters as well as in local source waters. Pathogens can come from recreational activities (e.g., body contact), wastewater discharges, surface runoff into the system, and inflows upstream of the reservoirs. We do not know all of the sources of pathogens or their relative contributions because of analytical limitations. Moreover, we are concerned over periodic spikes (e.g., during events), as these temporal increases in pathogen loadings could potentially result in a waterborne illness.

Tables 2 and 3 present the results of several surveys on Cryptosporidium and Giardia conducted by Metropolitan *(MWD?)* and by the Department of Water Resources. Results of nationwide surveys are also included. In general, it is difficult to compare results from different surveys because of differences in water quality and analytical techniques that may dramatically affect recovery efficiencies. For example, early data collected by Metropolitan (1981-1982 data) were generated using a much higher flow rate through the filter cartridges than is now known to be optimal for pathogen recovery. This may explain the lower levels compared to more recent survey data, such as those collected between 1994 and 1997, where Cryptosporidium oocyts up to 247 oocysts/100L were detected in Lake Silverwood.

Results of the DWR and MWD coordinated pathogen monitoring program (CPMP) were designed to replicate earlier surveys taking into account method improvements as well as sampling during storm run-off events. Preliminary results suggest that run-off events have much higher pathogen concentrations than would otherwise be detected by once a month monitoring. Results of extensive sampling during storm events at Lake Silverwood and Castaic also showed the significance of storm water run-off. The highest levels of pathogens were detected in first-flush samples that Metropolitan staff were able to collect. First flush samples were not collected by DWR in the CPMP, so it is likely that these results underestimate the actual numbers.

Collectively, while these results suggest that baseline SWP levels of pathogens may be lower than the nationwide surveys by LeChevallier and Rose, the results are highly dependent on how and when the samples were collected and analyzed. Consequently, it is difficult to draw firm conclusions regarding pathogen quality until more is known about the impacts of watershed runoff.

[need Tables 2 & 3] *not provided with the report.*

Identified data gaps

Regulatory. As noted above, there is a regulatory context involving control of pathogens and disinfection byproducts in drinking water. While the IESWTR and Stage 1 D/DBPR are well enough defined that their impacts can be predicted at this time, future regulations are not clear. There is a SDWA mandate that a Longer-Term ESWTR and Stage 2 D/DBPR be developed, based in part on data from the current ICR and reflecting the state of knowledge on health impacts from microbial pathogens and disinfection byproducts. Discussions on the content of these regulations will begin formally in 1999, leading to expected promulgation in 2002. These rules may center around relatively minor improvements in operational reliability. On the other hand, they may establish more stringent treatment requirements and/or MCLs. They cannot be predicted at this time.

Sources and loadings affecting water quality at intakes and storage reservoirs. There is a limited understanding of contaminant loadings from specific agricultural drains and other sources. To the extent we could determine loadings, it might be possible to identify particularly important sources of contamination for mitigation.

As noted above, the impacts of other proposed CALFED core activities, particularly creation of wetlands and other modifications that may result in increased TOC loadings, are poorly understood. Opportunities to improve our understanding of this are discussed below.

Treatment. Because utilities will have to comply with upcoming and planned drinking water regulations before changes in storage and conveyance could provide significantly improved water quality, most utilities have begun planning and initiating their approaches to compliance. We only have a limited understanding of what specific actions are anticipated at the treatment plants. To the extent possible, a better understanding would allow better prioritization of CALFED core program actions and perhaps development of other helpful actions. We suggest that this activity continue during refinement of the proposed action items and as part of their Phase III implementation. *(It should be the responsibility of the water utilities to evaluate the degree of treatment and the associated costs to meet worst case regulatory approaches by treatment at the plant and at various degrees of source control. This information is essential to developing a CALFED cost effective domestic water supply water quality control program.)*

SUGGESTED CORE ACTIONS FOR DRINKING WATER QUALITY IMPROVEMENTS

The CALFED Water Quality Program has several elements, including development of core activities to improve water quality that are independent of the several storage and conveyance alternatives under consideration. The purpose of this document is to identify the issues for the production of drinking water that arise from the qualities of Delta waters as sources, to develop and evaluate activities appropriate to the core program that can minimize these impacts, to identify opportunities for implementation of these activities, and to determine data gaps and necessary data-gathering activities. Therefore, no attempt was made in this document to evaluate the possible impacts of the general, large-scale CALFED storage and conveyance alternatives. Because of the growing consideration that CALFED alternatives will be decided upon in a phased approach over several years and because drinking water regulations that pose problems for treatment will be implemented prior to these decisions or any resulting water quality improvements, this document emphasizes activities likely to result in mitigation of adverse impacts in the next several years. *(the earliest that anything meaningful could be accomplished is likely to be at least 10 years.)* In addition, some ideas for research, demonstration, pilot and longer-term projects were discussed and developed. Activities for monitoring and assessment were developed for inclusion in the CALFED CMARP.

The minimum goal is to have water quality at the various points of concern sufficient to allow production of drinking water that is safe, meets anticipated regulatory standards and is acceptable to the consumers. Of primary importance is reduction and maintenance of pathogen loadings in source waters to less than one Cryptosporidium oocyst or Giardia cyst/100L This will enhance protection of public health and allow maximum flexibility in use of disinfectants with respect to disinfectant byproduct formation.

Depending on treatment currently in place or feasible for future construction and operation on a site-specific basis, decreases in TOC and bromide levels are desirable. That is, for systems depending on chlorine to provide disinfection credits, control of TOC may be more important than control of bromide. For systems depending on ozone to provide disinfection credits, control of bromide may be more important. For example, MWDSC will require large improvements in both bromide and TOC in order to comply with upcoming regulations *with minimum expenditures at the treatment works.*

Control of nutrients to prevent algal growth is important to minimize the necessity to use ozonation to control resulting taste and odor problems.

Improving turbidity and TDS levels will enhance treatment flexibility and success and consumer satisfaction.

Approaches to improving water quality were considered first with respect to the reference points of concern, to reflect better the dominant issues and opportunities. It is clear that some approaches are appropriate and/or feasible for some locations. Region-wide approaches were also considered. In all cases, the attempt was to focus on means to reduce the impacts of the constituents of concern irrespective of the choices for the several storage and conveyance alternatives being discussed. This was first to find approaches that would be beneficial regardless of the choice of alternative. A variety of suggestions were developed. Second, there was an expressed desire that the approaches be developed sufficiently so that their impacts could be evaluated with respect to changes brought from the various alternatives. This could not be generally done with existing data.

With respect to the contaminants of concern, our analysis concluded that core program actions could have minimal impact on levels of bromide, particularly for CA aqueduct users. Bromide is acknowledged to derive from seawater intrusion. Diverting or repelling seawater or substituting cleaner source waters would require substantial reconfiguration of general Delta flows, which make up the various CALFED alternatives. Similarly, TDS from seawater intrusion could not be controlled by core activities. Additionally, turbidity from stormwater runoff was not seen to be tractable to core program actions.

Opportunities for improving levels of nutrients, pathogens, non-seawater TDS and, to some extent, TOC were found. These are described below with respect to the reference points of concern and for the Delta as a whole.

Actions to improve water quality in the American and Sacramento Rivers

1) Control algal blooms in upstream reservoirs and aquatic weed growth in the lower American River

This is a water treatment issue for the Fairbairn Water Treatment Plant to reduce nutrient loadings supporting algal and aquatic weed growth. Impacts to the water supply from aquatic plant growth are taste and odor issues as well as clogging of fish screens. Additional studies are required specific to this source to determine why this problem occurs and what potential solutions could be. *(The Sacramento River Watershed Program has recently examined the algal related domestic water supply problems within the watershed and concluded that there are no domestic water supply water supply problems that can be attributed to nutrients in Sacramento and other communities in the watershed. There is need to clarify the difference between this report and the results of the Sacramento River Watershed Program on the algal related water supply problems in Sacramento.)*

2) Reduce impacts of agricultural activities on the Sacramento River due to spring runoff

Ongoing efforts by the Department of Food and Agriculture, Regional Water Quality Control Board Central Valley Region, and the rice industry to develop and implement management programs for agricultural runoff have greatly diminished impacts. Agricultural activities remain a concern as both a watershed and treatment issue. Rice pesticides, for example, continue to be detected at the Sacramento treatment plant intake. *(Are the rice field discharges causing treatment or other water quality problems for Sacramento? No according to representatives of the City of Sacramento.)* Conditions in the watershed could lead to potential exceedences of primary and secondary MCLs. It is suggested that CALFED support further stakeholder activities, including input from the Department of Food and Agriculture, Regional Board, and agricultural interest groups on research or programs needs that could result in water quality improvements. Queries to UC Extension specialists, Farm Advisors, County Agricultural Commissioners, etc. may also be helpful. Ideas for assistance could be for research/ evaluations on how to prevent drains from discharging during spring storms, design of holding basins, training and educational opportunities, etc.

3) Reduce impacts from cattle grazing along the Sacramento River by use of BMPs

The City of Sacramento, Department of Utilities has been tracking research into grazing animals and their potential contribution of pathogens to the Sacramento River system as well as the implementation of grazing management practices in the Sacramento River watershed. The UC Extension has been conducting extensive research on various grazing animals with the cooperation of the grazing industry. The Cattlemen's Association has been supporting research on BMPs for grazing lands and well as promoting these practices in its educational outreach programs. The UC Davis Extension program provides educational resources and rangeland water quality short courses for the grazing industry. CALFED could appropriately support stakeholder involvement and implementation of cattle management BMPs. Efforts would be generally useful to several watersheds affecting drinking water intakes in the Delta. *(While it is often said that cattle grazing near a waterway is detrimental to water quality, and there are a number of examples of where this has been shown, it is not clear that cattle grazing near the Main stem of the Sacramento River and its tributaries above Sacramento are detrimental to water utilities that use Delta water as a raw water supply.)*

4) Support research on impacts from wild animals

Wild animals may be a source of pathogens to the Sacramento and American Rivers and to the Delta in general. UC Davis is planning to conduct research on this potential source of pathogens. Of particular interest is information on loading of protozoan pathogens such as Giardia and Cryptosporidium. It is suggested that CALFED support these activities

(From the Review presented in this report, it is mot clear MWD and other water utilities are encountering pathogen problems because of the use of Delta as a raw water supply. The North Bay Aqueduct situation appears to be a local problem that does not involve the greater Sacramento River watershed.)

5) Determine and control impacts from Natomas East Main Drain

It was noted that there is a data gap here (where ?) with respect to understanding loadings and impacts. Because of interest in rerouting agricultural drains and relocating drinking water intakes in the northern parts of the Delta, it would be useful to determine the contamination impacts from Natomas East Main Drain. This could be done as an element of CMARP or in a smaller, directed study.

6) Further determine sources of contaminants of concern to watershed

Previous studies have shown that there is insufficient information on the sources of organic carbon in the Sacramento River watershed. The Sacramento River Watershed Program is collecting some data on organic carbon concentrations at a number of locations along the Sacramento River and its major tributaries. Data are needed on the concentrations and loads of organic carbon in urban runoff, wastewater discharges, and agricultural drainage. Regional Board staff could investigate the feasibility of including organic carbon as a monitoring parameter in all NPDES and waste discharge permits. *(This is likely to be of limited value since the primary sources are not NPDES permitted sources.)* Regional Board staff could also support the efforts of the urban water suppliers to include organic carbon monitoring in the extensive monitoring program being developed by CALFED.

Information is needed on the key sources of TDS in the Sacramento River watershed. As the population of the watershed grows, there will be a need to identify potential mitigation measures for increased wastewater and urban runoff discharges that are high in TDS. CUWA is undertaking a study of the key point sources of TDS in the watershed. Regional Board staff could support the efforts of CUWA on this study and the efforts of the urban water suppliers to include TDS in the CALFED monitoring program.

There are fairly limited data on pathogens in the Sacramento River watershed. Some data have been collected by DWR and by water agencies under the Information Collection Rule. Regional Board staff could support the efforts of the urban water suppliers to include pathogen monitoring in the Sacramento River Watershed Program and the CALFED monitoring program.

(The suggestions that the CVRWQCB should require that point and non-point dischargers in the Sacramento River Watershed should initiate monitoring for parameters that are of little or no interest to Sacramento River stakehholders. The attitude will likely continue to be that of if MWD wants these parameters monitored then MWD should pay for it. There are sufficient demands for monitoring funds to address Sacramento River Watershed problems that the stakeholders will likely want to use the monitoring funds available to address local problems rather than problems that only impact Delta water exporters. Rather than suggesting that the CVRWQCB require that the dischargers in the Sacramento River watershed monitor parameters of interest to MWD et al., the water utilities should find the resources for such monitoring within their constituency. This will almost certainly be more effective than the current approach.)

Actions to improve water quality in the North Bay Aqueduct:

1) Implement a watershed management program within the Barker Slough watershed.

Solano County Water Agency and the other NBA Contractors have developed a watershed management program to address the drinking water contaminants in the watershed, including TOC, pathogens and nutrients, and to get the cows out of the water around the Barker Slough intake. The first step was to form a Watershed Stakeholders Group to advise the NBA contractors on all aspects of the watershed management program. The next step is to identify areas that have the greatest impact on raw water quality and implement and evaluate best management practices (BMPs) that could potentially improve the quality of runoff water and the quality of water in Barker Slough at the pumping plant. The most suitable BMPs will be evaluated in a pilot study in which various BMPs will be constructed (structural) or implemented (non-structural) and then evaluated for their effectiveness by water quality monitoring. Several property owners have expressed an interest in working with the NBA Contractors to study various methods of improving water quality and several site visits have been conducted. A watershed management plan will be cooperatively developed based on the evaluation of BMPs in the pilot study. Proposition 204 funding for this was requested of the SWRCB and received at $580,000.

2) Conduct studies to further delineate the dry season organic carbon contributions and possible load reductions.

Laboratory and field studies on algal growth, combined with nutrient loading information are needed to understand the in-channel contribution of algae to the organic carbon loads at the BSPP during the dry season. In addition, studies are needed to determine streamside contributions from riparian vegetation.

Before this is undertaken those responsible should review the literature on this topic such as,

3) Relocation of the intake.

The water quality in the NBA is considered some of the poorest in the Delta for drinking water, resulting largely from degradation in the upper watershed. *(NBA or the Sacramento River?)* Future changes in the northwest Delta may cause a degradation of the water quality at Lindsey Slough, which appears to provide an element of dilution to the contamination from the upper watershed. Large CALFED environmental restoration projects located near the mouth of Lindsey slough may cause an increase in organic carbon levels. In addition, the goal of these restoration projects is the increase in the populations of fish species of concern. Increases in these fish populations may lead to restrictions in pumping at the BSPP. Two alternatives that have been mentioned include relocation of intake to the Colusa-Tehama Canal or to Miner Slough. These alternatives would result in sourcewater containing a larger amount of Sacramento River water which is of a higher quality in terms of organic carbon and turbidity to the water in Barker Slough.

This idea was not seen as suitable for the CALFED core program, but worthy of consideration in the discussion of alternatives. We suggest an in-depth analysis of the feasibility of relocation. *(This is a local water utility problem that should be addressed by the utilities impacted. CALFED* *funds should not be used to address local water utility problems that are associated with local sources of constituents.)*

Actions to improve water quality in the South Bay Aqueduct:

1) Implement a watershed management program within the SBA proper

The SBA is open from Bethany Reservoir to near Lake Del Valle. Sanitary surveys have identified specific problems resulting from ranching and other activities adjacent to this open portion of the SBA. For example, agricultural and stormwater runoff into the SBA are believed to substantially contribute to algal growth. A watershed management program should be developed to address nutrient and microbial pathogen contamination to SBA waters from agricultural activities, particularly cattle operations. This would include developing a stakeholder group of landowners, urban water managers, DWR, the CA Cattlemens Association and others to further delineate the sources of contaminants, identify Best Management Practices to reduce loading of contaminants and initiate corrections. Funding proposals are now in development. *(This like the NBA is a local water utility problem that is not a Delta-caused problem. CALFED funds should not be used for the issue.)*

2) Replace farmers bridges to reduce fecal and nutrient contamination from cattle.

The State Sanitary Survey for SBA pinpointed several poorly constructed cattle bridges over the SBA that allowed fecal material to drop into SBA waters. This contributes to microbial pathogen loads and algal growth. Replacement of these bridges by DWR is ongoing, but could be enhanced. Follow-up study to determine improvements and any further work are suggested. This could be combined with the watershed management activities recommended above.

3) Control algae in SBA by use of copper sulfate

Copper sulfate is currently being used to control the growth of algae in SBA. However, this is recognized as not an optimal solution. There are issues that may lead to reduced effectiveness or restricted use of copper sulfate in the future: 1) copper selects for the growth of algae that are tolerant to this chemical, 2) the copper is toxic to other aquatic organisms (invertebrates, fish) in the reservoirs, 3) there are drinking-water limits on copper, 4) new restrictions may be placed on copper sulfate usage in surface waters as a result of the proposed California Toxics Rule, and 5) copper accumulated in water treatment plant sludge can greatly increase disposal costs. Therefore, this is not a recommended approach and one that could be made unnecessary with adequate control of nutrients. *(As discussed in my Nutrients review, there is need to understand the sources of total and algal-available N and P in watershed for the exported water at the point of export form the Delta. Also consideration should be given to the potential for limiting nutrient control and the potential water quality benefits of implementing nutrient control programs on domestic water supply water quality. A key issue that must addressed by the water utilities before any nutrient control programs are initiated Delta watershed is for the utilities to achieve high levels of control of nutrient inputs to the Delta exported water.) (Also there is need to review the copper sulfate use issue since some of the statements made about the problems of the use of copper sulfate are not supported by the experience of others.)*

4) Develop and implement management programs for Lake Del Valle, including possible control of swimming and boating

Increasing concerns have surfaced for the significant microbial contamination of source waters from recreational bathers. It is recognized that, from a source water protection standpoint, the most desirable situation is to ban all whole-body contact in these sources. When this is not possible, restriction of swimming to areas bermed-off from the main water body is helpful. For Lake Del Valle, it is suggested that a feasibility study be done to determine costs of creating and maintaining a bermed-off swimming area. If this is feasible, CALFED funding for implementation may be appropriate.

Additional microbial contaminant sources for Lake Del Valle include boating, other whole-body contact activities and sanitary waste handling facilities. Control of these sources may include education, limits on location of activities up to complete bans.*(This is not a CALFED issue)*

5) Develop and implement management programs for the upper Lake Del Valle watershed

Ranching operations in the Arroyo Valle watershed above Lake Del Valle appear to contribute nutrients and perhaps pathogens to Lake Del Valle, which contribute to algal growth. A watershed management program patterned after that initiated by SFPUC for the Alameda Creek watershed above Calaveras Reservoir has been suggested. *(This is not a CALFED issue.)*

6) Address control of algae by other means

Several other approaches to control of algae in SBA have been suggested and require additional study. Physical removal using chains and control of floating algae by using attached algae as nutrient scrubbers have been proposed. Additional general research on algal control is warranted. *(Not CALFED.- should be funded by the water utility.)*

Actions to improve water quality in the Clifton Court Forebay:

1) Develop and implement watershed management programs for Clifton Court and Bethany Reservoir to address nutrients and pathogens

Much of the land surrounding Clifton Court and Bethany Reservoir is used for agriculture and cattle grazing. Several agricultural drains impact Clifton Court directly. Additionally, contamination from stormwater runoff can occur. A watershed management program similar to that initiated by North Bay Aqueduct users at Barker Slough is recommended to address nutrient and microbial pathogen contamination from agricultural activities, particularly cattle operations. This would include developing a stakeholder group of landowners, urban water managers, DWR, the CA Cattlemens Association and others to further delineate the sources of contaminants, identify Best Management Practices to reduce loading of contaminants and initiate corrections. Because of the location of these facilities with respect to the SBA, a separate effort from that proposed for the SBA above is probably necessary.

2) Control wastewater discharges from Discovery Bay outfall

The wastewater treatment plant for Discovery Bay discharges near Clifton Court Forebay and the CCWD Old River intake. It is believed that future plans for Discovery Bay include a several fold increase in discharges. These increased loadings and their impacts need to be estimated and addressed. As noted elsewhere, CCWD has proposed moving the discharge point away from the Old River intake. It is reasonable that the new site be also out of the area of influence for Clifton Court. Discussion on how to addresses this must include all parties. It plausibly should be an element of the CCWD Old River proposal, below. *(This is a local problem that needs to be addressed by the water utilities impacted by local pollution.)*

3) Control algae in Clifton Court by use of copper sulfate.

Copper sulfate has been used to control the growth of algae in water storage and conveyance facilities, apparently including Clifton Court. However, this is not an optimal solution. There are issues that may lead to reduced effectiveness or restricted use of copper sulfate in the future: 1) copper selects for the growth of algae that are tolerant to this chemical, 2) the copper is toxic to other aquatic organisms (invertebrates, fish) in the reservoirs, 3) there are drinking-water limits on copper, 4) new restrictions may be placed on copper sulfate usage in surface waters as a result of the proposed California Toxics Rule, and 5) copper accumulated in water treatment plant sludge can greatly increase disposal costs. Therefore, this is not a recommended approach. *(There is need to review this issue since some of the statements made about the problems of the use of copper sulfate are not supported by the experience of others.)*

4) Identify and mitigate high impact agricultural drains in the vicinity of intake

We believe that drains adjacent to drinking water intakes pose the greatest risks for adverse impacts to water quality. Besides the Discovery Bay (Reclamation District 800) outfall, Byron Tract was noted as having drainage substantially higher than influent water. This needs to be better characterized. We recommend detailed studies on the drains in this area, including modeling of loads. This could be followed by management activities. *(The role of agricultural drains within the Delta need to be understood as a source of TOC and TDS. Work on local problems of this type should be part of this study)*

5) Control seawater intrusion by barriers and operations. This is an ongoing activity and is addressed elsewhere in the CALFED process.

Actions to improve water quality in the Contra Costa Water District intakes (Mallard Slough, Rock Slough, Old River):

1) Relocation of Veale Tract agricultural drain

Current studies indicate that relocation and/or treatment of agricultural drainage from Veale Tract are the only effective means to reduce impacts to the Rock Slough intake. CCWD is developing a proposal for CALFED funding to move one specific Veale Tract agricultural drain to a location away from the intake as a pilot study to determine the net improvements in water quality associated with this type of mitigation. One possibility would be to relocate the discharge to Sand Mound Slough downstream of the one-way gates. As part of this activity, a watershed management approach will be used to identify stakeholders, develop a consensus approach and monitor water quality. Studies by CCWD are ongoing to further determine impacts from Veale Tract. CALFED funding for this pilot project is recommended. *(Activities of this type and many of the others mentioned in this report need to be conducted with respect to the impact on the other Delta resources.)*

2) Relocation of Discovery Bay wastewater treatment plant discharge

CCWD is developing a proposal for CALFED funding to move the combined Discovery Bay wastewater treatment plant discharge and agricultural drain (Reclamation District 800) impacting the Old River intake to a location away from the intake as a pilot study to determine the net improvements in water quality associated with this type of mitigation. One possibility is to relocate the discharges to Indian Slough and North Victoria Canal. As part of this activity, a watershed management approach will be used to identify stakeholders, develop a consensus approach and monitor water quality. Studies by CCWD are ongoing to further determine impacts from this drain. Funding for this pilot project is recommended.

3) Studies on control of agricultural drainage in the vicinity of intakes

CCWD considers management and control of local drainage to be among the most cost-efficient means of improving source water quality impacts at urban intakes in the Delta. Beyond the above described projects, drainage control programs may be effective in the vicinity of the Old River intake. These could include treatment, volume reduction through management practices, consolidation of discharges and/or relocation of the point of discharge. Studies by CCWD are underway to evaluate these possibilities. Development and implementation of BMPs from a watershed stakeholder process should be supported by CALFED.

Actions to improve water quality in the Delta Mendota Canal at Tracy's Intake:

1) Relocate outfall or otherwise manage wastewater treatment plant effluent in vicinity of intake

Tracy's drinking water intake is adversely influenced by discharges from Tracy's wastewater treatment facility. These discharges are expected to increase over time as the population of Tracy expands. It is proposed that the feasibility of improving treatment and/or moving the outfall be studied and, if possible, initiated.

2) Identify and mitigate high impact agricultural drains in the vicinity of intake

We believe that drains adjacent to drinking water intakes pose the greatest risks for adverse impacts to water quality. For Tracy, these drains have not been identified and characterized adequately. We propose a focused study on several drains in the vicinity of the intake. *(While this statement has been made several times in this report, there is no supporting evidence that* *local agricultural drains are the primary cause of a water utilities problems. This issue needs to be substantiated.)*

Actions to improve water quality in the San Joaquin River:

1) Establish a watershed management program for the San Joaquin River

There is a need to establish a San Joaquin River Watershed Program that is similar in scope to the Sacramento River Watershed Program. Such a program could address both drinking water and ecosystem concerns in the San Joaquin watershed. Information is needed on the concentrations and loads of organic carbon, TDS, and pathogens in the San Joaquin watershed. The Regional Board staff could work with the urban water agencies to encourage CALFED to include a comprehensive monitoring program for the San Joaquin River in its monitoring program. Regional Board staff could also investigate the feasibility of including key drinking water parameters, such as organic carbon and pathogens, in NPDES and waste discharge permits.

Actions to improve water quality in the San Luis Reservoir/ O'Neill Forebay

Contamination of San Luis Reservoir and O'Neill Forebay is predominantly the result of DMC water. No ideas to improve water quality specifically for this area were brought forward.

Actions to improve water quality in the CA Aqueduct, south of O'Neill/ Checkpoint 13

1) Control drainage of stormwater into aqueduct by physical modification of facilities

A primary problem identified for this stretch of the aqueduct is contamination from stormwater runoff from agricultural and cattle grazing activities. These result in adverse loadings of TDS, pathogens and nutrients and stimulate algal growth. The aqueduct is not adequately protected from stormwater runoff. It is suggested that design and implementation of appropriate modifications to berms, bypasses, storm drains, etc be done to divert stormwater away from and prevent its discharge into the aqueduct. We recommend design studies be funded by CALFED for this purpose, followed by implementation of modifications.

2) Develop and implement a watershed management program to minimize drainage into aqueduct

Much of the land surrounding the southern reaches of the CA aqueduct is used for agriculture and cattle grazing. A number of agricultural drains impact the aqueduct directly. Pump-in from groundwater programs can also contribute contamination. A watershed management program is recommended to address the nutrient and microbial pathogen contamination from these activities, including State Water Contractor projects for the Arroyo Tassaharo and control of adjacent uses. This would include developing a stakeholder group of landowners, urban water managers, DWR and others to identify best management practices to reduce loading of contaminants and initiate corrections.

3) Address contamination loadings from inappropriate O&M of CA and Federal aqueducts.

This is being considered elsewhere in CALFED.

Actions to improve water quality in Castaic Lake and Lake Silverwood:

1) Utilize management of lake operations to reduce algal growth. This is ongoing to some degree.

2) Develop and implement a watershed management program to control nutrients and pathogens

Cattle grazing operations in the watersheds around the reservoirs may result in increases in nutrients and pathogens. Nutrients from animal wastes can lead to problematic algal growth, particularly during summer. As noted above, algae can yield adverse flavors and odors and can compromise treatment flexibility. At this time, no grazing occurs in the Lake Silverwood watershed, but sheep are grazed in the Castaic Lake watershed. In addition, recreational boating and other uses in the watersheds and reservoirs can contribute to nutrients and pathogens. Development of a watershed management strategy to control these sources is desirable.

3) Control recreational use to minimize microbial pathogens from humans

We are concerned about pathogens in our SPW supplies, specifically Cryptosporidium, Giardia, and potentially viruses. Future drinking water regulations may include more stringent disinfection requirements for these pathogens. Although MWDSC is planning to retrofit the Jensen and Mills plants with ozonation in order to comply with requirements in the Stage 1 D/DBPR, we are concerned over simultaneous compliance with a long-term ESWTR and Stage 2 D/ DBP Rule. For example, if there are inactivation requirements for Cryptosporidium, higher doses of ozone will be required, which will result in increased bromate formation. Rather than have to face this type of risk/risk trade-off issue, we seek watershed control programs/facilities that can minimize pathogen loadings and the concentrations of DBP precursors.

This might be best accomplished by restricting whole body contact recreational use in the reservoirs. Modeling studies for Eastside Reservoir clearly show the adverse impacts of swimming for increasing microbial pathogen loads in storage reservoirs. It is recognized that, from a source water protection standpoint, the most desirable situation is to ban all whole-body contact in these sources. When this is not possible, restriction of swimming to areas bermed-off from the main water body is helpful. Currently, no swimming is allowed in Castaic Lake, but swimming is allowed in Lake Silverwood. For Lake Silverwood (and perhaps Castaic Lake), it is suggested that a feasibility study be done to determine costs of creating and maintaining a bermed-off swimming area. If this is feasible, CALFED funding for implementation may be appropriate. (This is a questionable CALFED activity.)

4) Control algae by use of copper sulfate

Copper sulfate has been used to control the growth of algae in water storage and conveyance facilities. However, this is not an optimal solution. There are issues that may lead to reduced effectiveness or restricted use of copper sulfate in the future: 1) copper selects for the growth of algae that are tolerant to this chemical, 2) the copper is toxic to other aquatic organisms (invertebrates, fish) in the reservoirs, 3) there are drinking-water limits on copper, 4) new restrictions may be placed on copper sulfate usage in surface waters as a result of the proposed California Toxics Rule, and 5) copper accumulated in water treatment plant sludge can greatly increase disposal costs. Therefore, this is not a recommended approach. (See above comment)

5) Control recreational boating use to minimize MTBE

There is increasing recognition that two-cycle engines are major contributors to MTBE and other fuel contaminants in source waters, particularly on storage reservoirs. Bans on two-cycle engines on reservoirs have been imposed by some utilities already. As new CA DHS drinking water regulations are promulgated for MTBE, more emphasis must be placed on removing MTBE sources. We recommend bans on two-cycle engines in these storage reservoirs.

Bay Delta regional opportunities to improve drinking water quality:

1) Minimize pathogens from recreational boating

Dumping of sewage from houseboats, recreational boaters and other river recreationalists is a problem for pathogen contamination in the watershed. Educational solutions could include programs such as developing partnerships with recreational interests; distribution of materials at marinas, parks, recreational supply stores; signage at recreational areas; and participation in community events.

We suggest a stakeholder process to evaluate additional educational and regulatory needs. This would include California Department of Boating and Waterways, S.F. Bay Estuary Project, boating and marina interests, other recreational interests, Park Departments, enforcement agencies such as the U.S. Coast Guard, Regional Water Quality Control Board, County Sheriff Department, etc. in discussions. CALFED funding could be used to support identified solutions such as educational efforts through programs such as the Department of Boating of Waterways, the Sacramento River Watershed Program, local and other efforts to get the message out, facility improvements, etc. Facility improvements could include improved or additional pumpout and restroom facilities.

2) Reduce organic carbon loadings to the Delta from agriculture

(Much of this section is a repeat of other sections. Due these issues need to be discussed twice?)

There are a number of potential methods to reduce organic carbon loading to Delta waterways. These methods have been discussed and some have received preliminary evaluation but none has been adequately studied to assess the actual reduction in loading, the feasibility, or the costs. The MWQI Program is undertaking studies to evaluate some of these measures.

Treat agricultural drainage. The MWQI Program has developed a work plan to assess the feasibility of treating agricultural drainage to improve organic carbon concentrations in the Delta waterways. This work will be completed at the end of 1998. A preliminary assessment was conducted to provide input to the Ag/Urban and CALFED processes. Brown and Caldwell conducted a study to examine current treatment technologies for reducing TOC in agricultural drainage. The study findings showed that up to a 60% reduction in TOC concentrations could occur with conventional ferric chloride coagulation-flocculation. The preliminary assessment of improvements in Delta water quality used the results of the Brown and Caldwell study and the drainage volume estimates to estimate improvements in Delta channel DOC concentrations as a result of treating the drainage from the islands that contribute the greatest percentage of the drainage volume to the Delta (37 to 46% of total drainage volume). The preliminary assessment showed that there is the potential to improve channel DOC conditions to less than 3 mg/L with treatment. The greatest reduction in DOC concentrations occurred in the winter months. (It will be far cheaper to reduce the TOC at the treatment works.)

Reduce frequency of leaching. Most Delta islands are leached every three years. If the islands were only leached during years when Sacramento and San Joaquin flow was high, the high flows could potentially flush the leachate out of the system. By not leaching in low flow years, there is the potential to improve organic carbon concentrations in the south Delta. However, the implications of not leaching must be carefully discussed with Delta agricultural interests. We recommend a stakeholder process be initiated to discuss this and determine the need for additional studies. From this, a BMP approach can be developed and implemented.

Rerout agricultural drainage. Rerouting several key agricultural drains could potentially improve export water quality. For example, CCWD believes that rerouting the agricultural drain on Veale Tract away from Rock Slough could provide lower TOC concentrations at their pumping plant. Brown and Caldwell evaluated the feasibility of collecting Delta agricultural drainage and discharging it past Chipps Island. That study determined that over 700,000 acre-feet of drainage with a peak flow of 1600 cfs would need to be collected and discharged. As noted above, we recommend two pilot studies of CCWD at Rock Slough and Old River to determine the efficacy of moving problematic drains. In addition, we recommend development and use of Delta flow models to specifically assist with this. Ongoing efforts of MWDSC,CUWA, DWR and USGS to use models to estimate water quality at the intakes should be supported and extended by CALFED.

Store in detention ponds with release during high flows. Agricultural drainage could potentially be stored in detention ponds and released during periods of high flow when it would have less impact on Delta water quality. An option that could improve export water quality would be to reduce the agricultural drainage at times when pumping rates are low. This would not improve south Delta water quality. Realtime monitoring of various water quality parameters, including organic carbon, could be used to determine optimum times for release of stored drainage water. However, there are concerns that storing water in detention ponds may actually increase the organic carbon concentration of the drainage.

Fallow agricultural lands or convert to other crops. Some water quality scientists believe that converting from agricultural crops that require extensive tillage and irrigation to low tillage options such as permanent pasture and grazing or to upland and riparian habitat would reduce the loading of organic carbon discharged from Delta islands.

Reduce agricultural drainage volume and possibly organic carbon load by converting Delta islands to flooded wetlands. In additions to the benefits described above for fallowing agricultural lands with peat soils, maintaining saturated soil conditions will further reduce oxidation and therefore organic carbon loading as well.

Reduce agricultural drainage volumes and organic carbon loading by implementing irrigation efficiency measures. Flooding for salt leaching and some irrigation methods (e.g., spud ditch irrigation) are extremely inefficient with respect to irrigation and salt management and produce large volumes of drainage water and large loads of TOC. Implementation of water conserving irrigation and salt management methods could significantly decrease drainage water volumes and TOC loads.

3) Reconsider wastewater and stormwater permits

It was recognized that wastewater and stormwater discharges may result in unacceptable loading of pathogens, nutrients and TOC and that in general the CEQA process and development of NPDES permits do not adequately address impacts for drinking water. Expansion of the Sacramento Regional wastewater facility, Fairbairn WTP, Tracy WTP and Discovery Bay WTP and the development of the Mountain House residential community were identified as potential problems for adverse loadings. It is suggested that discussions between stakeholders (SWRCB, DWR, DHS, drinking water and wastewater utilities and others) be initiated to determine what is needed and what can be done.(What are the real problems that are to be addressed by these discussions?)

4) Identify problems and solutions to urban runoff

Urban runoff from Sacramento and other urban areas is a potential source of pathogens and other contaminants. The Sacramento Stormwater Management Program is currently conducting literature reviews and preparing an issues paper to consider this potential problem.

CALFED could support activities to better identify problems and solutions such as literature reviews, research, and public education activities. One suggestion for stormwater management is to develop and implement proactive pollution reduction programs using the regulatory standards approach applied to stormwater to the maximum extent practicable. (I do not understand what is meant by this statement, what specific program are envisioned?)

5) Manage restoration projects to minimize adverse and maximize positive impacts for drinking water quality

As noted above, there is the potential that CALFED and other habitat restoration projects may yield adverse impacts on drinking water quality, particularly with regards to TOC. We recommend that CALFED locate habitat restoration projects to avoid TOC contamination at intakes. To the extent possible, consideration should be given to construct restoration projects that yield reduced TOC loadings at intakes. Substantial further research is warranted on this issue. As discussed above, substantial uncertainty exists on TOC production and possible loadings from wetlands restoration, particularly with respect to production of more reactive and problematical TOC fractions. Proposals have been developed for CALFED consideration by USGS and DWR.

Revised Draft

Excessive Fertilization Water Quality Problems in the Sacramento River Watershed and Delta

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The Problem

The excessive fertilization (eutrophication) of waterbodies is one of the most common significant causes of readily discernible water quality impacts. The excessive growth of aquatic plants (algae and water weeds) is causing impaired water quality in some parts of the Sacramento River watershed especially the Pit River above Lake Shasta and in Clear Lake, within the Sacramento - San Joaquin River Delta and in water supply reservoirs that utilize Delta waters as a source of supply. Specific problems include impaired use of water in Sacramento River tributaries in the northern watershed and excessive growth of attached algae and floating water weeds (water hyacinths) in the Delta which interfere with recreational use of the Delta. Of particular concern to water utilities is the excessive growth of algae in water supply reservoirs that use Delta waters which lead to severe taste and odor problems, shortened filter runs and increased trihalomethane (THM) precursors which lead to increased chloroform and other potential carcinogens in treated water supplies.

Cause of the Problem

Excessive fertilization of waterbodies by nitrogen and phosphorus compounds can lead to severe water quality deterioration. The chemicals of greatest concern are nitrate, nitrite and ammonia, and to a lesser extent, organic nitrogen. Soluble orthophosphate is the form of phosphorus that is readily usable by algae. Particulate phosphate, such as that associated with erosion, is largely unavailable to support algal growth.

From the information available, the growth of algae and other aquatic plants in the Sacramento River system and Delta is primarily controlled by the rate of addition of nitrate and ammonia to these waters from land runoff/drainage and wastewater discharges. At times, the concentrations of algal available nitrogen compounds is growth rate limiting. This typically occurs during late summer at peak summer algal biomass. Generally, there is a large (10 fold) excess of soluble orthophosphate compared to the algal available nitrogen present during peak biomass during the late summer which indicates that phosphorus is not now limiting algal biomass and that it may be difficult to control phosphorus inputs sufficiently to make it limiting. Of particular concern as nutrient sources are domestic wastewater additions to the Sacramento River and its tributaries, as well as runoff from cultivated agriculture and dairies. While phosphorus does not appear to be limiting aquatic plant growth, its addition above normal background to the Sacramento River system is a key element in contributing to the excessive fertilization of these waters.

It is well established that there are no single-value nutrient water quality criteria/standards such as a certain concentration of nitrate or phosphate that leads to excessive fertility-induced water quality problems. The impact from nitrogen and/or phosphorus on aquatic plant-related water quality problems depends on a variety of factors such as the concentrations of available forms of nutrients; sunlight duration, intensity and penetration; the morphological and hydrological characteristics of the waterbody; etc. While light limitation is always a factor governing phytoplankton growth rates, from the information available , the Secchi Depth data indicated that at times the light transparency of the Delta waters is such that the rate of growth of phytoplankton is severely light limited.

At this time, there is a poor understanding of the sources of nitrogen and phosphorus compounds for the Sacramento River system and Delta and the relationship between current nutrient loads and the water quality use impairments associated with excessive growths of algae and other aquatic plants in these waters. This is an area that needs attention in order to formulate technically valid, cost-effective nutrient control programs to manage the excessive fertilization of the Delta and its tributaries.

The lower parts of the Sacramento River near Sacramento are not experiencing excessive algae and other aquatic plant growth which cause significant impairment to recreational use of these waters or domestic water supply problems. This type of situation is typically found in river systems which can have elevated concentrations of nutrients without experiencing significant water quality problems. The ability of rivers, such as the Sacramento River, to absorb without significant problems high nutrient loads is related to the turbulence of the river which prevents algae from growing to maximum biomass based on the nutrient loads and accumulating near the surface of the water as floating scum.

While not a problem of the Sacramento River system, the upper reaches of the Delta near Stockton in the San Joaquin River system are experiencing excessive algal growth in some areas where there is limited water exchange - flushing that lead to nuisance growths of blue-green algae and low dissolved oxygen conditions which are detrimental to fish populations.

Impacts of Nutrients on Aquatic Ecosystems

The introduction of aquatic plant nutrients to a waterbody, in addition to stimulating the excessive growth of algae, also stimulates fish production. There is a direct relationship between nutrient loads to waterbodies and fish biomass. However, with increasing fertility, especially at high levels, the types of fish that develop tend to be less desirable, such as rough fish - carp. From a fisheries resource manager perspective, the Delta is characterized as having insufficient primary production (algal growth) to support the desired fish populations. This appears to be related to two factors. First, the short residence time of the water within the Delta before it either leaves the Delta through pumping - export to the Central Valley agriculture and southern California or discharge to San Francisco Bay precludes the development of maximum algal growth based on the nutrients available. However, when Delta waters are allowed to stand in water supply reservoirs for extended periods of time, excessive algal growths occur in these waters.

Another factor that appears to be limiting algal growth within the Delta is the reduced light penetration associated with the discharge of Delta island agricultural waters to the Delta channels which because of the high total organic carbon and its associated color derived from farming of peat soils causes reduced light penetration which slows the rate of algal growth. This may be one of the reasons why the water hyacinths do well in the Delta since they float on the surface.

Another factor that is believed to be influencing secondary and tertiary production (fish growth) in the lower-brackish Delta is the invasion of Delta waters by the Asian clam Potamocorbula which covers substantial areas of the bottoms of some areas. It is believed that these clams are significantly changing the food web within the lower Delta - Upper San Francisco Bay which, in turn, could affect the fisheries resources of the area where the clams are dominant.

One of the often ignored impacts of aquatic plant nutrients on water quality is their impact on sediment toxicity to some forms of aquatic life. Several studies have shown that the primary cause of aquatic sediment toxicity is low dissolved oxygen, and the resultant development of toxic concentrations of ammonia and hydrogen sulfide. For most waterbodies the primary cause of low DO in sediments is the BOD of algae that become part of the aquatic sediments. The algal biomass that causes the sediment DO depletions are usually controlled by the algal N and P input to the waterbody. While, most sediment-based water quality management programs focus on heavy metals and selected organics, aquatic plant nutrients are a far more import cause of aquatic life toxicity than these chemicals.

The relationship between nitrogen and phosphorus loads to the Delta and the desirable aquatic resources within the Delta, such as fish populations, is poorly understood. It could be that substantial changes in nutrient loads would have little or no impact on fish and other desirable forms of aquatic life populations. On the other hand, significantly reducing the nutrient loads to the Delta would be in the direction of improving domestic water supply raw water quality for the water utilities that use Delta waters as a source.

Selection of the CALFED Preferred Diversion Alternative. An area of particular concern that needs immediate attention by CALFED before selecting the preferred alternative for diverting Sacramento River water to the Central Valley and southern California is the impact of these diversions on nutrient-caused and other water quality problems in the Delta, northern San Francisco Bay and in the water supply reservoirs that use Delta water as a primary raw water source. The potential alternative of enhanced flow through the Delta or around the Delta in a

"Peripheral Canal" could significantly change nutrient and other pollutant loads to various parts of the Delta, San Francisco Bay and downstream water supply reservoirs. The potential consequences of the altered approaches for diverting Sacramento River water to central and southern California could significantly impact the Delta's water quality. Of particular concern is the impact of altering the nutrient loads to various parts of the Delta and the Bay on eutrophication-related water quality and fisheries resources.

There is an urgent need for CALFED to place as a high priority for attention the reliable preliminary assessment of the potential consequences of each of the proposed diversion alternatives on Delta water quality. This information should be available before a preferred alternative is selected. Further, CALFED should immediately formulate a technical advisory panel that would develop a monitoring and assessment program that would focus on nutrient water quality-related issues within the Delta and downstream water supply reservoirs. This information is of importance to the Sacramento River system watershed stakeholders since some of these stakeholders may be asked to control nutrient inputs to the Sacramento River system which while not causing water quality problems in the main stem of the River above the Delta, are potentially significant causes of problems within the Delta and water supply reservoirs that use the Delta as a water supply source.

Approach Toward Managing the Problem

There is need to quantify the magnitude, extent and duration of excessive fertilization problems within the Sacramento River system, Delta and in downstream reservoirs used for water supply purposes. Within the Delta there is need to initiate a monitoring program on the areal extent of water hyacinth and excessive attached algal growth which impair recreational uses of the Delta. For domestic water supply problems, the frequency and severity of tastes and odors and other problems and the costs associated with their control should be compiled. This information would provide insight into the magnitude of the excessive fertility of the Sacramento River and Delta waters to the use of these waters for domestic water supply purposes.

An assessment of algal available nitrogen and phosphorus loads to various parts of the Sacramento River watershed and the Delta should be undertaken. Further, the factors controlling excessive growths of algae and water hyacinths within those parts of the Sacramento River watershed and Delta that are experiencing excessive aquatic plant growth should be examined. The ultimate goal of this effort is to develop a nutrient load - excessive fertilization water quality response relationship that can be used to begin to predict the impacts of altering nutrient loads on the water quality problems caused by excessive fertility.

Based on an understanding of algal available nutrient loads and their impacts on water quality, it would be possible to assess the potential benefits in reduced water quality deterioration, as well as the detriments to increased fish production associated with controlling nutrient loads from various sources within the Sacramento and San Joaquin River systems and the Delta to various degrees. Nutrient control from both wastewater and agricultural land runoff is practiced in many parts of the world in order to reduce the excessive fertilization of waterbodies. It is estimated that on the order of 100 million people in the world have their wastewaters treated to remove phosphorus and, in some cases, nitrogen compounds to manage excessive fertilization of waterbodies receiving the wastewater discharges. Further, there are substantial areas of the US, such as in the Great Lakes states and the Chesapeake Bay area, as well as in other countries, where nutrient control from agricultural activities is practiced. A review should be conducted to determine the potential benefits of applying techniques that are being used in other areas to the Sacramento River watershed and Delta in order to manage nutrient loads to the Sacramento River system and Delta.

Suggested Approach

Because of the importance of nutrient-related water quality problems within the Delta and for water utilities using Delta waters, CALFED should provide the funds necessary to develop a technical review panel and consultants to assist the panel to examine the nutrient-related water quality problems within the Delta watershed, Delta and downstream of the Delta. The Sacramento River Watershed Toxics and Monitoring Subcommittees should appoint a panel that would, through CALFED support, conduct a critical review of the existing information on nutrient-related water quality problems within the various parts of the Sacramento River watershed as well as downstream within the Delta. The Sacramento River Watershed Program should include review of the impacts of the nutrients present in the Sacramento River as it enters the Delta since this will become a key issue in justifying any nutrient control programs from Sacramento River watershed sources. The Sacramento River watershed nutrient water quality studies should be closely coordinated with the CALFED activities and should represent the Sacramento River watershed part of the CALFED nutrient water quality studies.

Additional Information

This review is based on a discussion of these issues, "Excessive Fertilization of the Sacramento River Watershed and Delta," currently being developed by Dr. G. Fred Lee. This review contains references to the literature and other information that provides background to the summary generalizations discussed herein. The authors welcome comments or questions on the issues discussed. They are particularly interested in any information that others may have on these issues.

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References

Department of Water Resources, "Water Quality Conditions in the Sacramento-San Joaquin Delta, 1970-1993," Report to the State Water Resources Control Board, Environmental Services Office, December (1996)

Department of Water Resources, "Water Quality Conditions in the Sacramento-San Joaquin Delta During 1994," Report to the State Water Resources Control Board, Environmental Services Office, September (1997).

Jones, R.A. and Lee, G.F., "Chlorophyll-A Raw Water Quality Parameter" J. Am. Water Works Assoc. 74:490-494 (1982).

Lee, G. F., "Eutrophication" Transactions of the Northeast Fish and Wildlife Conference, pp 39-60 (1973).

Lee, G.F. and Jones, R.A., "Effects of Eutrophication of Fisheries," Reviews in Aquatic Sciences, 5:287-305, CRC Press, Boca Raton, FL (1991).

Lee, G.F. and Jones, R.A., "Regulating Drinking Water Quality at the Source, " Proc. University of California Water Resources Center Conference: Protecting Water Supply Water Quality at the Source, Sacramento, CA 39pp, April (1991). Part of this paper has been published in the proceedings as:

Lee, G.F. and Jones, R.A., "Managing Delta Algal Related Drinking Water Quality: Tastes and Odors and THM Precursors," pp. 105-121, April (1991).

Lee, G.F. and Jones, R.A., "Impact of the Current California Drought on Source Water Supply Water Quality," Presented at CA/NV AWWA Fall Conference, Anaheim, CA 30pp, October (1991).

Lee, G.F., Jones, R.A. and Rast, W., "Availability of Phosphorus to Phytoplankton and Its Implication for Phosphorus Management Strategies," In: Phosphorus Management Strategies for Lakes, Ann Arbor Press, Ann Arbor, MI, pp 259-308 (1980).

Lee, G.F., Jones-Lee, A. and Rast, W., "Alternative Approaches for Trophic State Classification for Water Quality Management, Part I: Suitability of Existing Trophic State Classification Systems," Report of G. Fred Lee & Associates, El Macero, CA (1995a).

Lee, G.F., Jones-Lee, A. and Rast, W., "Alternative Approaches for Trophic State Classification for Water Quality Management, Part II: Application of Vollenweider-OECD Eutrophication Modeling Approach," Report of G. Fred Lee & Associates, El Macero, CA (1995b).

Lee, G.F., Jones-Lee, A., and Rast, W., "Secchi Depth as a Water Quality Parameter," Report of G. Fred Lee & Associates, El Macero, CA (1995c).

Winternitz, Leo, Personal communication to G. Fred Lee (1998)