Appendix A

Stage 1 Funded and Implemented Projects

Hydrologic Flow Measurement & Assessment of Organic Loads

United States Geological Survey

End Date 10/31/2002 *Amount:* $300,000.00

Primary objectives for this project include: 1) installation and operation of a continuous flow monitoring station at Hood on the Sacramento River, 2) evaluation of state of the art technology applied to flow calibration frequency techniques to improve hydrologic data for the United States Geological Survey stream gauging station on the San Joaquin River at Vernalis, and 3) assessment of organic loads from watersheds upstream of the Delta for water years 1980–1999.

USGS Water Resources Investigation Report 03-4070 "Organic Carbon Trends, Loads, and Yields to the Sacramento–San Joaquin Delta, California, Water Years 1980–2000" was the primary deliverable. This report found that there were only a few discernable organic carbon trends at the Delta locations investigated and they were slightly downward.

Recovery, Purification, and Utilization of Salts from Agricultural Drainage Water in the San Joaquin Valley

UC Davis

End Date 6/1/2005 *Amount:* $368,421.00

Primary objectives for this project included a comprehensive evaluation of water recovery and salt utilization in the Panoche Drainage District. The US EPA supported, through the DWR, this UC Davis project addressing salt recovery, purification, and utilization. Salt management is essential to sustainability of irrigation dependent agricultural practices and maintaining ecosystem health.

The project investigated recovery and purification processes, designed and built a salt recovery and purification pilot plant, tested plant performance, performed technical and economic modeling, used the produced salt in various industrial applications, and designed a farm scale salt recovery and purification plant. By developing beneficial uses of salts generated from subsurface agricultural drainage waters will likely reduce salt and selenium loads into the San Joaquin River and other water bodies in the State.

Rock Slough and Old River Water Quality Actions Phase I

Contra Costa Water District

End Date 3/1/2002 *Amount:* $450,000.00

Historical measurements show that salinity at Contra Costa Water District's (CCWD) major drinking water intakes at Rock Slough and Old River could at times be significantly higher than in the surrounding delta channels. A number of studies have suggested that nearby agricultural drainage discharges and wet weather runoff events may contain other constituents of concern including organic carbon, pathogens and nutrients.

This was the first in a series of projects with Contra Costa Water District investigating the causes and solutions for salinity increases in the Contra Costa Canal. One of the key findings was that agricultural drainage into Rock Slough and Old River was a significant source of salt and other pollutants. These projects identified three high priority actions; relocation of an agricultural drain on Veale Tract, installation of a diffuser on a Byron Tract drain near the Old River intake, and lining sections of the Contra Costa Canal.

Sources and Magnitudes of Water Quality Constituents of Concern in Drinking Water Supplies Taken from the Sacramento-San Joaquin Delta

Richard Woodard

End Date	9/22/2000	*Amount:*	$45,000.00

This was a preliminary report of baseline water quality conditions for major stream inflows and discharges to Delta waters, for drinking water supply diversions, and for the intakes of the major drinking water suppliers using the Sacramento-San Joaquin Delta.

Even though some of the data quality, aggregation techniques, and statistical analysis of the data where questioned in an independent scientific review, this remains a useful summary of the water quality conditions for the period in question.

Bromate Control with Carbon Dioxide Addition

Alameda County Water District

End Date	12/1/2004	*Amount:*	$120,000.00

ACWD evaluated the design and economic feasibility of carbon dioxide as a pH depression strategy for reducing bromate formation during ozonation of SWP water, and the use of air stripping to remove excess carbon dioxide from the ozone contactor.

The project showed that carbon dioxide gas is a reliable and cost effective means of reducing bromate formation upon ozonation of Delta water, and that its addition is much less complicated than that of hazardous acids such as sulfuric acid.

Integrating Ultraviolet Light to Achieve Multiple Treatment Objectives

Metropolitan Water District of Southern California

End Date	5/30/2005	*Amount:*	$610,000.00

MWD evaluated the ability of ultraviolet light treatment, when integrated with other oxidants such as chlorine, ozone, and chlorine dioxide, to protect public health. It investigated integration of UV light technology with primary disinfectants and conventional treatment process to provide high-quality drinking water from the California SWP.

This study found that UV can effectively be integrated into a conventional treatment process reducing the amount of primary disinfectant needed. The combination of UV and other disinfectants can reduce formation of disinfection byproducts while achieving the required pathogen inactivation.

Resolution of Outstanding Issues in Delta Hydrodynamics and Water Quality Models

East Bay Municipal Utilities District

End Date 5/30/2005 *Amount:* $115,000.00

This project used higher-dimensional models in order to implement new empirical formulations in existing one-dimensional Delta models. The final stage included evaluation of the accuracy of the model results on applications such as carriage water evaluations, impacts of Delta Cross Channel gates operations, and effects on seawater intrusion due to increase in tidal habitats in the Delta.

This project quantified errors and uncertainties and recommended solutions to several existingmodeling issues. In some cases, issues can be resolved with alternative formulations; in other cases, there is a need for targeted studies to better understand hydrodynamic processes. These types of errors can make the models unable to accurately show even relative changes in water quality conditions due to alternative conditions.

Determining the Contribution of Riverine, In-Delta, and Aqueduct Sources of Organic Carbon to Loads in the State Water Project using AMS Carbon Dating and Stable Isotope Characteristics

Department of Water Resources

End Date 12/31/2007 *Amount:* $396,088.00

Department of Water Resources used environmental isotopes of carbon (C), nitrogen (N) and sulfur (S) to trace organic carbon sources in the Delta and determined the contribution of natural organic matter (NOM) derived from peat island soils using Accelerator Mass Spectrometry (AMS). The project evaluated the impact of future Delta alternatives on carbon sources and loads in the SWP. Information regarding the chemical characteristics of organic carbon cycling in the Delta will also be provided.

Improving Delta Drinking Water Quality: Managing Sources of Disinfection Byproduct-Forming Material in the State Water Project

United States Geological Survey

End Date 5/30/2005 *Amount:* $1,368,813.00

US Geological Survey identified and quantified the dominant processes and sources that control the concentration of natural organic matter (NOM) and disinfection byproduct precursor (DBPP) forming materials in the State Water Project. The project also identified mitigation efforts or management actions that may be implemented to reduce the concentration of DBPP-forming materials at water treatment plants.

THMFP correlates with TOC at Banks and Tracy Pumping Plants which have higher average TOC in the wet season when the San Joaquin River dominates. The major sources in the San Joaquin River are Mud Slough and Salt Slough. The San Luis Reservoir is filled when the pumps see the highest concentrations of bromide and TOC. Reduced pumping at Edmonston seems to delay or decrease THMFP at Check 41, and TOC is not well correlated to THMFP at Check 41.

Vernalis Real-Time Water Quality Monitoring Station

Department of Water Resources

End Date 5/31/2005 *Amount:* $628,000.00

Department of Water Resources constructed a water quality monitoring station at Vernalis on the San Joaquin River including a telemetry system.

This water quality monitoring station allows for real-time continuous monitoring of TOC/DOC, bromide, flow and other parameters. Much of this data is available online through the California Data Exchange Center (CDEC). This station provides the boundary condition between the Delta and the San Joaquin River.

Adaptive Real-Time Monitoring and Management of Seasonal Wetlands and the San Luis National Wildlife Refuge to Quantify Contaminant Sources and Improve Water Quality in the SJR

Berkeley National Laboratory

End Date 5/31/2005 *Amount:* $375,854.00

Berkeley National Laboratory and collaborators constructed and maintained monitoring station systems at San Luis National Wildlife Refuge to evaluate managed wetland drainage and water quality. Data obtained from this study was used to develop a multi-objective habitat evaluation and salinity management program to optimize wetland functions and minimize water quality impacts on the San Joaquin River.

This project explored the potential for adjusting the timing of discharges of water from managed wetlands to reduce impacts on water quality in the San Joaquin River. This would allow the large State and federal refuges in the San Joaquin Valley to participate in the DWR led real-time salinity management program. The project had to consider salt accumulation in soils, plant species, and bird utilization of these areas to develop discharge protocols that still meet refuge bird habitat objectives. The project successfully demonstrated methods for coordinated discharge from wetlands to reduce water quality impacts.

Agricultural Drainage Treatment: Intermediate-Scale Experiments Phase I

Panoche Drainage District

End Date 12/1/2002 *Amount:* $296,686.00

UC Berkeley developed an Algal-Bacterial Selenium Removal (ABSR) process to remove selenium and nitrogen from subsurface agricultural drainage in the Panoche Drainage District. This project constructed, operated, and monitored a 16-fold scale-up (1 acre-foot/day or 220 gpm) ABSR facility at a site adjacent to the existing ABSR pilot facility.

North Bay Aqueduct Alternative Intake Study

Solano County Water Agency

End Date 5/30/2004 *Amount:* $188,560.00

SCWA conducted an engineering cost and environmental analysis of an alternate intake for the NBA.

Construction of an intake at one of the preferred locations was estimated to cost $151 million to $179 million when the study was done in 2004.

NBA Ion Exchange for Organic Carbon Removal

Solano County Water Agency

End Date 9/30/2004 *Amount:* $490,419.00

SCWA evaluated ion exchange resins as an advanced pretreatment process to remove organic carbon from North Bay Aqueduct water, which could substantially reduce disinfection byproduct (DBP) formation. Project included bench scale and pilot tests.

The MIEX ion exchange resin was effective in reducing organic carbon concentrations but costis a factor.

Little Panoche and Cantua Creek Watersheds

Westside Resource Conservation District

End Date 5/30/2004 *Amount:* $200,000.00

WCRD conducted assessments of Little Panoche and Cantua Creek watersheds to identify and quantify significant sources of sediment and selenium, as well as erosion and transport mechanisms that affect land use in the Valley floor and water quality in the California Aqueduct.

WCRD identified BMPs for future implementation of projects that may affect the quality of water for Bay Delta users. Assessment of effectiveness was difficult because there was almost no runoff during the study.

Full Scale Demonstration of Agricultural Drainage-Water Recycling Process Using Membrane Technology

WaterTech Partners

End Date 7/1/2004 *Amount:* $319,993.00

WATERTECH Partners and UC Davis used nanofiltration as a hardness preferential precipitation pretreatment to reverse osmosis (RO) for the removal of salts including selenium from agricultural drainage water at Panoche Drainage District. The existing 250-gpm RO plant (equivalent to 1.0 AF/day) with nanofiltration was the only full-scale drainage-water treatment facility in existence in the San Joaquin Valley at the time. The project was funded by the CBDA Ecosystem Restoration and Drinking Water Quality Programs.

This project successfully demonstrated a new membrane treatment system for removal of salt, selenium, boron, and other pollutants from agricultural drainage water. The project overcame the usual membrane fouling problems encountered with this waste stream by removing salts as they precipitated.This results in a manageable 10% concentrated brine waste stream that can then be evaporated.

Investigating In-situ Low Intensity Chemical Dosing to Decrease Delta Waters DOC Concentrations and DBP Precursors while Accelerating Wetland Peat Accretion Rates and Reducing Flooding Risks

United States Geological Survey

End Date 3/1/2009 *Amount:* $1,534,270.00

USGS will investigate in-situ low intensity chemical dosing of coagulants in constructed wetlands to retain dissolved organic carbon and reduce DBP precursor discharges from island agricultural drainage to the Delta. Settling of coagulant floc in the wetland may provide additional mineral sediments to the wetland system, and, if the wetland is placed along the toe of the island levee, may provide stabilization and lower flooding risk. Project is funded by CBDA Ecosystem Restoration and WQ Programs.

Dairy Nutrient Management

East Stanislaus Resource Conservation District

End Date 4/30/2005 *Amount:* $271,930.00

This project addressed the challenges of disposing of dairy wastes by providing personalized engineering and training assistance to dairy operators to help set up infrastructure to manage their nutrients, training them in its use, and by using affordable computer technology to automate the massive recordkeeping tasks.

This project assisted dairy producers in implementing management practices to apply nutrients at agronomic rates.

Determining Mitigation Strategies to Prevent Contaminants from Animal Feeding Operations from Entering Drinking Water Sources

Merced County Division of Environmental Health

End Date 3/31/2008 *Amount:* $568,000.00

Merced County Division of Environmental Health and cooperating entities are assessing the occurrence and processes that control the fate and transport of pathogens, antibiotic resistant pathogens, pharmaceutically active compounds, endocrine disruptors and other organic waste products derived from animal feeding operations. Merced County is also collecting and analyzing samples from hydrologic pathway compartments including soils, drainage water and shallow groundwater, and using these assessments to evaluate animal waste stream management practices to prevent contaminants from reaching drinking water supplies in the San Joaquin Valley.

The objective of this project is to gain a better understanding of the presence and transport of pathogens and pharmaceuticals in groundwater in animal feeding operations. This understanding and knowledge will then provide a scientific basis for management of water quality in the Califorina Central Valley.

County of Tuolumne Water Quality Plan

Tuolumne County

End Date 6/1/2005 *Amount:* $182,995.00

This project assessed the adequacy of the current County Codes, land use designations, and management practices used by the County to limit impacts to water quality from storm water runoff and nonpoint source pollution; to develop a Water Quality Plan with conditions, mitigating measures or best management practices to be utilized to reduce the impacts to water quality; and to monitor their effectiveness following implementation of the Water Quality Plan, through amendments to the Tuolumne County Ordinance Code.

The Water Plan addresses storm water runoff and nonpoint source pollution impacts on water quality within Tuolumne County's watersheds.

Assessing the Occurrence and Sources of E.coli and EC 0157 Contamination in Castaic Lake

Metropolitan Water District of Southern California

End Date 3/31/2006 *Amount:* $609,500.00

This project conducted a thorough microbial monitoring and molecular fingerprinting study in the watershed to improve source water quality, identify sources of nonpoint pollution, protect public health, and implement best management practices to reduce/eliminate coliform contamination. It assessed the sources and loads for recent increases in E.Coli levels in the Castaic Lake watershed.

Fences were constructed to minimize cattle access to the watershed. Birds (gulls) were also identified as a significant source of pollutants and steps were taken to reduce the numbers using the lake.

Lake Perris Pollution Prevention and Source Water Protection program

Metropolitan Water District of Southern California

End Date 3/31/2006 *Amount:* $1,390,800.00

This project examined and may eventually implement solutions to nonpoint source pollution water quality constraints that limit the use of Lake Perris to meet several CALFED objectives. The primary finding of this project is that body contact recreation was a significant source of pathogens in Lake Perris. Seismic safety concerns required that the water level be lowered for repairs. Because the lake was partially drained, this project was terminated before implementation of the preferred solution.

North Bay Aqueduct Watershed Best Management Practices

Solano County Water Agency

End Date 7/1/2005 *Amount:* $399,608.00

This project implemented a major recommendation from a prior grant to build a fence around selected NBA watershed channels to stop livestock from entering. With the exclusion of livestock in the watershed channels, there is expected to be a measurable improvement in turbidity and pathogens over time.

This project also successfully implemented alternate water supply management practices along much of the channel upstream from the Barker Slough Pumping Plant.

Control of Agricultural Runoff

Turlock Irrigation District

End Date 3/1/2006 *Amount:* $742,000.00

This project implemented a program focused on ensuring that the grower has both physical and operational tools necessary to meet water quality standards at the point where it leaves the field and enters the TID system. The program also included a water quality monitoring component to measure the effectiveness of the program in meeting the established goals; and an education component to provide growers information on irrigation management practices that can be implemented to control the quantity and quality of agricultural return flows.

Water quality improvements in agricultural drainage generated by the project benefited all downstream uses of the San Joaquin River.

The Water You Play in is the Water You Drink

Contra Costa County Clean Water Program

End Date 3/31/2007 *Amount:* $982,655.00

The CWP developed and implemented a comprehensive, long-term public outreach and education program and established a marina BMP pilot program, focusing on reducing contaminant loading associated with marinas, water contact sports, and recreational boating that affect drinking water quality in Delta waterways.

The project installed boat waste recycling facilities, distributed clean boating kits during two boating seasons, created an environmental services map for distribution, and monitored high recreation areas for water quality impacts. Recreational impacts on drinking water quality are relatively minor.

Steelhead Creek Drinking Water Quality Study and Watershed Assessment (NEMDC)

Department of Water Resources

End Date 9/30/2006 *Amount:* $595,131.00

This project addressed the water quality problems associated with rapid urbanization in the Steelhead Creek (the Natomas East Main Drainage Canal [NEMDC]) watershed and its largest tributary, Dry Creek, using an integrated approach of monitoring flow and water quality, assessing land use change, evaluating upper watershed stressors affecting water quality, and identifying solutions for improvement.

This data will also ultimately be used to model the contributions of organic carbon and other parameters from this and other similar types of urban discharges to the Delta and major water project intakes.

Salt & Martinez Creeks Watersheds Assessments

Westside Resource Conservation District

End Date 6/30/2005 *Amount:* $200,000.00

The purpose of the proposed project is to assess the Salt Creek and Martinez Creek watersheds for contaminant issues and overall watershed health and management as related to public health concerns for downstream water users.

This assessment will be used as the basis for future implementation projects in the watersheds that may effect the quality of water for SWP users.

Orestimba Creek Watershed – Agricultural Water Quality Pilot Project

Coalition for Urban/Rural Environmental Stewardship

End Date 3/1/2006 *Amount:* $275,000.00

The project evaluated possible irrigation return flows pollutant control actions and promoted cooperative efforts in identifying and implementing the most appropriate site-specific reduced risk practices. It developed a mathematical model and used the assessment and the environmental fate model to evaluate current manure management practices. Stakeholders were informed of the critical processes controlling the fate of the constituents studied and of effective mitigation strategies identified.

The project evaluated the cost of various management practices for reducing pollutant runoff from irrigated agriculture and started a program to encourage local farmers to adopt and implement cost effective practices. Local cost information, cost information from the literature, and load reduction information from the literature were combined to in their reports on management practices. Implementation of a monitoring and BMP implementation program is continuing, supported by additional SWRCB grants.

Reducing Non-point DOC and Nitrogen Exports from Rice Fields: A Pilot Study and Quantitative Survey to Determine the Effects of Different Hydrologic and Straw Management BMPs

Contra Costa Water District

End Date 3/31/2006 *Amount:* $869,715.00

The study assessed DOC, DBPPs and N loads from rice production; compared these export rates with those of wetlands and corn (the other primary Delta land practice alternatives); and determined if these loads can be further reduced. Based on the study findings, relevant BMPs to minimize exports of DOC, DBPPs and N could be developed.

This project explored the potential for reduction in DOC discharge and subsidence on Delta islands from growing rice as an alternative to corn. The project found that new rice varieties grow well in the Delta making it a viable crop but DOC loads were highly variable. Water management, specifically the amount of field overflow, was the key factor determining annual DOC load. The complex water supply and drainage networks on Delta islands made flow and water level management challenging. At the lowest flows, rice produced less DOC than corn.

Real-time Continuous Monitoring of Bromide and Nutrients at H.O. Banks Pumping Plant and SJR at Vernalis

Santa Clara Valley Water District

End Date 5/1/2005 *Amount:* $274,556.00

This project will expand the range of water quality parameters currently being measured in real-time at critical points in the Delta and State Water Project by installing continuous ion chromatographs (IC) at the H.O. Banks Pumping Plant on the State Water Project (Phase I) and at Vernalis on the San Joaquin River (Phase II).

These continuous real-time analyzers have been installed and are working. DWR's Municipal Water Quality Investigations program has been operating these units and provides the data in their Real Time Data and Forecasting Project weekly water quality report. The units have had some operational problems but have provided previously unavailable high frequency chloride, fluoride, bromide, sulfate, and nitrate data.

CBDA Rock Slough and Old River Water Quality Improvement Projects Phase III

Contra Costa Water District

End Date 6/1/2005 *Amount:* $1,300,000.00

This project conducted additional investigation and identification of ways of reducing WQ degradation to Delta urban water users by reducing impacts from local agricultural drainage. It also developed BMPs. This project identified the Rock Slough and Old River agricultural drainage projects and lining Contra Costa Canal as the highest priorities for implementation.

CCC Encasement Project

Contra Costa Water District

End Date 9/30/2009 *Amount:* $7,313,000.00

This project includes design and construction to encase the first 1900 feet of the Contra Costa Canal. This is another of a set of projects identified through CALFED funded studies of local impacts on drinking water quality in eastern Contra Costa County.

Reductions in salinity at Contra Costa Canal Pumping Plant #1 will be significant and measurable after the project is completed. The project will eliminate a long standing problem of saline groundwater infiltration into an unlined portion of the canal. This project encloses the first 1900 feet of the canal but CCWD plans to extend the lining project to enclose the entire unlined portion of the canal, a total of approximately 3.9 miles.

Irvine Desalter Project

Irvine Ranch Water District

End Date 7/24/2007 *Amount:* $1,200,800.00

The Irvine Desalter Project pumps mineral rich groundwater to a reverse osmosis water treatment plant for demineralization prior to treatment to make it suitable for domestic use. The project also helps to protect downgradient wells from migration of poor quality water.

East San Joaquin Water Quality Framework

San Joaquin River Group

End Date 3/31/2007 *Amount:* $3,031,689.00

This project has implemented a cooperative strategy to coordinate, manage and conduct a water quality monitoring program in the East San Joaquin Valley that supports the identification and quantification of both point and nonpoint sources of pollutants pursuant to meeting water quality objectives.

The project identified potential sources of constituents of concern: flushing of organic debris (TKN), fertilizers and sewage (phosphorus), but other sources are less clear (organic carbon, nitrate).

Development of a Watershed Management Program for the South Bay Aqueduct System

Alameda County Water District

End Date 3/31/2008 *Amount:* $240,594.00

The goals of this project include establishment of an ongoing forum for watershed stakeholders to discuss management issues through the Watershed Workgroup, development of a functioning Watershed Management Program for the SBA System Watershed, development of a long-term strategy for SBA system watershed management and completion of a written Watershed Protection Program Plan, and heightened awareness in the local community about watershed protection and Best Management Practices (BMPs) through

This project is designed to protect Delta water quality from further degradation in Bethany Reservoir, along the open portions of the SBA, and in Lake Del Valle. The project includes baseline and wet season monitoring, development of a watershed protection plan, educate the public, and establish a watershed work group. The project has clarified the potential pollutant sources to the SBA and has developed educational materials and management practices to address them.

Agricultural Discharge Management Program Monitoring and Evaluation - West Stanislaus County

San Joaquin Valley Drainage Authority

End Date 7/31/2008 *Amount:* $1,321,250.00

This project is examining and evaluating four BMP strategies currently being used in the region for the control of sediments and pesticides: in-field practices, ponds, vegetated biofiltration systems, and constructed wetlands.

This is a follow-on project to the previously funded Orestimba Creek project. The goals are to enhance and consolidate monitoring efforts and to conduct water quality effectiveness evaluations of agricultural drainage management practices in use in this area.

Source identification, monitoring and outreach for reducing agricultural pathogens into the Sacramento-San Joaquin Delta Estuary

UC Davis School of Veterinary Medicine

End Date 3/1/2008 *Amount:* $899,776.00

This project will identify animal agricultural operations that contribute bacteria to the sloughs of the eastern Delta, develop and extend beneficial herd management practices that reduce protozoa contamination, develop regulatory guidance for more effective use of bacterial indicators, and enhance the ability of local communities, regulatory agencies, conservation groups, and agricultural managers to effectively monitor water quality and implement intervention strategies.

This project is monitoring pathogen indicators and pathogens in sloughs and tributaries in the eastern and northwestern Delta. The project will identify any linkage to animal agriculture in these areas and work with local ranchers and farmers to implement BMPs. The application of state-of-the-art analytical methods will help with assessment of microbial pathogen threats to Delta water supplies.

Long Term Risk of Groundwater and Drinking Water Degradation from Dairies and Other Nonpoint Sources in the San Joaquin Valley

UC Davis

End Date 2/20/2010 *Amount:* $1,557,661.00

This project addresses nonpoint source contamination of groundwater in the San Joaquin Valley dairy regions. Specifically, nitrate, salinity, and microbial pathogens are of concern. The project meets critical source and ambient groundwater monitoring needs in Stanislaus/Merced County and Tulare/Kings County.

This project is seeking to quantify the impacts of dairies on groundwater quality in the Central Valley with a focus on nitrate contamination. The project will use multi-level monitoring wells and models of groundwater movement to attempt to focus in on specific dairy manure management practices.

Hydrologic Flowpaths in Oak Woodland Landscapes: Implications for Dissolved Organic Carbon and Nutrient Transport

UC Davis

End Date 3/31/2008 *Amount:* $355,633.00

This project is investigating the temporal and spatial dynamics of hydrologic flow paths across landscapes of four watersheds having different management strategies in the Sierra Nevada Foothills Research and Extension Center. This project will study how these flow paths influence the export of dissolved organic carbon and nutrients to surface water bodies.

This project will monitor and quantify DOC and nutrients (N & P) loads in streams and hydrologic flow paths of four watersheds with contrasting management practices (control, low intensity grazing, high intensity grazing and prescribed fire) that ultimately feed the Delta and Central Valley water bodies.

The Drinking Water Education Program

Water Education Foundation

End Date 3/31/2008 *Amount:* $479,952.00

The Drinking Water Information Program addressed the public's perception that tap water is not safe to drink through the development and dissemination of a full-length documentary, a summary video, a "Where Your Drinking Water Comes From" website, and one minute radio spots to help reduce NPS pollution and improve water quality.

This project produced and ran radio ads in January 2007, produced a website in 2006 (on the WEF website), and produced a documentary video which was scheduled to air in May 2007.

Implementation of Buffer, Irrigation, and Grazing BMPs to Reduce Pathogens, TOC/DOC, and Turbidity from Rangelands and Irrigated Pastures

UC Davis

End Date 3/31/2009 *Amount:* $886,133.00

Current grazing and irrigation practices on the ~7,000,000 acres of rangeland and 500,000 acres of irrigated pasture in the Sacramento and San Joaquin River Watersheds is contributing to elevated microbial pathogen, organic carbon and colloidal pollutants levels in surface runoff. More information in required to provide guidance on the effective implementation of integrated buffer, grazing, and irrigation BMPs to reduce these pollutants in runoff from these landscapes. This project will develop this knowledge, translate it into specific BMPs, and extend these recommendations to water resources protection staff and land

This project will improve water quality from irrigated pasture and rangeland through a systems approach which implements not only vegetative buffers, but simultaneously implements improved irrigation and grazing management.

Harding Drain Watershed Agricultural and Urban Impacts-Evaluation Education and Outreach

Turlock Irrigation District

End Date 3/1/2008 *Amount:* $1,368,000.00

More data and information are needed on water quality in the Harding Drain and activities within the watershed to address existing impairment and pollutant loadings from the drain to the San Joaquin River. Although relatively extensive data have been collected at the mouth of the Harding Drain under a variety of programs, there has been no comprehensive assessmentof water quality conditions and sources within the watershed.

A comprehensive understanding, including both existing and new data, is needed to guide implementation of actions to improve water quality, through a Watershed Plan. This project willprovide a detailed assessment of water quality, development of a watershed plan, education and outreach through a Watershed Coordinator, and on-site consultation on BMPs for the Harding Drain Watershed.

Development and Implementation of Ricefield Management Practices to Improve Water Quality

UC Davis

End Date 3/31/2009 *Amount:* $1,157,763.00

Recent changes in cultural practices including straw, pest and irrigation management all have potential impacts on the quality of downstream waters for TOC, turbidity, pesticides and nutrients. The switch from field burning to winter flooding for straw management, seeding, and pest management practices are being evaluated. This project is developing and implementing management practices to mitigate the impact of rice field tail water to protect drinking water quality.

The project is finding that alternative rice culture methods such as drill seeding and no-till work well and may have weed management and nitrogen management advantages.

Management of DOC, DBPP and nutrients loads from major agricultural land uses and development of BMPs

United States Geological Survey

End Date 3/1/2008 *Amount:* $4,208,707.00

Little is known about the effects of management practices on drinking water constituents of concern from agricultural systems, and whether active management in watersheds will help. Confounding our understanding of the importance of agricultural activities in producing DWCCs is the dearth of information regarding potential export and influence on aquatic processes leading to the production of water quality constituents of concern. This project is investigating in detail the processes and pathways resulting in the export of drinking water constitiuents from the Willow Slough watershed in Yolo County.

Early results suggest that organic carbon spikes occur in winter storms (7-8 mg/L) and this organic carbon has a higher aromatic content from terrestrial sources. Irrigation season organic carbon is largely from plant/algal growth in drainage channels.

Evaluating BMP Effectiveness to Reduce Volumes and Improve Quality of Runoff from Urban Environments

UC Davis, Department of Environmental Horticulture

End Date 3/1/2008 *Amount:* $2,900,350.00

This project will quantify the effectiveness of best management practices implemented in residential landscapes to reduce dry season runoff volume and the pesticides, drinking water pollutants, and mercury loads in the runoff. This study takes place in Sacramento and Orange Counties and will include an economic assessment of the cost effectiveness of BMPs utilized to reduce pollution.

The goals of this project are to characterize pollutant loads from low density urban development during dry weather and early wet season periods and to evaluate BMPs. The project team will evaluate landscaping and educational BMPs and will do an economic evaluation of BMPs. The project has installed monitoring stations at selected urban watersheds in both Southern and Northern California. The monitoring program has collected samples over a range of flow conditions and has analyzed them for a long list of constituents. Initial findings show the consistent presence of pathogen indicators and pesticides in urban runoff. All sites include flow measurement allowing for load calculation.

Demonstration of on-farm vegetated buffers for reducing NPS pathogen pollution into tributaries of the Fresno and San Joaquin Rivers

Coarsegold Resource Conservation District

End Date 3/1/2007 *Amount:* $341,761.00

This project developed and implemented on-farm vegetated buffers as a demonstration project for how to reduce microbial contamination of foothill tributaries draining into the Fresno and San Joaquin Rivers. The grantees also conducted field days, workshops, and developed training manuals for how to install and monitor vegetated buffers and how to better monitor pathogen water quality from non-irrigated pasture runoff.

Dominguez Gap Wetlands Multiuse Project

Los Angeles County Flood Control District

End Date 12/31/2007 *Amount:* $2,350,000.00

The Dominguez Gap Spreading Grounds is owned and operated by the County of Los Angeles Department of Public Works and consists of two basins, one on each side of the Los Angeles River. This project developed extensive wetland and riparian habitat in the east basin to enhance water quality before infiltration in the west basin.

Evaluating the Drinking Water Impact of Wetland Derived Organic Carbon

Lawrence Berkeley National Laboratory

End Date 3/31/2008 *Amount:* $465,750.00

The hypothesis of this research is that different wetland management practices will result in different water quality outcomes and that these management practices will have a significant impact on the quantity and quality of the organic carbon that is released when the wetlands are drained.

Average loads of TOC, DOC, VSS, TSS and nutrients from the San Luis National Wildlife Refuge are less than 10% of the loads observed in the San Joaquin River at Lander Avenue. Salt Slough loads are an order of magnitude greater than wetlands, but wetland drainages can have significantly higher concentrations of OC and other constituents than source waters and agricultural drains. The THMFP of wetland organic carbon seems to be decreased by biological activity in natural water bodies.

Development of new isotope tools for assessing sources of organic matter and nutrients in the SJR

United States Geological Survey

End Date 2/28/2008 *Amount:* $844,000.00

This project will use an isotopic and chemical mass balance approach to determine the temporal and spatial variations in the relative contributions of different sources of nutrients and organic matter to the San Joaquin River-Delta-Bay system, with special focus on the critical reach upstream of Vernalis.

Delta POM is most likely a mixture of algal and terrestrial materials, the San Joaquin River seems to discharge a larger fraction of new algal material and this material either degrades and/or mixes with older or more terrestrial POM as it moves through the Delta and into the Bay. Isotopic tools are useful for determining these sources.

Evaluation of groundwater nitrate and organic carbon inputs to the lower San Joaquin River and their sources

United States Geological Survey

End Date 2/1/2008 *Amount:* $977,500.00

This project uses three approaches to quantify nitrate and DOC in groundwater accretions and determine the sources and loads of these constituents.

This project is still in its early stages. Algal blooms increase POC and DOC. The San Joaquin River tends to have low DOC in April, high during winter which is generally associated with storms (surface runoff) and possibly wetland drainage. Tributary loads are small compared to mainstem loads.

Watershed Monitoring and Technical Studies to Support Development of Central Valley Drinking Water Policy

California Urban Water Agencies

End Date 3/31/2008 *Amount:* $970,000.00

This project involves conducting the technical studies needed to develop a drinking water policy for the Central Valley. The technical studies include review of existing data, developing and conducting a water quality monitoring program to fill data gaps, conducting a source loading analysis for selected constituents of concern, identifying and evaluating potential control strategies for those constituents, reviewing what other states and countries have done to protect drinking water supplies, and conducting a stakeholder outreach program.

Upon completion, the project will result in a Basin Plan Amendment that will include a policy for protecting drinking water quality in the Sacramento/San Joaquin/Delta watershed.

Bay Area Blending and Exchange Project

CBDA

End Date 12/1/2004 *Amount:* $1,300,000.00

The Bay Area Blending/Exchange (BAB/E) project was established to identify regional opportunities for enhancing water supply and/or water quality for Bay Area agencies, with a goal to help achieve CALFED water quality and water supply reliability objectives.

This project contributed to development of two IRWMPs. Actions evaluated included interties, surface water storage, groundwater storage and conjunctive use, enhanced conservation, water recycling, desalination and conveyance actions.

CBDA Drinking Water Quality Program Support and Workshops

National Water Research Institute:

End Date 5/30/2005 *Amount:* $100,000.00

The National Water Research Institute provided support to CALFED Water Quality Program (WQP) by conducting two activities, peer reviews of CALFED WQP funding proposals and conducting a Nominal Group Technique workshop and following activities to provide a definition of what an “equivalent level of public health protection” means related to numerical objectives for TOC and bromide concentrations in Delta drinking water supplies.

San Joaquin Valley Water Quality Exchanges Project

Metropolitan Water District of Southern California

End Date 3/8/2009 *Amount:* $20,000,000.00

MWD is developing water supply and water quality exchange agreements with local purveyors to improve the quality of water Metropolitan receives via the California Aqueduct.

To date approximately $3.6M has gone primarily to studies to identify potential projects and partnerships. It is expected that of the remaining $16.4M, approximately $16.2M will be spent on the Arvin-Edison South Canal Improvement Project and $0.2M on continuing studies. The South Canal expansion will allow MWD to recover greater quantities of low TOC and bromide ground water supplies when retrieving previously stored groundwater from the existing Arvin-Edison/ Metropolitan Water Management Program. These high quality supplies will be delivered to the California Aqueduct primarily during the fall and winter months when Metropolitan's SWP water supplies have relatively higher TOC and bromide levels.

San Luis Drain Oxygen Demand Reduction Project

Grassland Basin Drainers (San Luis & Delta Mendota Water Authority)

End Date 3/31/2006 *Amount:* $145,680.00

This project studied algae growth in the San Luis Drain with the objective of understanding factors controlling algal biomass and TOC production in this system.

The hyopothesis was that the San Luis Drain inoculates the San Joaquin River algal production, and therefore it would be good to reduce algae in the San Luis Drain. This study suggests light availability is not limiting algal growth in San Luis Drain. Nutrient limitation plays an important role, but a density dependent decay component is needed to describe the decline of algal biomass. Additional monitoring will explore the active grazing populations.

Sacramento Valley Regional Water Quality Management

Butte County

End Date 5/31/2005 *Amount:* $249,330.00

This project explored the process and institutional issues of regional planning as well as the quality, uses, and impacts on drinking water sources. The project also developed a drinking water quality strategy and identified associated implementation activities.

The project improved coordination of water supply and water quality activities in the four participating Sacramento Valley counties.

Development of a Delta Region Drinking Water Quality Management Plan

Contra Costa Water District

End Date 5/31/2005 *Amount:* $250,000.00

The objectives were to understand existing and future water quality conditions at Delta urban intakes, identify challenges and issues confronting agencies diverting water from the Delta, and developing projects and programs at local, regional, and statewide levels to address these issues and meet their water quality goals.

CCWD's primary issue is high bromide at their intakes, SCWA's primary issue is high turbidity and organic carbon at their intake, the City of Stockton's proposed intake has low bromide and organic carbon. At a regional level, this project identified opportunities for regional advanced treatment studies and cooperation on technologies to reduce the capital costs of conveyance construction.

Development of the Southern California Regional Drinking Water Quality Management Plan

Metropolitan Water District of Southern California

End Date 5/31/2005 *Amount:* $250,000.00

Multiple southern California agencies developed an analytical framework to use in evaluating water quality tools, actions, and strategies.

The project confirmed that disinfection byproduct precursors are a problem in imported Delta waters, prepared sample strategies to achieve CALFED objectives, and estimated the associated cost.

UV Light and Multiple Disinfectants

Contra Costa Water District

End Date 12/31/2007 *Amount:* $715,000.00

This project addressed a long-standing problem for drinking water utilities that use brackish source waters, such as those found in the Bay-Delta. The temporal and seasonal variations in water quality, especially for bromide and organic carbon, make treatment to comply with USEPA drinking water standards very difficult. As utilities strive to comply with increasingly stringent regulations, they must find ways to modify and extend the performance of their existing treatment facilities. This has been a particular issue in the CALFED Bay-Delta drinking water discussions, but is also a concern in the Chesapeake Bay, Tampa Bay and other areas in the country where water sources have seawater influence. The project identified inter-linked treatment approaches that can successfully treat these waters to meet drinking water standards and protect public health but showed that there are limits to what these treatment technologies can do.

San Joaquin River Water Quality Improvement - Reuse Development

Panoche Drainage District

End Date 3/31/2007 *Amount:* $389,500.00

The proposed project installed a subsurface drainage collection system and planted approximately 270 acres of salt tolerant crops that will be irrigated with subsurface drain water produced within the Grassland Drainage Area. Observation wells were installed to monitor the water levels through the life of the project and beyond. Upon project completion and maturity of the planted crops, subsurface drain water that currently is discharged to the San Joaquin River via the Grassland Bypass Project will be diverted to the project. This will decrease in the subsurface drainage water volume that reaches the SJR.

Lower Kellogg Creek Biofilter/Retention Pond Implementation Project

Reclamation District 800

End Date 3/31/2008 *Amount:* $894,500.00

This project will construct a biofilter/retention pond in lower Kellogg Creek to remove contaminants prior to discharge into the Sacramento-San Joaquin Delta. Most of the year, flows in lower Kellogg Creek are sustained by agricultural runoff and other rural runoff in the Kellogg Creek watershed. These flows are known to convey sediment with varying levels of toxicity, as well as other dissolved contaminants to the Delta.

The goal for this project is to construct a sediment trap/biofilter on Kellogg Creek near the town of Discovery Bay in the southwest Delta. The system will pass most Kellogg Creek water through the system during the irrigation season yet will not restrict flows during flood events.

Real-Time, Salt and Nutrient Drainage Load Reduction Strategies - Patterson & West Stanislaus Irrigation Districts

Patterson Irrigation District

End Date 3/31/2008 *Amount:* $997,000.00

A local partnership program named the Southwest Stanislaus County Regional Drainage Water Management Program has been developed and implementation of projects to meet water quality goals has begun with initial financial assistance from the CALFED Water Use Efficiency Program. Program and individual project goals are geared specifically to: a) reducing the salt loading to the San Joaquin River (SJR); b) reducing Organophosphorus (OP)Pesticide levels in the drainage water discharged to the San Joaquin River; c) reducing constituents adversely affecting the dissolved oxygen level within the San Joaquin River; and d) developing new water supplies through construction of operational spill and tailwater recovery systems to further improve the local efficiency of water management. This grant proposal is being submitted by two members of the Southwest Stanislaus County Regional Drainage Water Management Program; Patterson Irrigation District (PID) and West Stanislaus Irrigation District (WSID).

The main objectives of this project are to plan, design, and construct a drainage detention andreuse reservoir and other agricultural drainage management actions in west Stanislaus County to control salt and nutrient loading to the San Joaquin River. Construction has begun on the reuse reservoir, the biggest ticket item in the project. This reservoir is the kind of infrastructure needed in the San Joaquin Valley for effective real-time salinity management.

Adaptive, coordinated real-time management of wetland drainage

Grassland Water District

End Date	3/31/2008	*Amount:*	$998,029.00

This proposal expands a pilot research project that was started under CALFED Ecosystem Restoration Funding by the Grassland Water District (GWD), into the State wildlife management areas. The proposed project implements real-time salt management for the first time in two duck clubs within the GWD and in two seasonal wetlands within the Los Banos Wildlife Management Area. Each site to be operated in response to San Joaquin River assimilative capacity load targets for salt will be paired with a site managed using conventionalpractices and drawdown patterns. A coordinated, real-time flow and water quality monitoring program will be designed and implemented at all project sites – these data will be telemetered, quality-checked, and made publicly available through the existing web site maintained by the Grassland Water District.

The project will calculate and forecast available assimilative capacity for salt in the San Joaquin River.

Measuring the Effectiveness of Agricultural Management Practices On Water Quality in the Legal Delta and Its Tributaries In San Joaquin County

San Joaquin County Resource Conservation District

End Date	2/28/2009	*Amount:*	$842,125.00

This project is using water quality monitoring to measure the effectiveness of agricultural best management practices (BMPs). The evaluation will focus on the effectiveness of BMPs designed to address the following combination of categories: erosion and sediment control, nutrient management, pesticide management, education and outreach, and irrigation water management.

Application of Beneficial Management Practices to Reduce Runoff from Irrigated Agriculture

Contra Costa Resource Conservation District

End Date	2/29/2008	*Amount:*	$313,766.00

This project is implementing and evaluating the effectiveness of beneficial management practices (BMPs) on strategic irrigated agricultural sites using one or more conservation practices at each site. The BMPs include erosion and sediment control measures, and irrigation water management measures, from a selected list of nine conservation practices. The goal is to reduce or eliminate runoff from irrigated lands in eastern Contra Costa County.

Water quality monitoring before and after BMP implementation will be used to assess the effectiveness of selected BMPs. This project is the source improvement element of the CALFED efforts to improve water quality in the southwest Delta.

Agricultural Drainage Control Project

Stevinson Water District

End Date 2/28/2009 *Amount:* $603,300.00

This project is constructing artificial wetlands and ancillary facilities to control discharges of agricultural drainage and storm water to the San Joaquin River. The wetlands will recharge groundwater, allow for reuse of stormwater/drainage, and release water to the San Joaquin River during periods of higher assimilative capacity for salt.

Monitoring Constructed Wetlands to Improve Water Quality of Irrigation Return Flows

UC Davis

End Date *Amount:* $500,000.00

This project has identified several constructed wetlands receiving agricultural drainage in the Central Valley and has installed monitoring stations to help determine the effectiveness of this widely used management practice. The project is looking at general water quality constituents such as organic carbon, suspended solids, and a long list of other contaminants including pesticides. Sediment and groundwater pathways are also being investigated.

CBDA Rock Slough and Old River Water Quality Improvement Projects Phase III

Contra Costa Water District

End Date 6/30/2006 *Amount:* $2,825,000.00

One of a series of projects to identify ways of improving water quality at Contra Costa Water District intakes by reducing impacts from local agricultural drainage. This project re-routed agricultural drainage away from Rock Slough and installed a diffuser on an agricultural drain near CCWD's Old River intake. These two projects measurably reduced the impact of these discharges on Contra Costa Water District's Rock Slough and Old River intakes. Although expressed primarily as reduction in chloride concentration, these projects addressed all pollutants including salinity, organic carbon, turbidity, nutrients and pathogens.

Delta Cross Channel & Through Delta Facility Studies

Department of Water Resources

End Date 10/1/2006 *Amount:*

This package of studies is designed to address two CALFED ROD objectives: 1) Evaluate and implement improved operational procedures for the Delta Cross Channel (DCC) to address fishery and water quality concerns. 2) Simultaneously evaluate a screened through-Delta facility on the Sacramento River of up to 4000 cfs.

Recirculation

United States Bureau of Reclamation

End Date 12/31/2007 *Amount:* $923,000 (2006-2007)

Delta-Mendota Canal (DMC) Recirculation is a concept being studied by Reclamation and DWR to augment San Joaquin River flows with Delta water to reduce salinity and to maintain adequate flows required for beneficial uses. To accomplish this, the study is investigating options for recirculating water pumped from the Jones Pumping Plant through the DMC for release to the San Joaquin River. These releases would reach the San Joaquin River and eventually the South Delta via Newman Wasteway or other yet to be identified routes. Initial tests show the releases can be effective in reducing San Joaquin River salinity.

Appendix B:

Trend Analyses

Foreward

(excerpt from Chapter 5 of the CALFED Water Quality Program Stage 1 Final Assessment)

Because CALFED water quality targets are specified as specific numerical source averages, another way of assessing partial progress is to determine whether bromide and total organic carbon concentrations have increased or decreased at Delta intakes. Therefore, a statistical trend analysis was produced to determine whether water quality is improving or declining and to what degree (Appendix B). Because only monthly or weekly samples are available at many locations over the entire period of record, this trend analysis was done based on monthly averages (to smooth out biases caused by a higher number of samples in one period of time versus another). This same data was then analyzed for trends within specific months over 1990-2006, to determine whether water quality has changed over specific months, but results revealed either no trends, or trends driven by hydrology.

Overall trends in water quality from 1990-2006, in combination with the trends in flows from 1990-2006, suggest that water quality is strongly dependent on flow conditions, and both flow conditions and water quality have improved over this period of time, probably because of the extreme drought conditions in the early 1990s and the wet conditions in 2005 and 2006. Given the relatively small number of implementation projects funded by the WQP in Stage 1 and the absence of any relevant large scale regulatory or agency program, a resultant trend is not expected in either constituent at any location. A multivariate correlation was attempted to determine whether sources of water are correlated to certain hydrologic factors (precipitation, flow), but the Delta is a very complicated and highly managed system, which greatly complicates such an analysis. The 2006 Update of the SWP Sanitary Survey also found no significant trends in organic carbon trends over the period of 1998-2006. The USGS is also working on a trends analysis of organic carbon in the Delta, but their work was not available in time for this report.

10540 White Rock Road, Suite 180
Rancho Cordova, California 95670

Tel: (916) 444-0123
Fax: (916) 635-8805

www.brownandcaldwell.com

July 13, 2007

BROWN AND
CALDWELL

Lisa Holm, P.E.
Program Manager
California Bay-Delta Authority
Water Quality Program
650 Capitol Mall, 5th Floor
Sacramento, California 95814

017/132786

Subject: CALFED Water Quality Program, Final Stage 1 Assessment Report – Trend Analysis of Delta Diversions

Dear Ms. Holm:

This letter report presents the results of trend analyses conducted on water quality and flow data from several locations within or near the Delta. The statistical methodology is described, and results of the trend analysis are summarized and discussed. Also, data compilation and preparation are briefly described. Input data, graphs, and complete results are shown on the enclosed figures.

Data Compilation and Preparation

Data for the trend analysis were supplied to Brown and Caldwell by personnel from CALFED. The data were loaded into an Access database to protect the integrity of the data and to simplify data analysis. That database is provided on the enclosed CD.

Monthly average concentrations were calculated for all constituents selected for trend analysis. The number of data points involved in the average varies by analyte and location. In a few cases, there are no data points for a month. The most complete datasets, which are those for electrical conductivity (EC), consist of daily measurements. Only two nondetect values were encountered, however they were not used in the analysis because detection limits were not available.

Concentration data were analyzed from five locations including: Banks, Barker, Delta Mendota Canal (DMC), Old River and Rock Slough. Constituents analyzed include bromide, dissolved organic carbon (DOC), electrical conductivity (EC), and total organic carbon (TOC).[1] Not all constituents were selected for trend analysis at every location. The selection depended on availability of data and interest in the constituent. A total of 12 datasets were included in the trend analysis. Each dataset was analyzed 13 times: once using all the data and once for each of the 12 calendar months.

Trend analysis was also conducted on five datasets of flow measurements including pumping at Banks and Barker, Sacramento River and San Joaquin River inflow, and the Delta Outflow Index.[2] The flow datasets were analyzed using all data over the period of record; they were not analyzed by month.

Methodology

Prior to trend analysis, the water quality data were evaluated graphically using time versus concentration graphs and boxplots. The graphs were constructed with the same vertical scale and placed side-by-side to allow for easy comparison. Time versus concentration graphs are helpful for identifying temporal variability and data gaps. They are also essential for interpreting the results of trend analysis. For example, a trend analysis may indicate no trend whereas the time versus concentration plot may show a steep increase with concentration over time followed by a steep decrease, which could cancel each other out during the trend test.

Boxplots are ideal for evaluating differences between multiple groups of environmental data. They are also useful for examining data spread, central tendency, skewness, and the presence or absence of outliers. The type of boxplot used in this analysis is the standard boxplot. The box itself contains the center 50 percent of the data (i.e., the interquartile range), and the median is indicated as a horizontal line within the box. The top edge of the box is the 75th percentile and the bottom edge is the 25th percentile. Vertical lines, sometimes called whiskers, extend to the last observation within one step beyond either end of the box. A step is 1.5 times the height of the box. Data points that fall outside one step are

---

[1] In the data received from CALFED, bromide from Banks was described as "dissolved bromide" and bromide at the other locations was just called "bromide". This terminology was carried throughout the trend analysis

[2] The terminology "index" is used even though the data are presented in flow units because the value is calculated rather than measured directly.

considered to be "outliers", and values that fall outside of two steps are labeled "extreme". On the enclosed figures, outliers are shown as circles and extremes are shown as triangles.

The time versus concentration graphs and the boxplots both show that there is a considerable amount of variability depending on the time of year that the measurement was taken. To further understand this variability, trend analysis was conducted on the data by month. It was deemed more appropriate to analyze the data by month rather than by wet and dry season because the nature of the variability differs between locations and also between analytes. In addition, trend analysis was conducted using all of the data combined.

Trend analysis was conducted with the Mann-Kendall hypothesis test, which is a widely-used, nonparametric procedure. WQStat Plus® (1998), a software package for analyzing water quality data, was used to perform the analysis. The Mann-Kendall test is particularly well-suited for analyzing environmental data because; (1) it allows for missing values and unevenly spaced measurements, (2) there are no distributional assumptions, (3) outliers have minimal effect, and (4) some nondetects can be present in the data. The Mann-Kendall test is described in a number of references including Gibbons (1994), Gilbert (1987), Hollander and Wolfe (1973), and U.S. EPA (2006).

The null and alternative hypotheses for this analysis are:

H_o: slope = 0 (null)

H_a: slope ≠ 0 (alternative)

The null hypothesis of "no trend" was rejected if the absolute value of the test statistic exceeded the absolute value of the critical value. The critical value depends on the number of observations and the significance level. Critical values on the WQStat Plus® graphs correspond to a two-sided analysis where there is interest in both increasing and decreasing trends, which is the case for this analysis.

WQStat Plus® provides results for four significance levels (or alpha values): 0.01, 0.05, 0.1, 0.2. The significance level is the percentage of time that the null hypothesis will be incorrectly rejected. For example, an alpha value of 0.05 means that a trend will be incorrectly declared as significant 5 percent of the time. Although it is common to report results for only one significance level, all results are summarized on the enclosed figures to provide a better representation of trends in the data. For instance, a trend that is significant at all four significance levels is a stronger trend than one that is only significant at an alpha value of 0.2.

Discussion of Results

Trend analysis results for the complete (versus monthly) datasets at a significance level 5 percent are given in Table 1. As mentioned above, comprehensive results of the trend analysis are presented on the enclosed figures.

Table 1. Trend Analysis Results for Complete Datasets

Location	Variable	Time Interval	Significance at Alpha = 0.05
Water Quality Datasets:			
Banks	Dissolved Bromide	1990-2006	Down
Banks	DOC	1989-2006	Down
Banks	EC	1990-2006	Down
Barker	Bromide	1990-1997	Down
Barker	DOC	1989-2006	Not significant*
Barker	EC	2001-2006	Down
DMC	Bromide	1990-1997	Down
DMC	DOC	1989-1999	Down
DMC	EC	1990-2006	Down
Old River	TOC	1994-2006	Down
Rock Slough	EC	1989-2006	Down
Rock Slough	TOC	1991-2006	Down
Flow Datasets:			
Banks	Pumping	1990-2006	Up
Barker	Pumping	1990-2006	Up
Delta	Outflow Index	1990-2006	Up
Sacramento River	Inflow	1990-2006	Up
San Joaquin River	Inflow	1990-2006	Up

*Trend is significantly down at alpha = 0.1.

Table 1 shows that 11 of the 12 water quality datasets exhibit significant downward trends at an alpha level of 0.05, and all of the flow datasets have significant upward trends. Results in the enclosed figures show that many of the monthly datasets have upward trends that are not statistically significant. An important factor when interpreting hypothesis tests is that the power of the test increases with increasing sample size. Since it is easier for hypothesis tests to detect trends for larger sample sizes, care must be taken when comparing results. Also, important trends may not be evident if the sample sizes are small. There is only one significant upward trend in the water quality data; January DOC at Barker at a significance level of 0.2. All other significant trends in the water quality data are downward.

References

Gibbons, R.D. 1994. Statistical Methods for Groundwater Monitoring. John Wiley & Sons, Inc., New York, NY, 286 pages.

Gilbert, R.O. 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Company, New York, NY.

Hollander, M. and D.A. Wolfe. 1973. Nonparametric Statistical Methods. John Wiley and Sons, New York, NY.

U.S. EPA. 2006. Data Quality Assessment: Statistical Methods for Practitioners EPA QA/G-9S. Office of Environmental Information, United States Environmental Protection Agency, Washington D.C. February 2006. Document number EPA/240/B-06/003.

WQStat Plus®. 1998. A statistical software package for analyzing groundwater quality data. NIC Environmental Division, Groundwater and Environmental Statistical Software and Consulting.

If you have any questions regarding this letter report, please do not hesitate to contact me at (916) 444-0123.

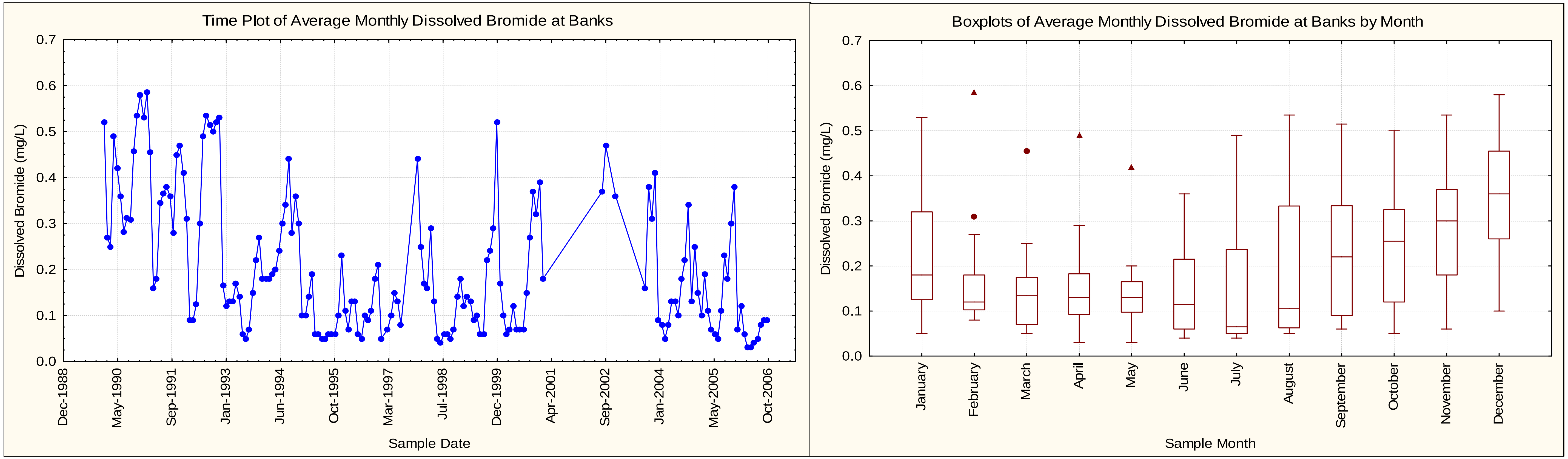
Sincerely,

BROWN AND CALDWELL

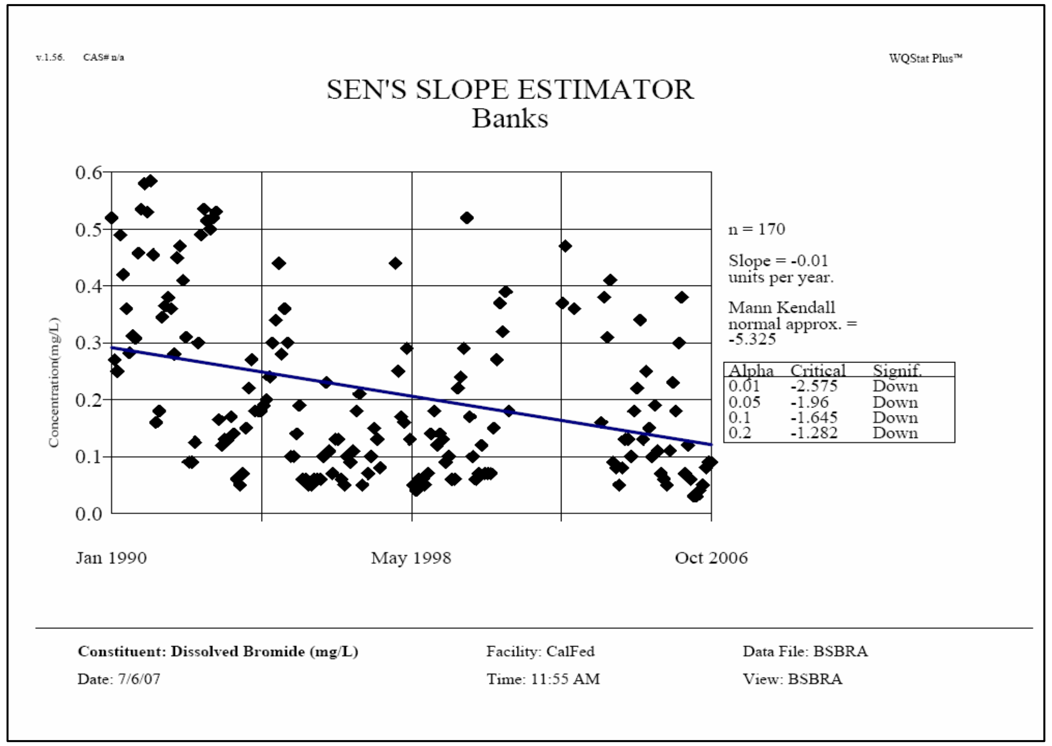
Nadine Adkins, Ph.D., P.E. #44487
Principal Engineer/Statistician

LIST OF FIGURES

Figure 1. Trend Analysis Using Average Monthly Concentrations of Dissolved Bromide at Banks



ALL DATA



SEN'S SLOPE ESTIMATOR
Banks

n = 170

Slope = -0.01
units per year.

Mann Kendall
normal approx. =
-5.325

Alpha	Critical	Signif.
0.01	-2.575	Down
0.05	-1.96	Down
0.1	-1.645	Down
0.2	-1.282	Down

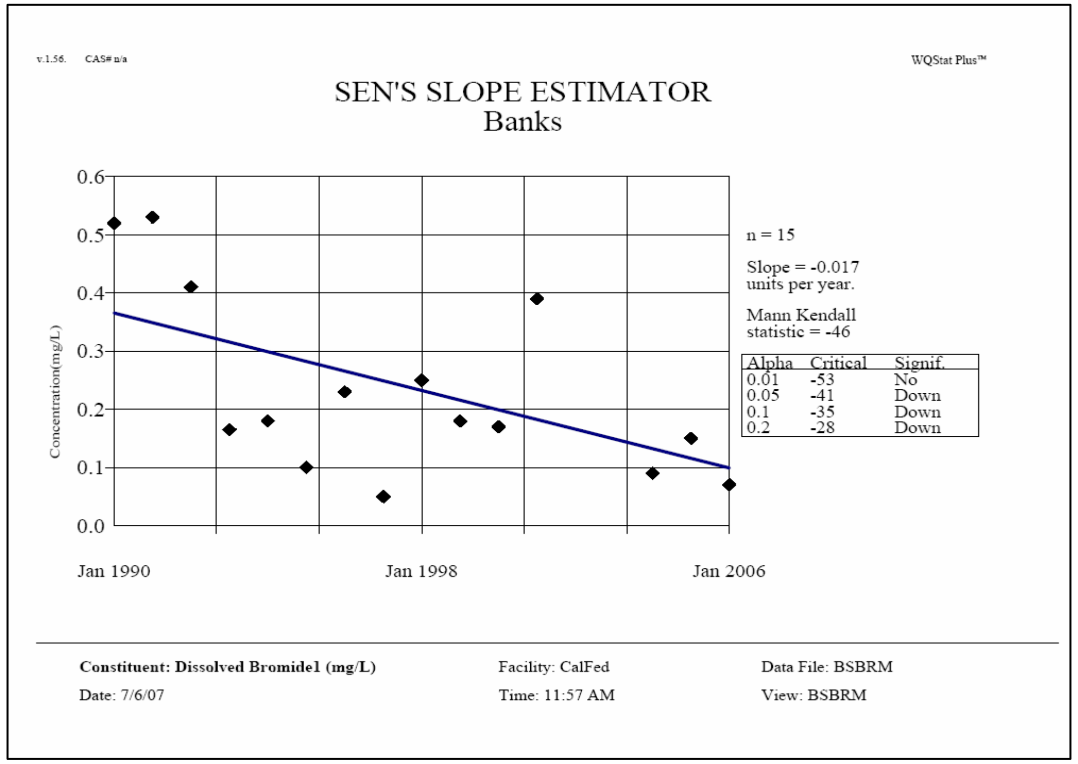
Constituent: Dissolved Bromide (mg/L)
Date: 7/6/07

Facility: CalFed
Time: 11:55 AM

Data File: BSBRA
View: BSBRA

Figure 1. Trend Analysis Using Average Monthly Concentrations of Dissolved Bromide at Banks

JANUARY



v.1.56. CAS# n/a

WQStat Plus™

SEN'S SLOPE ESTIMATOR
Banks

n = 15

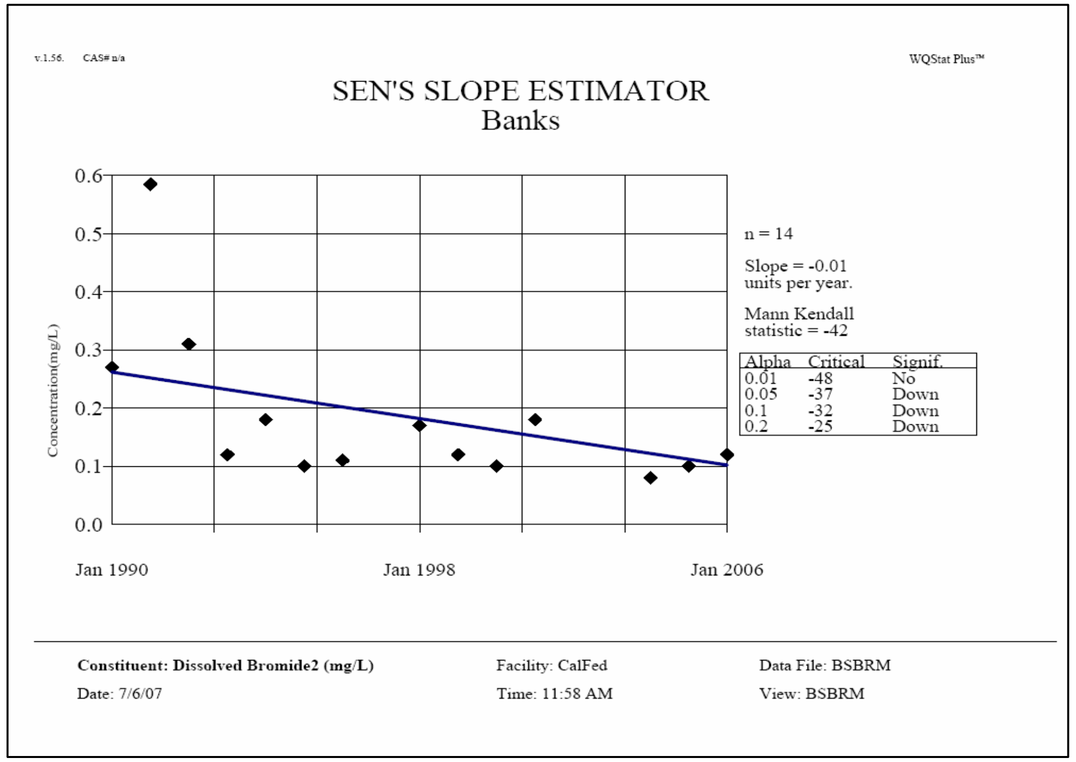
Slope = -0.017
units per year.

Mann Kendall
statistic = -46

Alpha	Critical	Signif.
0.01	-53	No
0.05	-41	Down
0.1	-35	Down
0.2	-28	Down

Constituent: Dissolved Bromide1 (mg/L) Facility: CalFed Data File: BSBRM
Date: 7/6/07 Time: 11:57 AM View: BSBRM

FEBRUARY



v.1.56. CAS# n/a

WQStat Plus™

SEN'S SLOPE ESTIMATOR
Banks

n = 14

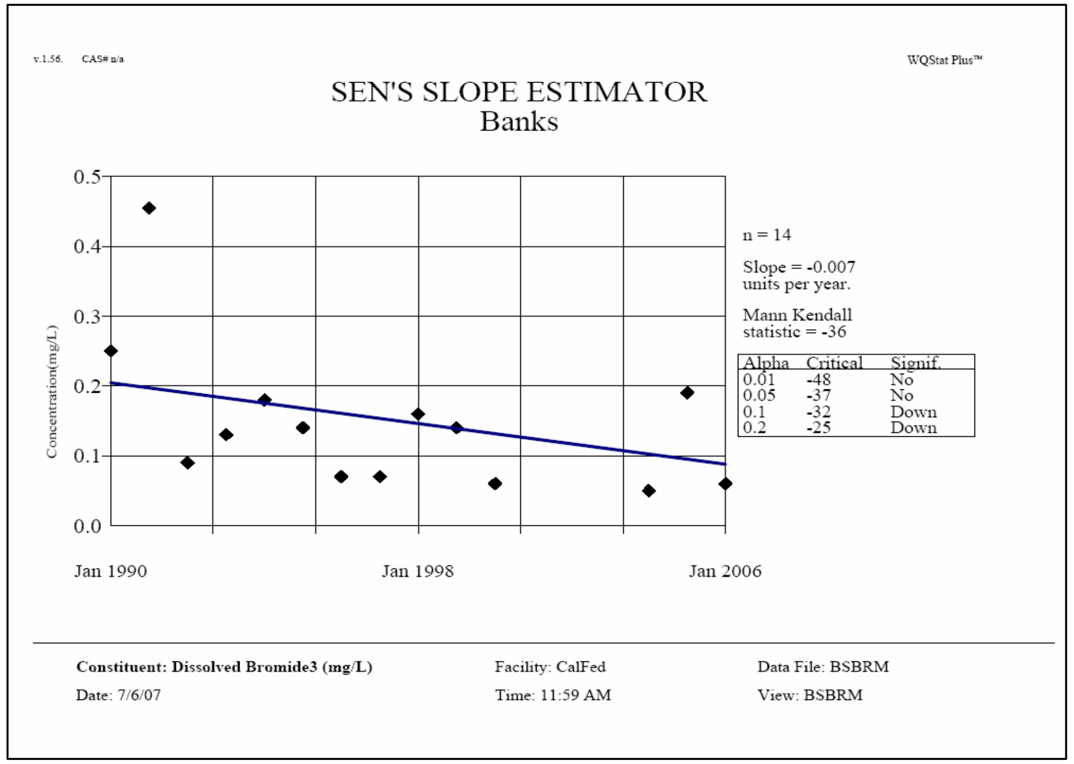
Slope = -0.01
units per year.

Mann Kendall
statistic = -42

Alpha	Critical	Signif.
0.01	-48	No
0.05	-37	Down
0.1	-32	Down
0.2	-25	Down

Constituent: Dissolved Bromide2 (mg/L) Facility: CalFed Data File: BSBRM
Date: 7/6/07 Time: 11:58 AM View: BSBRM

MARCH



v.1.56. CAS# n/a

WQStat Plus™

SEN'S SLOPE ESTIMATOR
Banks

n = 14

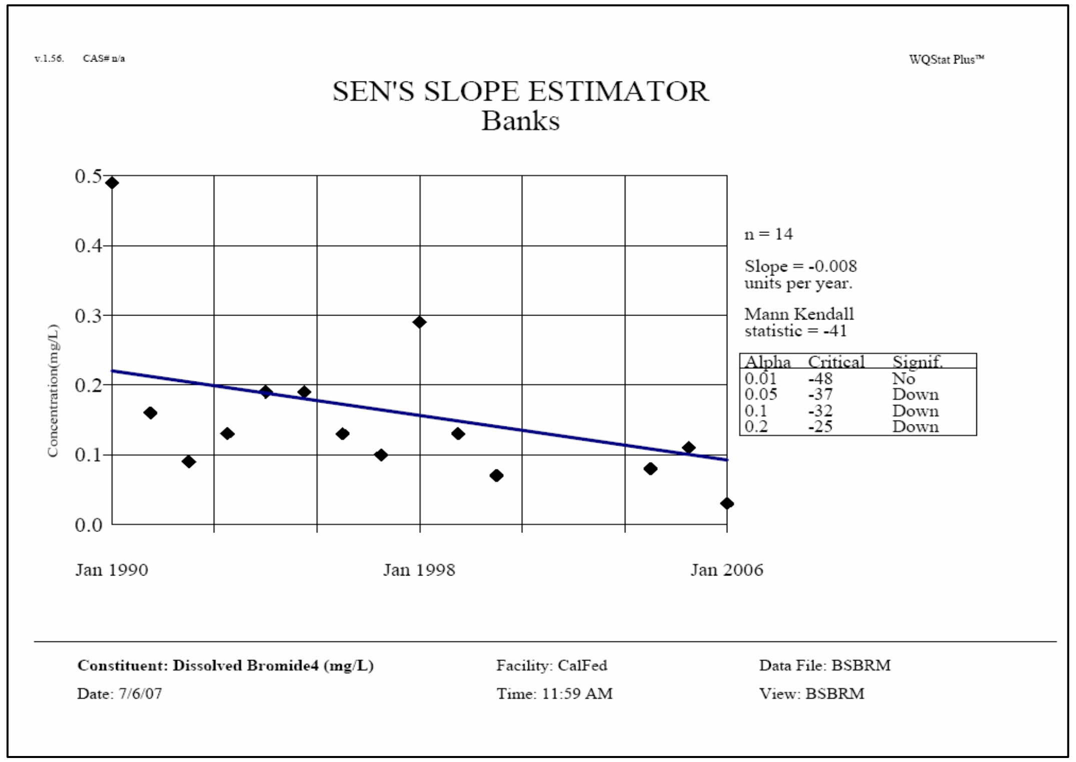
Slope = -0.007
units per year.

Mann Kendall
statistic = -36

Alpha	Critical	Signif.
0.01	-48	No
0.05	-37	No
0.1	-32	Down
0.2	-25	Down

Constituent: Dissolved Bromide3 (mg/L) Facility: CalFed Data File: BSBRM
Date: 7/6/07 Time: 11:59 AM View: BSBRM

APRIL



v.1.56. CAS# n/a

WQStat Plus™

SEN'S SLOPE ESTIMATOR
Banks

n = 14

Slope = -0.008
units per year.

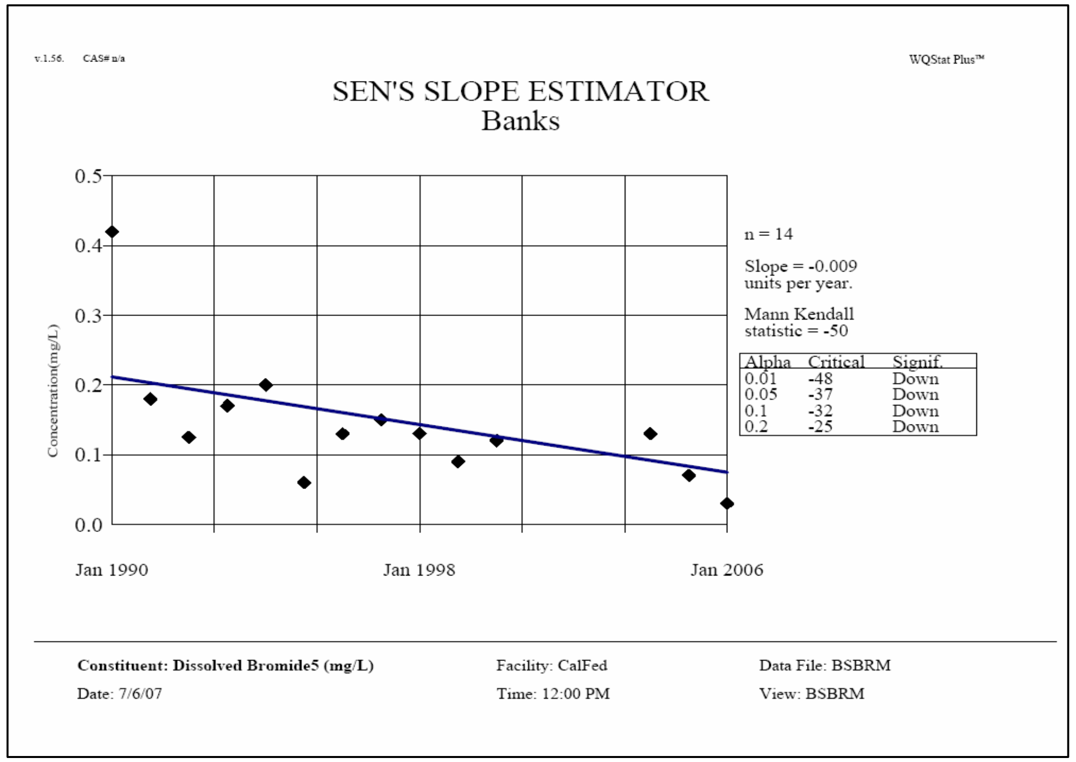
Mann Kendall
statistic = -41

Alpha	Critical	Signif.
0.01	-48	No
0.05	-37	Down
0.1	-32	Down
0.2	-25	Down

Constituent: Dissolved Bromide4 (mg/L) Facility: CalFed Data File: BSBRM
Date: 7/6/07 Time: 11:59 AM View: BSBRM

Figure 1. Trend Analysis Using Average Monthly Concentrations of Dissolved Bromide at Banks

MAY



n = 14

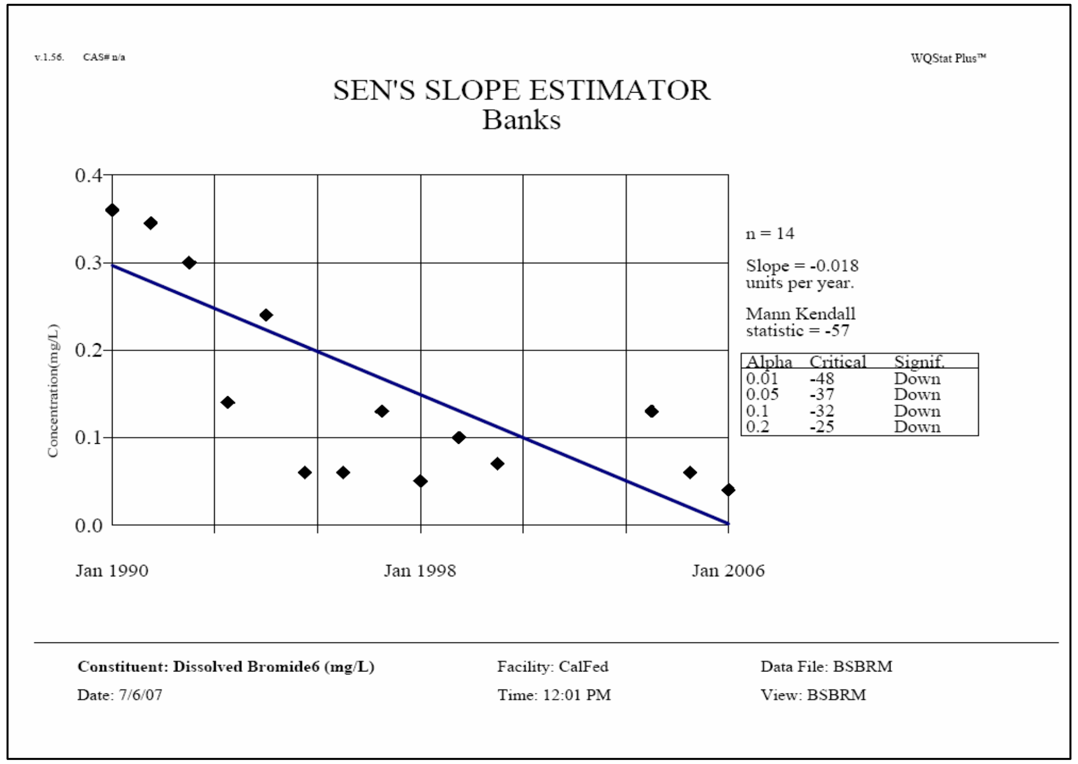
Slope = -0.009 units per year.

Mann Kendall statistic = -50

Alpha	Critical	Signif.
0.01	-48	Down
0.05	-37	Down
0.1	-32	Down
0.2	-25	Down

Constituent: Dissolved Bromide5 (mg/L)
Facility: CalFed
Data File: BSBRM
Date: 7/6/07
Time: 12:00 PM
View: BSBRM

JUNE



n = 14

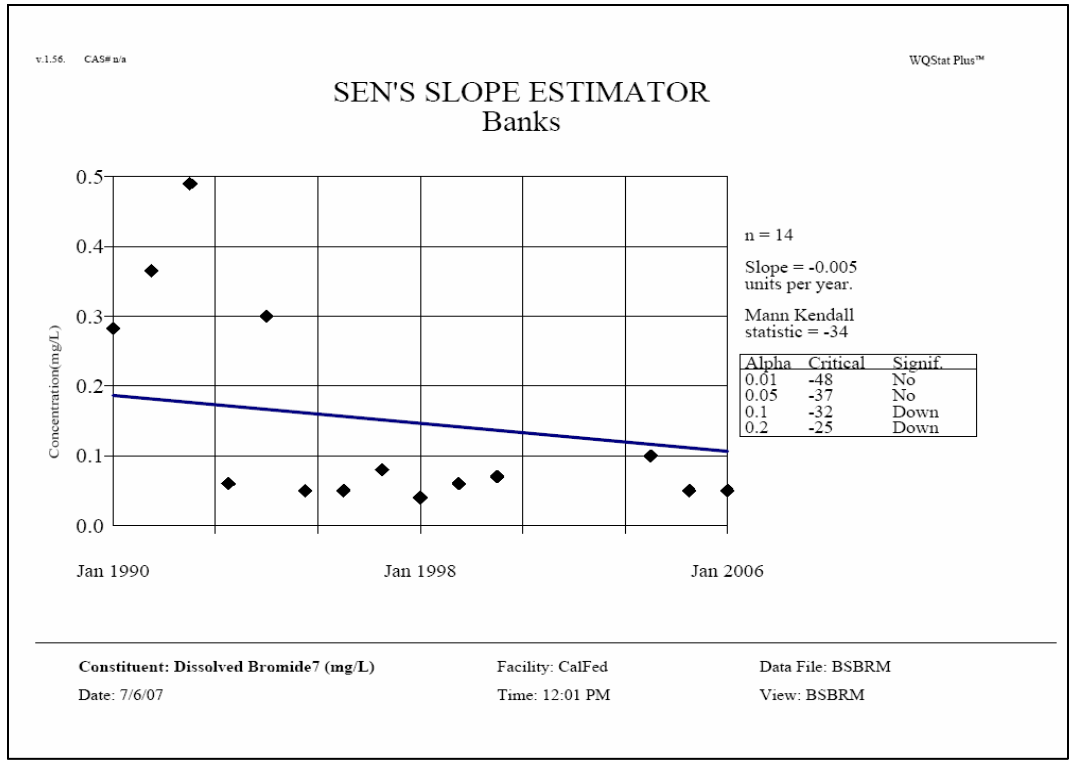
Slope = -0.018 units per year.

Mann Kendall statistic = -57

Alpha	Critical	Signif.
0.01	-48	Down
0.05	-37	Down
0.1	-32	Down
0.2	-25	Down

Constituent: Dissolved Bromide6 (mg/L)
Facility: CalFed
Data File: BSBRM
Date: 7/6/07
Time: 12:01 PM
View: BSBRM

JULY



n = 14

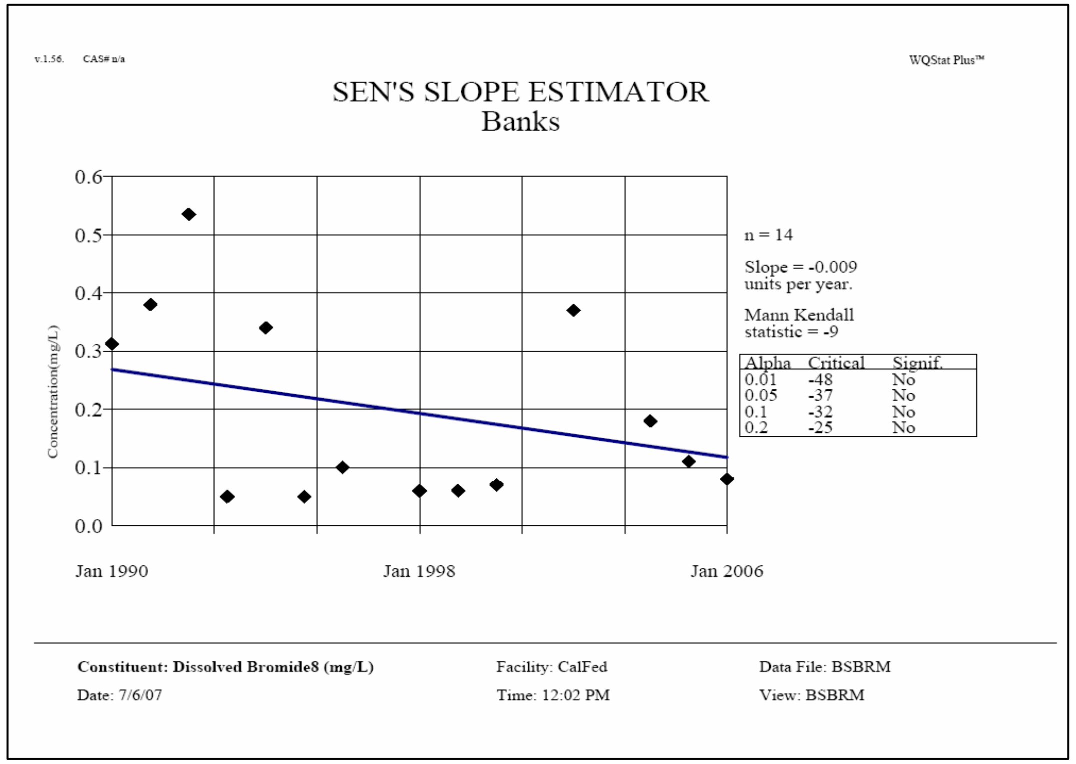
Slope = -0.005 units per year.

Mann Kendall statistic = -34

Alpha	Critical	Signif.
0.01	-48	No
0.05	-37	No
0.1	-32	Down
0.2	-25	Down

Constituent: Dissolved Bromide7 (mg/L)
Facility: CalFed
Data File: BSBRM
Date: 7/6/07
Time: 12:01 PM
View: BSBRM

AUGUST



n = 14

Slope = -0.009 units per year.

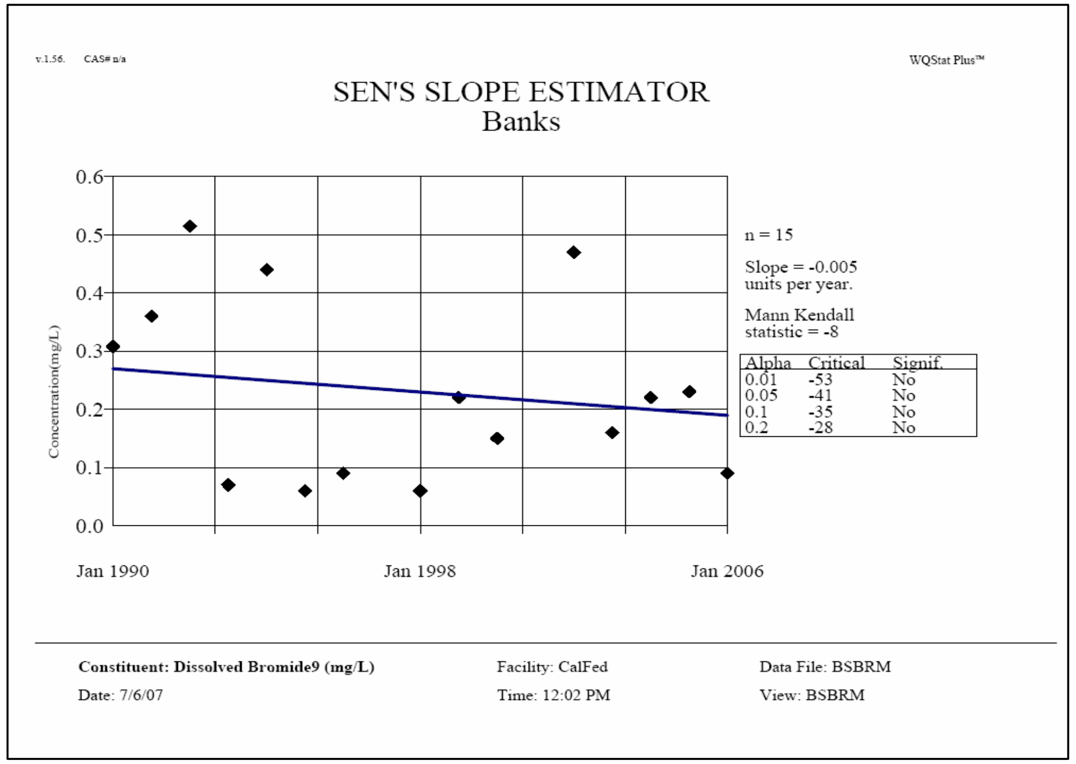
Mann Kendall statistic = -9

Alpha	Critical	Signif.
0.01	-48	No
0.05	-37	No
0.1	-32	No
0.2	-25	No

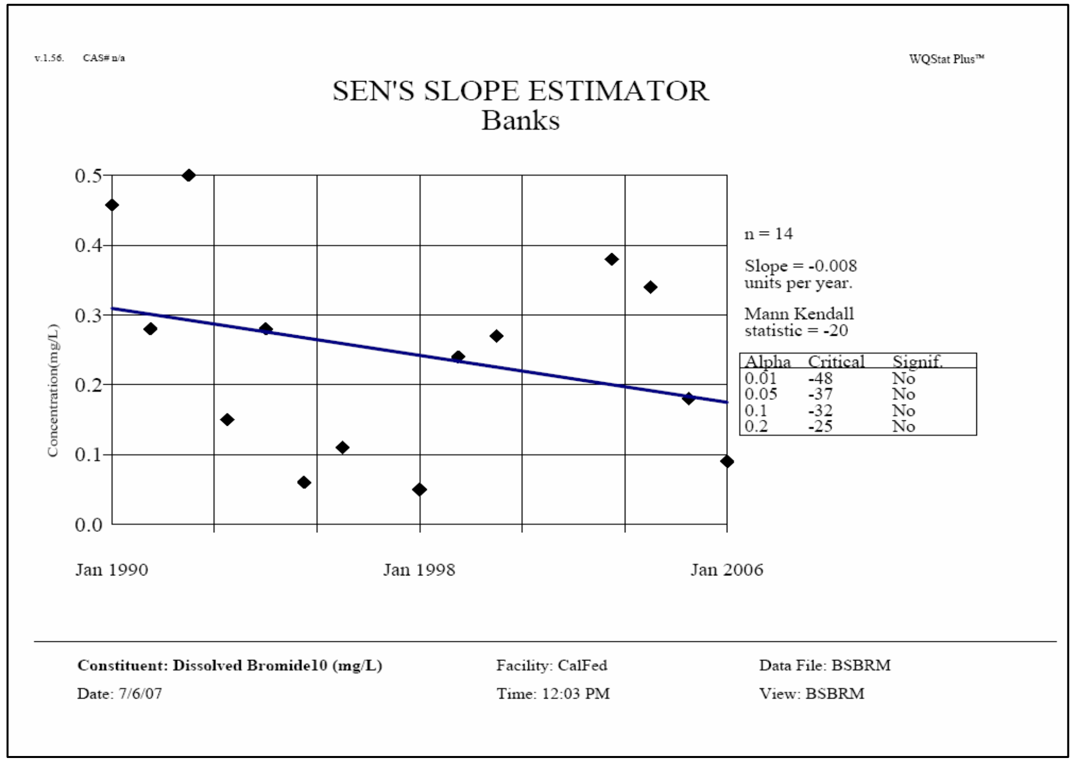
Constituent: Dissolved Bromide8 (mg/L)
Facility: CalFed
Data File: BSBRM
Date: 7/6/07
Time: 12:02 PM
View: BSBRM

Figure 1. Trend Analysis Using Average Monthly Concentrations of Dissolved Bromide at Banks

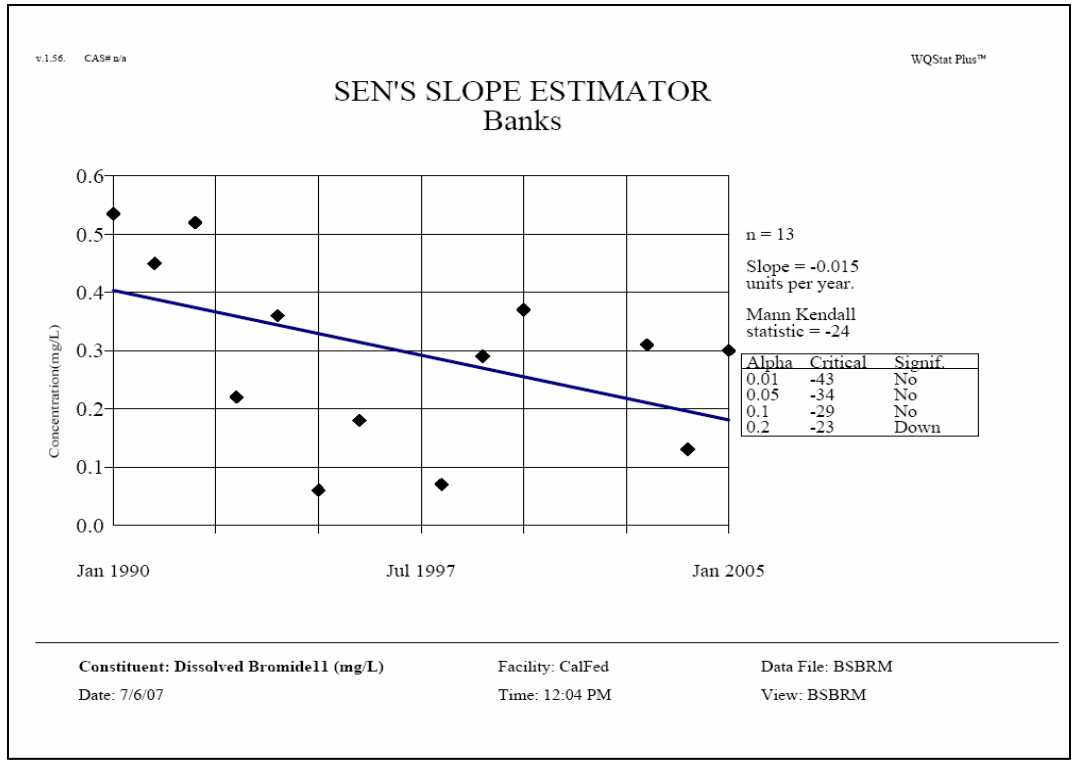
SEPTEMBER



OCTOBER



NOVEMBER



DECEMBER

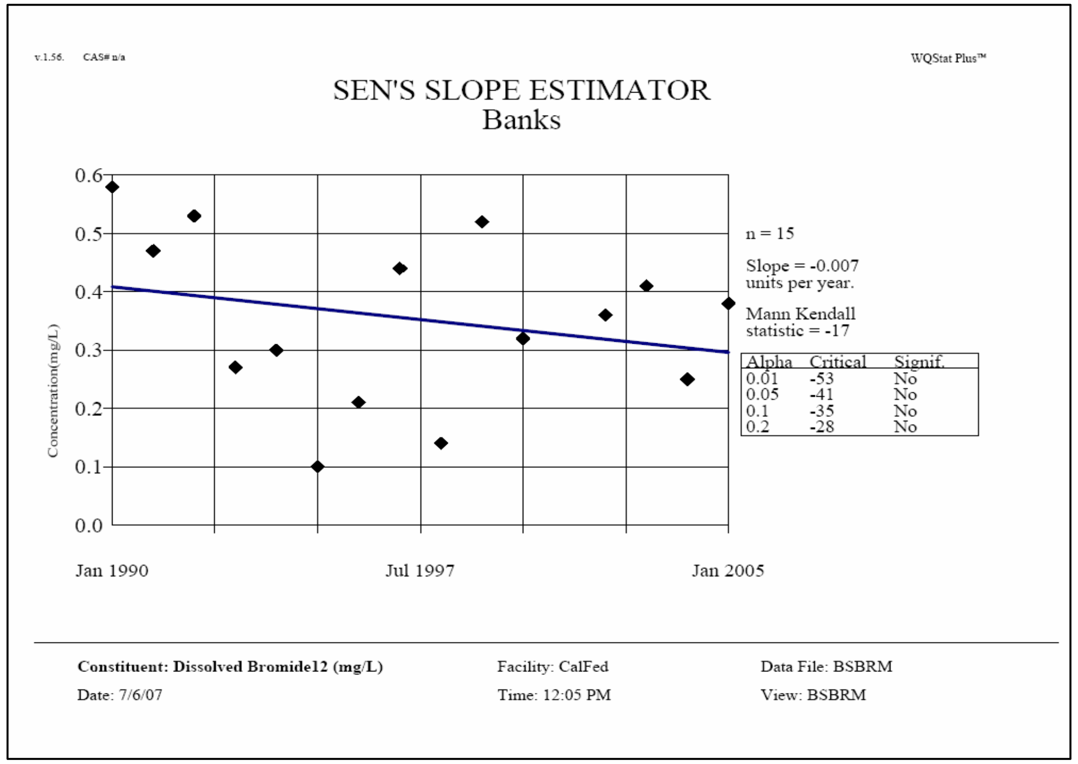
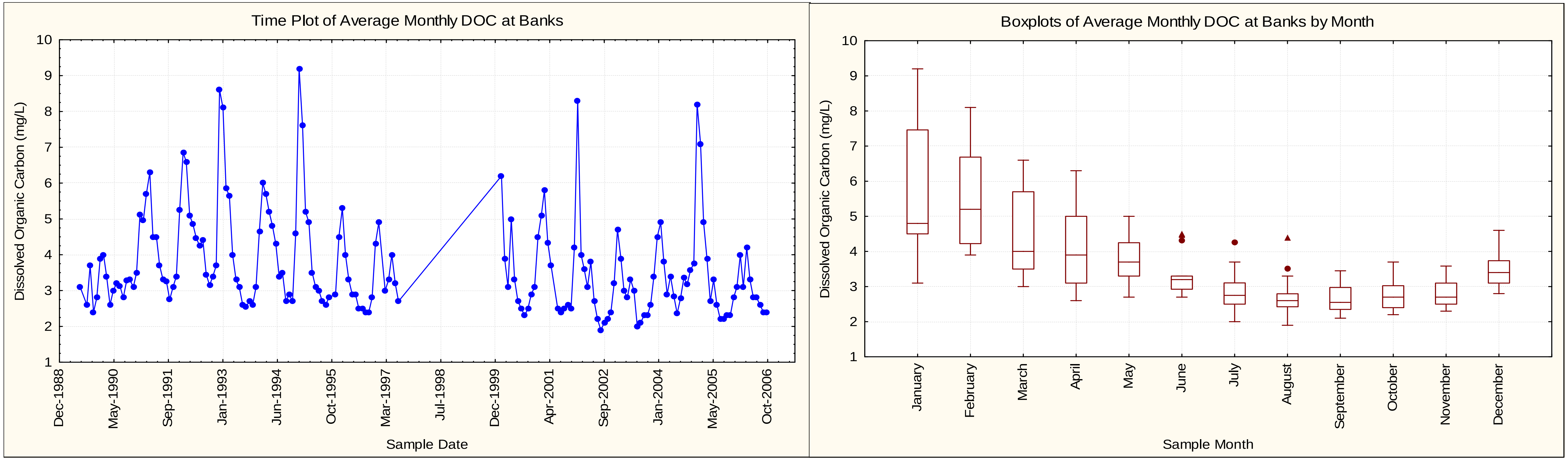


Figure 1. Trend Analysis Using Average Monthly Concentrations of Dissolved Bromide at Banks

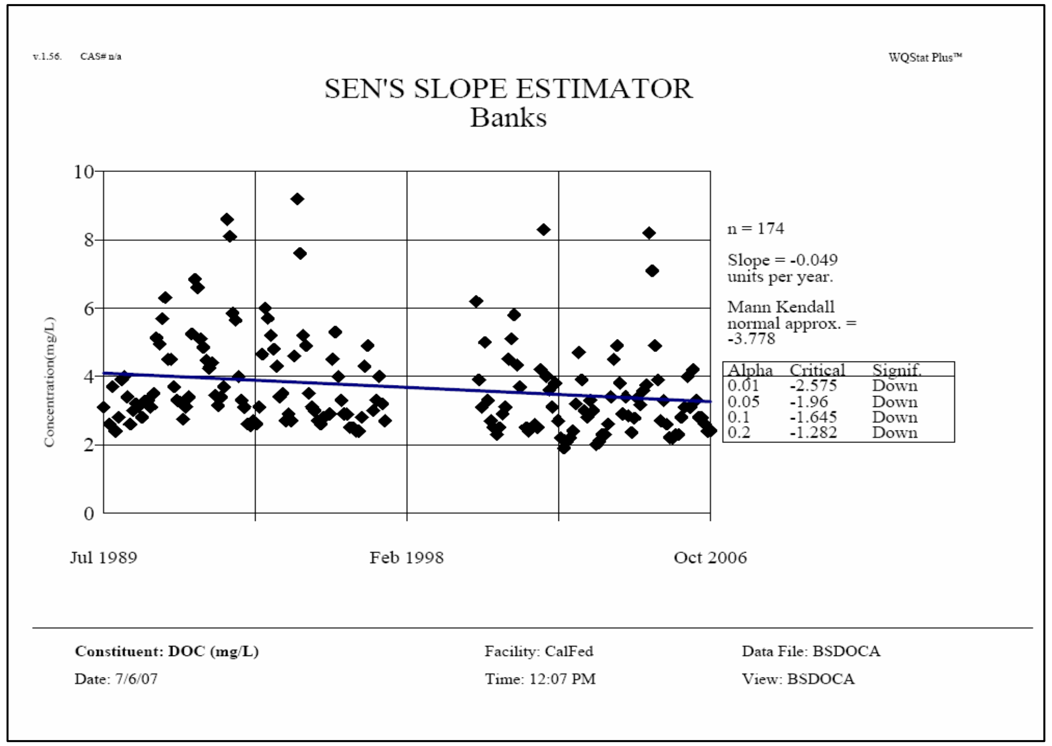
DATA USED IN TREND ANALYSIS - AVERAGE MONTHLY CONCENTRATIONS OF DISSOLVED BROMIDE (MG/L)												
Sample Year	January	February	March	April	May	June	July	August	September	October	November	December
1990	0.5200	0.2700	0.2500	0.4900	0.4200	0.3600	0.2825	0.3125	0.3075	0.4580	0.5350	0.5800
1991	0.5300	0.5850	0.4550	0.1600	0.1800	0.3450	0.3650	0.3800	0.3600	0.2800	0.4500	0.4700
1992	0.4100	0.3100	0.0900	0.0900	0.1250	0.3000	0.4900	0.5350	0.5150	0.5000	0.5200	0.5300
1993	0.1650	0.1200	0.1300	0.1300	0.1700	0.1400	0.0600	0.0500	0.0700	0.1500	0.2200	0.2700
1994	0.1800	0.1800	0.1800	0.1900	0.2000	0.2400	0.3000	0.3400	0.4400	0.2800	0.3600	0.3000
1995	0.1000	0.1000	0.1400	0.1900	0.0600	0.0600	0.0500	0.0500	0.0600	0.0600	0.0600	0.1000
1996	0.2300	0.1100	0.0700	0.1300	0.1300	0.0600	0.0500	0.1000	0.0900	0.1100	0.1800	0.2100
1997	0.0500		0.0700	0.1000	0.1500	0.1300	0.0800					0.4400
1998	0.2500	0.1700	0.1600	0.2900	0.1300	0.0500	0.0400	0.0600	0.0600	0.0500	0.0700	0.1400
1999	0.1800	0.1200	0.1400	0.1300	0.0900	0.1000	0.0600	0.0600	0.2200	0.2400	0.2900	0.5200
2000	0.1700	0.1000	0.0600	0.0700	0.1200	0.0700	0.0700	0.0700	0.1500	0.2700	0.3700	0.3200
2001	0.3900	0.1800										
2002								0.3700	0.4700			0.3600
2003									0.1600	0.3800	0.3100	0.4100
2004	0.0900	0.0800	0.0500	0.0800	0.1300	0.1300	0.1000	0.1800	0.2200	0.3400	0.1300	0.2500
2005	0.1500	0.1000	0.1900	0.1100	0.0700	0.0600	0.0500	0.1100	0.2300	0.1800	0.3000	0.3800
2006	0.0700	0.1200	0.0600	0.0300	0.0300	0.0400	0.0500	0.0800	0.0900	0.0900		

SUMMARY OF TREND ANALYSIS RESULTS													
	Dissolved Bromide												
	January	February	March	April	May	June	July	August	September	October	November	December	All Months
Number of Observations:	15	14	14	14	14	14	14	14	15	14	13	15	170
Significance													
Alpha													
0.01	no	no	no	no	down	down	no	no	no	no	no	no	down
0.05	down	down	no	down	down	down	no	no	no	no	no	no	down
0.1	down	down	down	down	down	down	down	no	no	no	no	no	down
0.2	down	down	down	down	down	down	down	no	no	no	down	no	down

Figure 2. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at Banks



ALL DATA



SEN'S SLOPE ESTIMATOR
Banks

n = 174

Slope = -0.049
units per year.

Mann Kendall
normal approx. =
-3.778

Alpha	Critical	Signif.
0.01	-2.575	Down
0.05	-1.96	Down
0.1	-1.645	Down
0.2	-1.282	Down

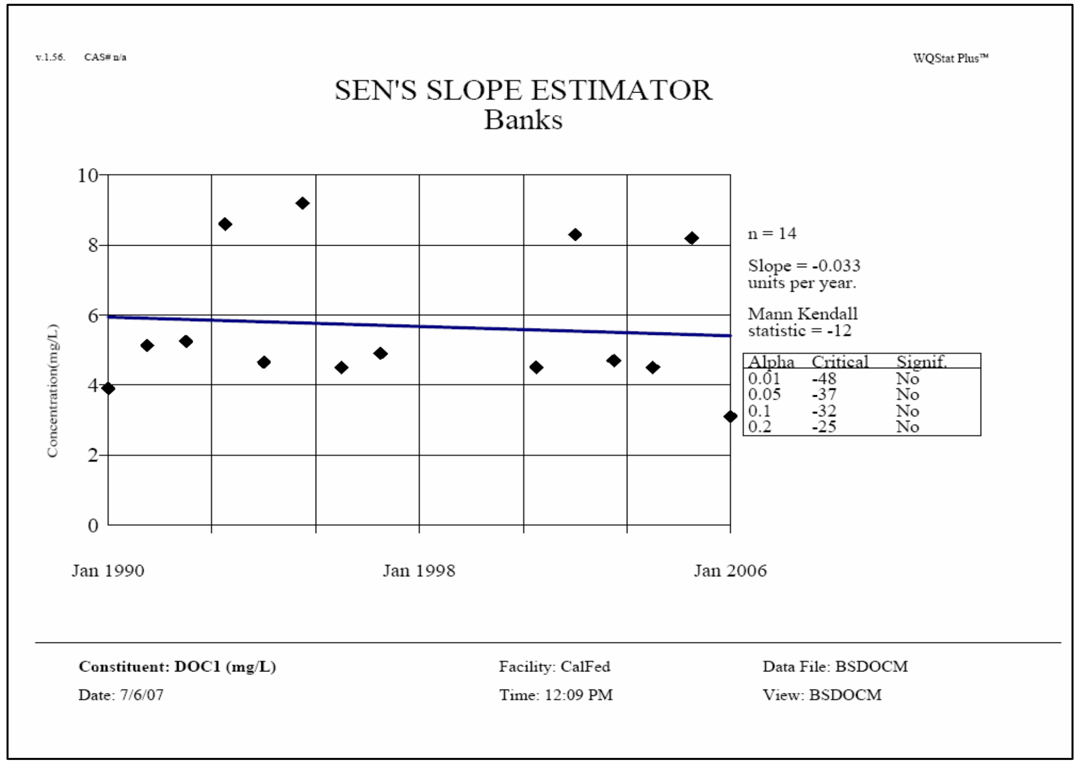
Constituent: DOC (mg/L)
Date: 7/6/07

Facility: CalFed
Time: 12:07 PM

Data File: BSDOCA
View: BSDOCA

Figure 2. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at Banks

JANUARY



SEN'S SLOPE ESTIMATOR
Banks

n = 14

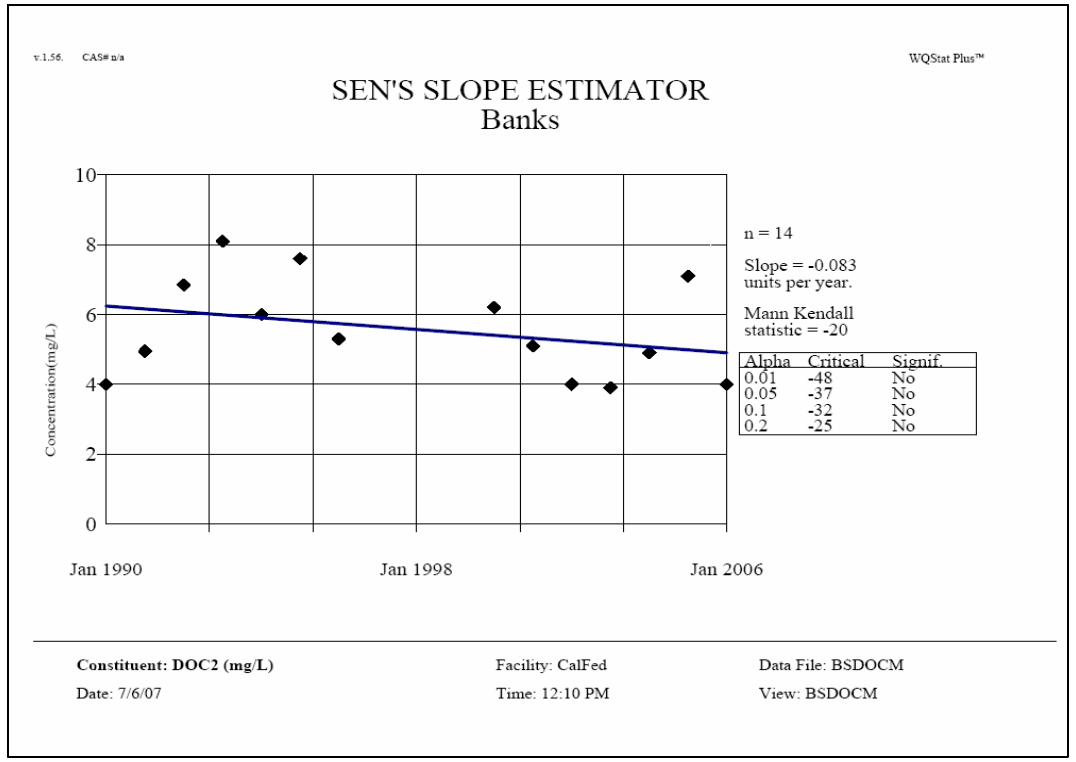
Slope = -0.033
units per year.

Mann Kendall
statistic = -12

Alpha	Critical	Signif.
0.01	-48	No
0.05	-37	No
0.1	-32	No
0.2	-25	No

Constituent: DOC1 (mg/L)
Date: 7/6/07
Facility: CalFed
Time: 12:09 PM
Data File: BSDOCM
View: BSDOCM

FEBRUARY



SEN'S SLOPE ESTIMATOR
Banks

n = 14

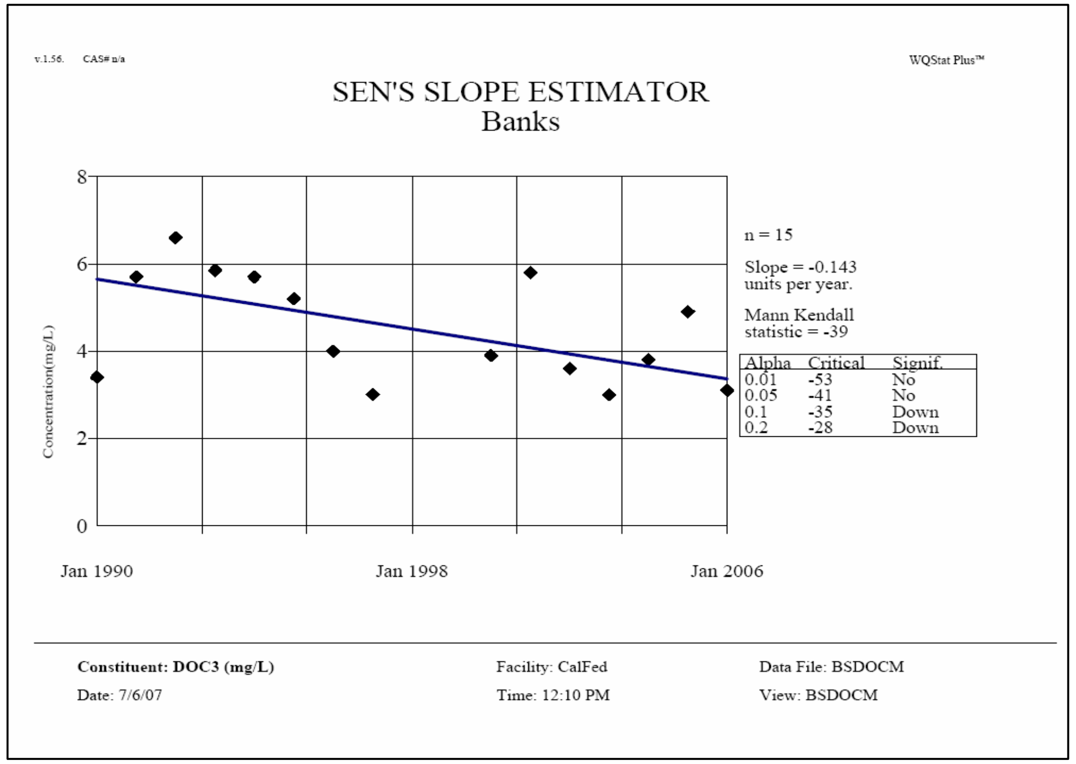
Slope = -0.083
units per year.

Mann Kendall
statistic = -20

Alpha	Critical	Signif.
0.01	-48	No
0.05	-37	No
0.1	-32	No
0.2	-25	No

Constituent: DOC2 (mg/L)
Date: 7/6/07
Facility: CalFed
Time: 12:10 PM
Data File: BSDOCM
View: BSDOCM

MARCH



SEN'S SLOPE ESTIMATOR
Banks

n = 15

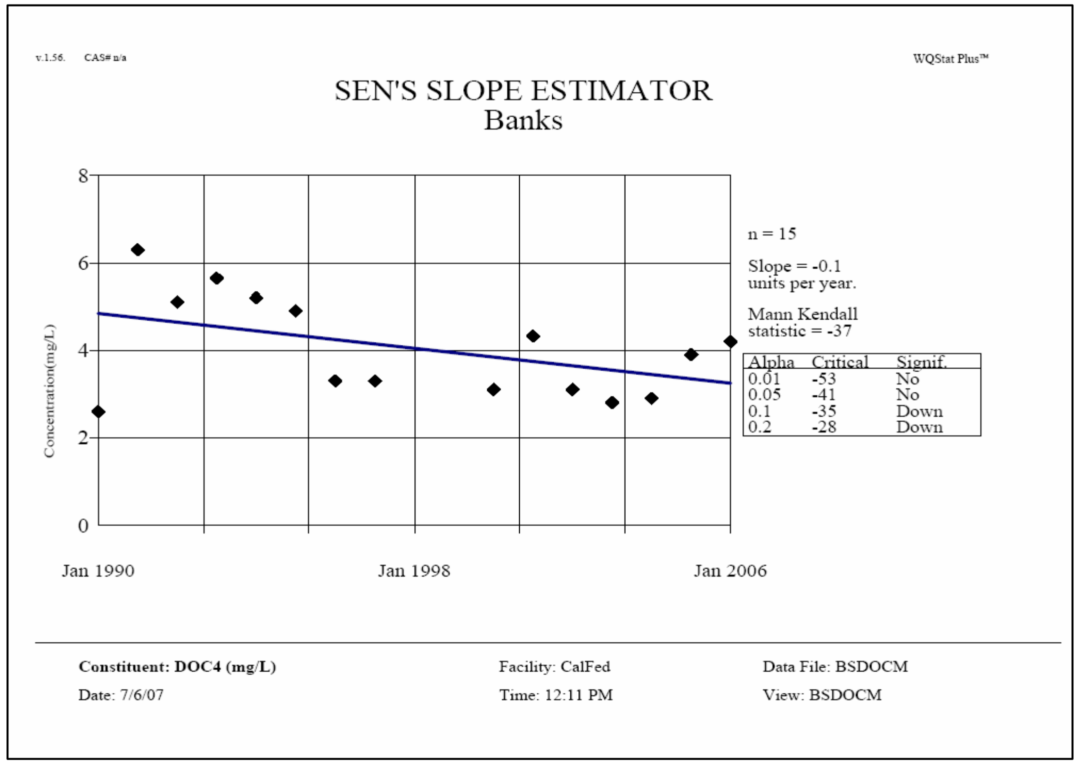
Slope = -0.143
units per year.

Mann Kendall
statistic = -39

Alpha	Critical	Signif.
0.01	-53	No
0.05	-41	No
0.1	-35	Down
0.2	-28	Down

Constituent: DOC3 (mg/L)
Date: 7/6/07
Facility: CalFed
Time: 12:10 PM
Data File: BSDOCM
View: BSDOCM

APRIL



SEN'S SLOPE ESTIMATOR
Banks

n = 15

Slope = -0.1
units per year.

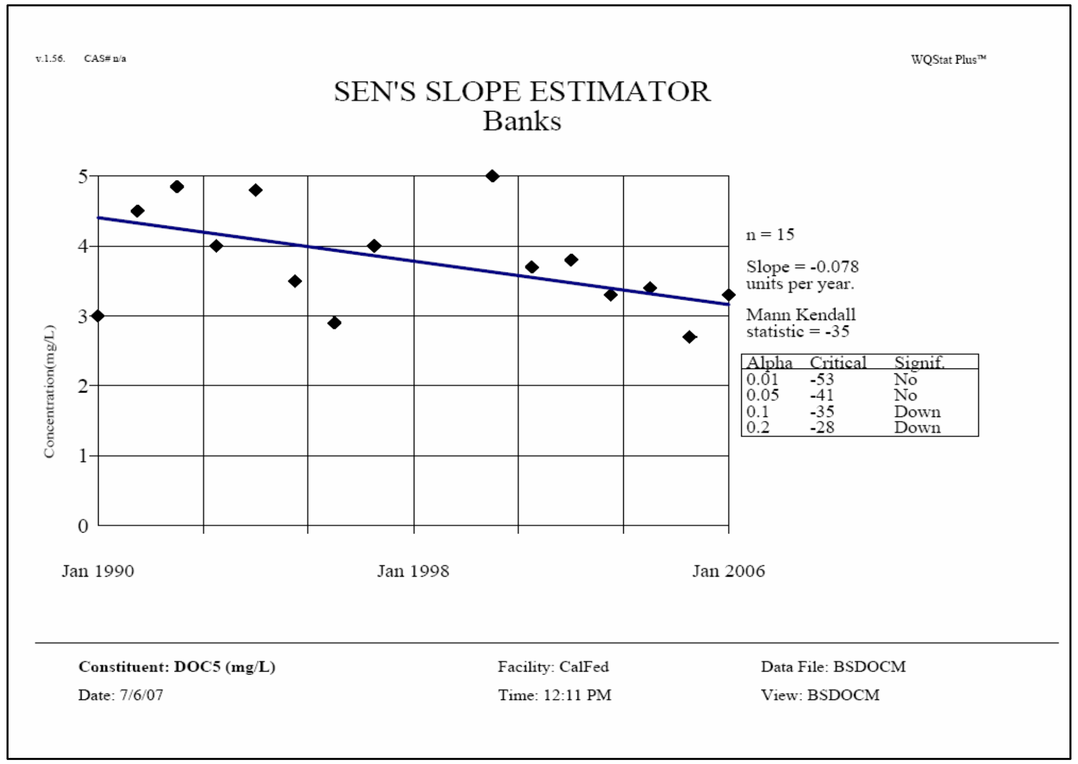
Mann Kendall
statistic = -37

Alpha	Critical	Signif.
0.01	-53	No
0.05	-41	No
0.1	-35	Down
0.2	-28	Down

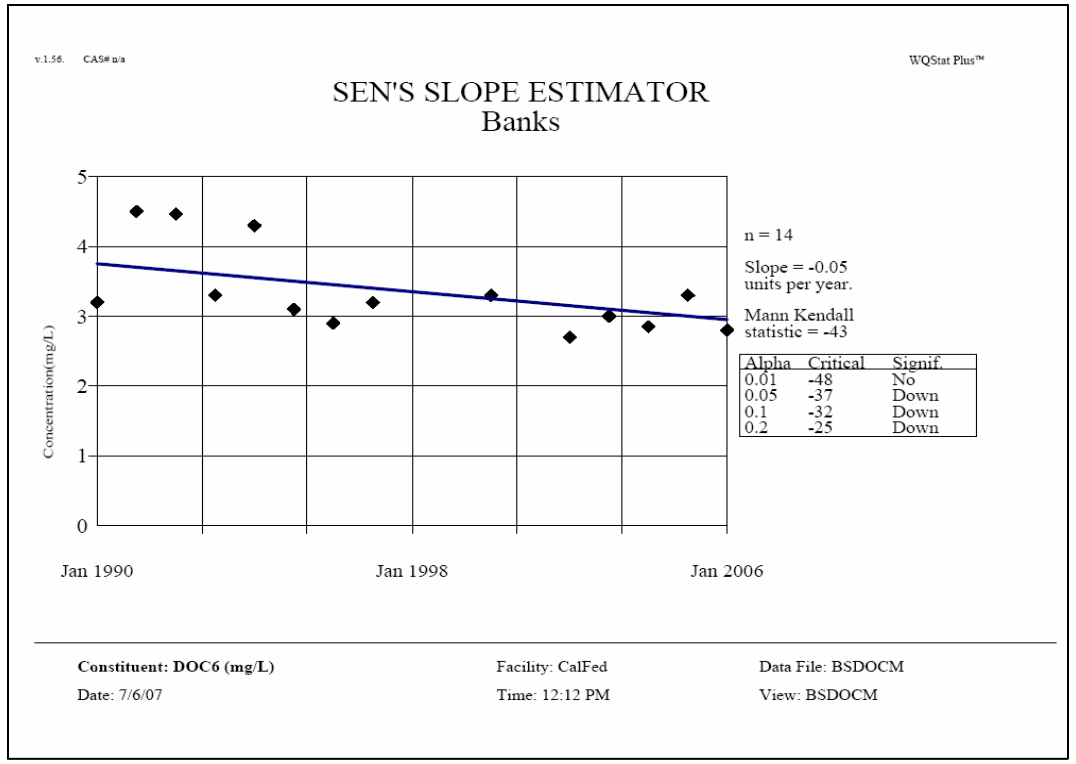
Constituent: DOC4 (mg/L)
Date: 7/6/07
Facility: CalFed
Time: 12:11 PM
Data File: BSDOCM
View: BSDOCM

Figure 2. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at Banks

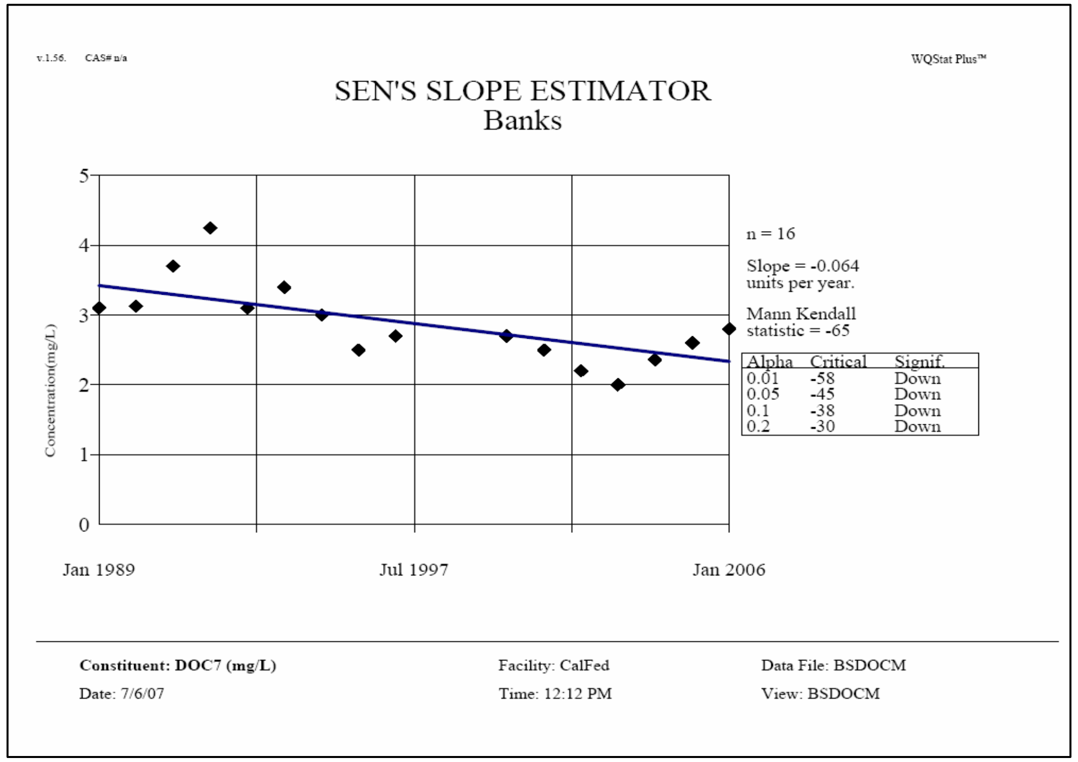
MAY



JUNE



JULY



AUGUST

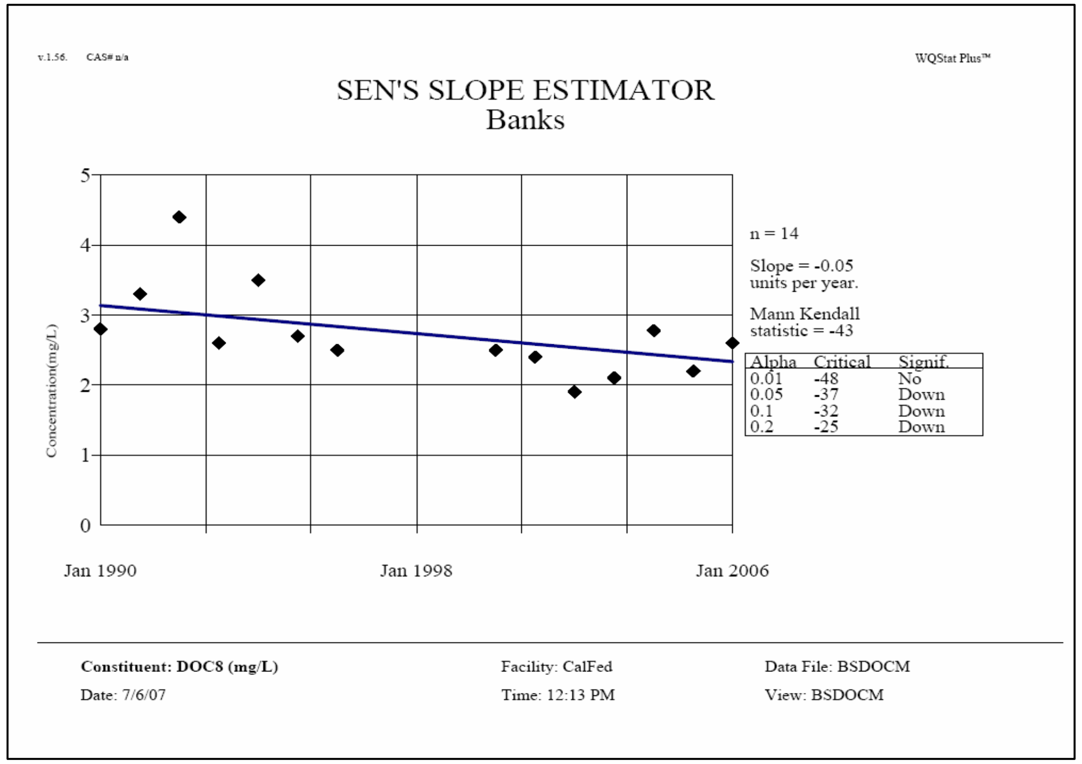
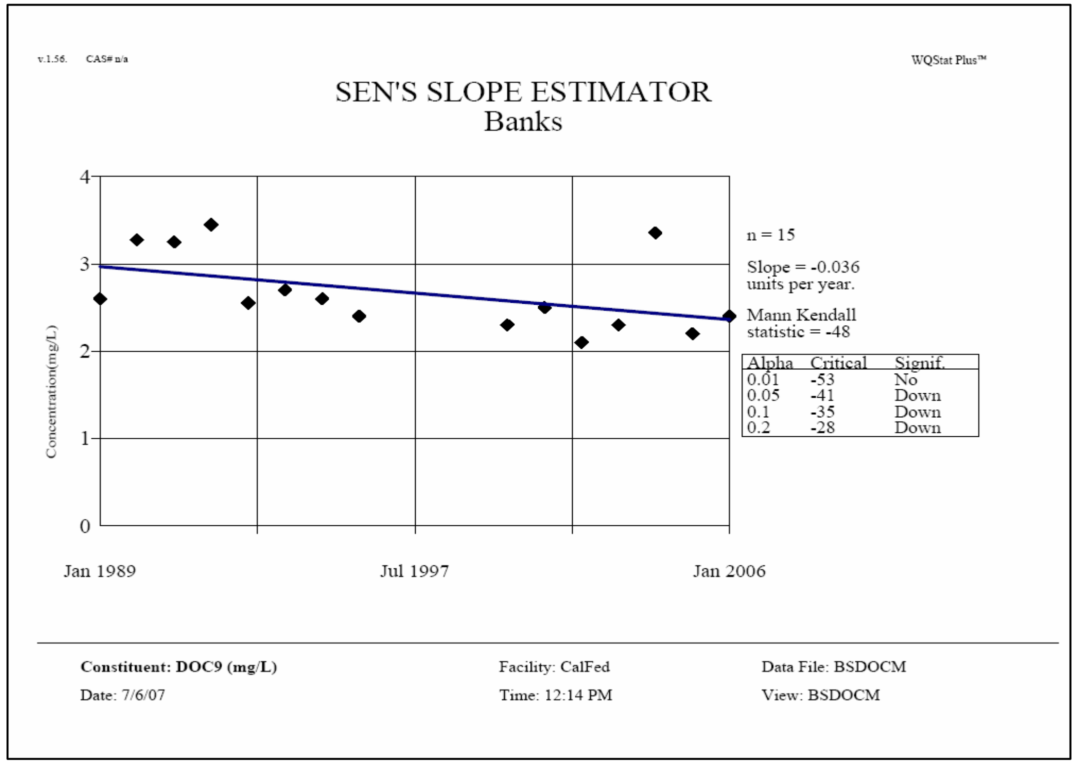
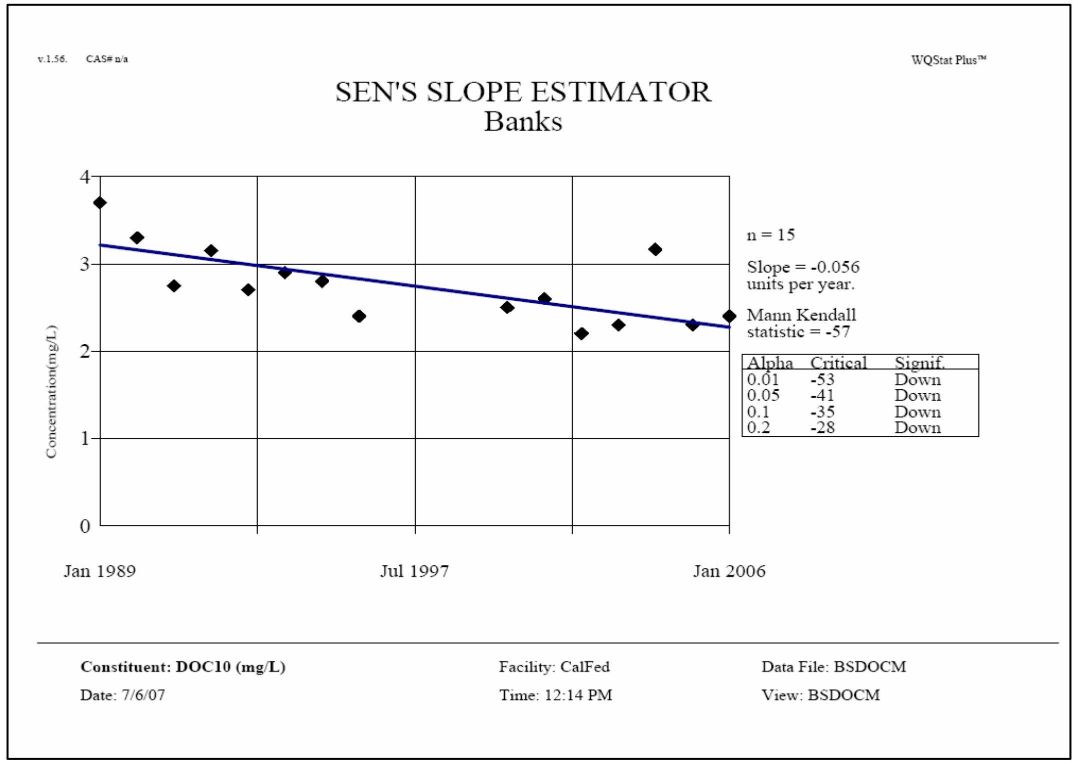


Figure 2. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at Banks

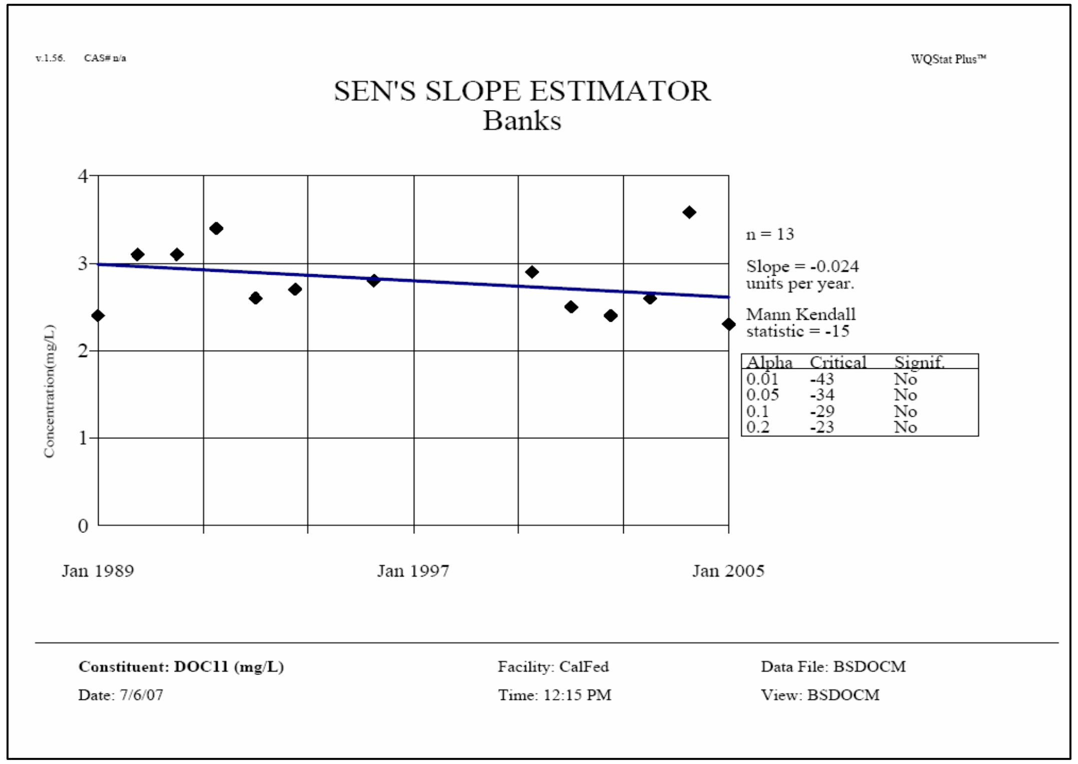
SEPTEMBER



OCTOBER



NOVEMBER



DECEMBER

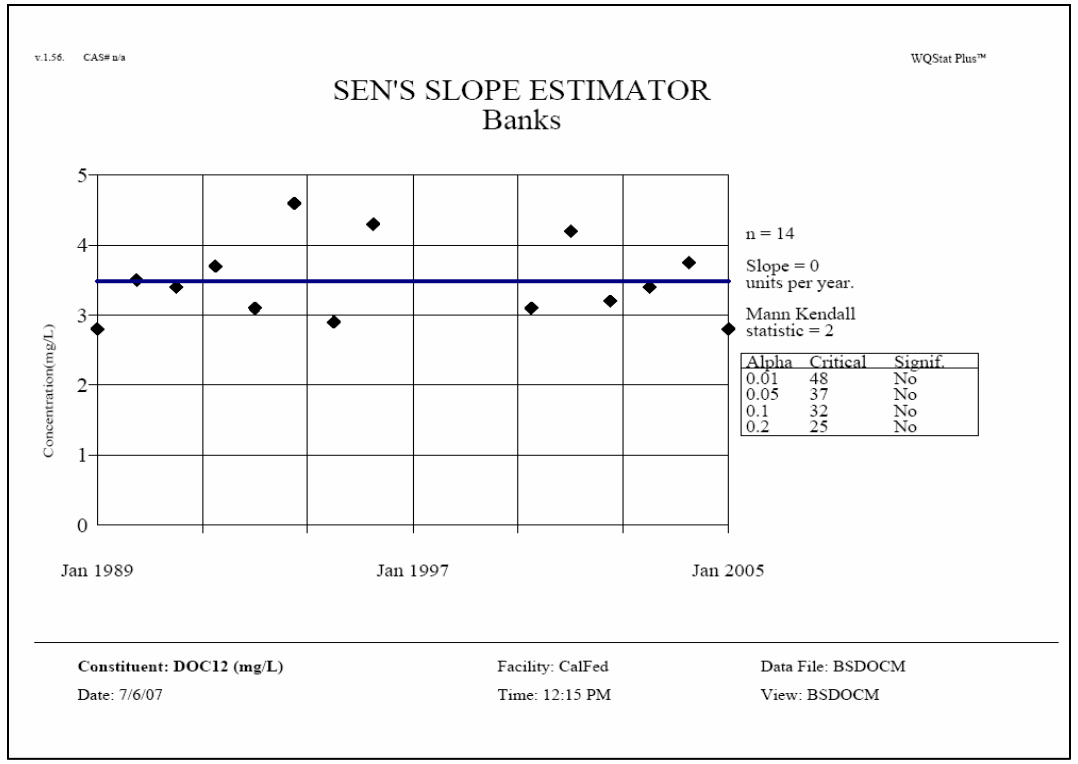
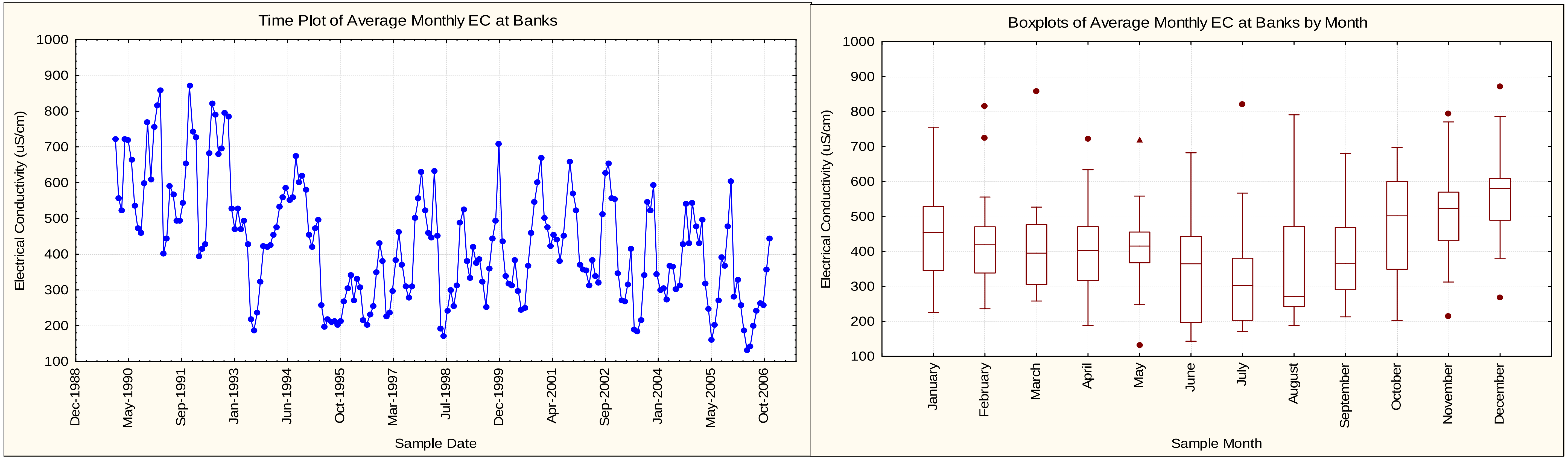


Figure 2. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at Banks

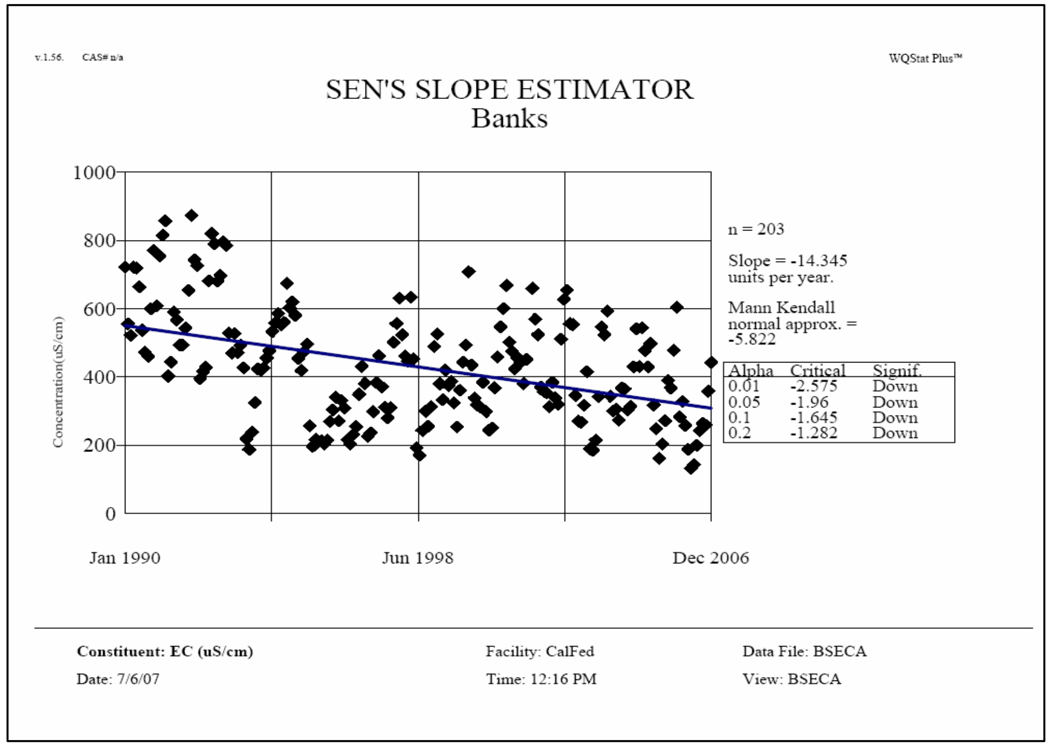
DATA USED IN TREND ANALYSIS - AVERAGE MONTHLY CONCENTRATIONS OF DISSOLVED ORGANIC CARBON (MG/L)												
Sample Year	January	February	March	April	May	June	July	August	September	October	November	December
1989							3.10		2.60	3.70	2.40	2.80
1990	3.90	4.00	3.40	2.60	3.00	3.20	3.13	2.80	3.28	3.30	3.10	3.50
1991	5.13	4.95	5.70	6.30	4.50	4.50	3.70	3.30	3.25	2.75	3.10	3.40
1992	5.25	6.85	6.60	5.10	4.85	4.47	4.25	4.40	3.45	3.15	3.40	3.70
1993	8.60	8.10	5.85	5.65	4.00	3.30	3.10	2.60	2.55	2.70	2.60	3.10
1994	4.65	6.00	5.70	5.20	4.80	4.30	3.40	3.50	2.70	2.90	2.70	4.60
1995	9.20	7.60	5.20	4.90	3.50	3.10	3.00	2.70	2.60	2.80		2.90
1996	4.50	5.30	4.00	3.30	2.90	2.90	2.50	2.50	2.40	2.40	2.80	4.30
1997	4.90		3.00	3.30	4.00	3.20	2.70					
2000		6.20	3.90	3.10	5.00	3.30	2.70	2.50	2.30	2.50	2.90	3.10
2001	4.50	5.10	5.80	4.33	3.70		2.50	2.40	2.50	2.60	2.50	4.20
2002	8.30	4.00	3.60	3.10	3.80	2.70	2.20	1.90	2.10	2.20	2.40	3.20
2003	4.70	3.90	3.00	2.80	3.30	3.00	2.00	2.10	2.30	2.30	2.60	3.40
2004	4.50	4.90	3.80	2.90	3.40	2.85	2.36	2.78	3.36	3.17	3.58	3.75
2005	8.20	7.10	4.90	3.90	2.70	3.30	2.60	2.20	2.20	2.30	2.30	2.80
2006	3.10	4.00	3.10	4.20	3.30	2.80	2.80	2.60	2.40	2.40		

SUMMARY OF TREND ANALYSIS RESULTS													
	Dissolved Organic Carbon												
	January	February	March	April	May	June	July	August	September	October	November	December	All Months
Number of Observations:	14	14	15	15	15	14	16	14	15	15	13	14	174
Significance													
Alpha													
0.01	no	no	no	no	no	no	down	no	no	down	no	no	down
0.05	no	no	no	no	no	down	down	down	down	down	no	no	down
0.1	no	no	down	down	down	down	down	down	down	down	no	no	down
0.2	no	no	down	down	down	down	down	down	down	down	no	no	down

Figure 3. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Banks



ALL DATA



v.1.56. CAS# n/a

WQStat Plus™

SEN'S SLOPE ESTIMATOR
Banks

n = 203

Slope = -14.345
units per year.

Mann Kendall
normal approx. =
-5.822

Alpha	Critical	Signif.
0.01	-2.575	Down
0.05	-1.96	Down
0.1	-1.645	Down
0.2	-1.282	Down

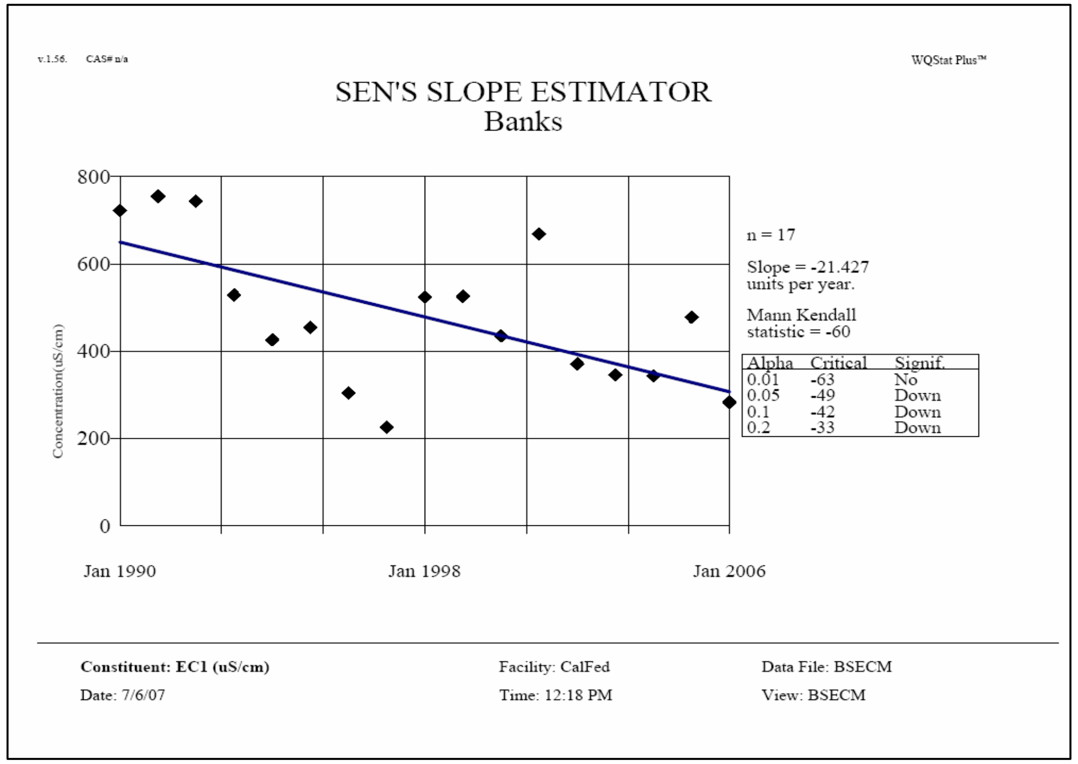
Constituent: EC (uS/cm)
Date: 7/6/07

Facility: CalFed
Time: 12:16 PM

Data File: BSECA
View: BSECA

Figure 3. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Banks

JANUARY



n = 17

Slope = -21.427 units per year.

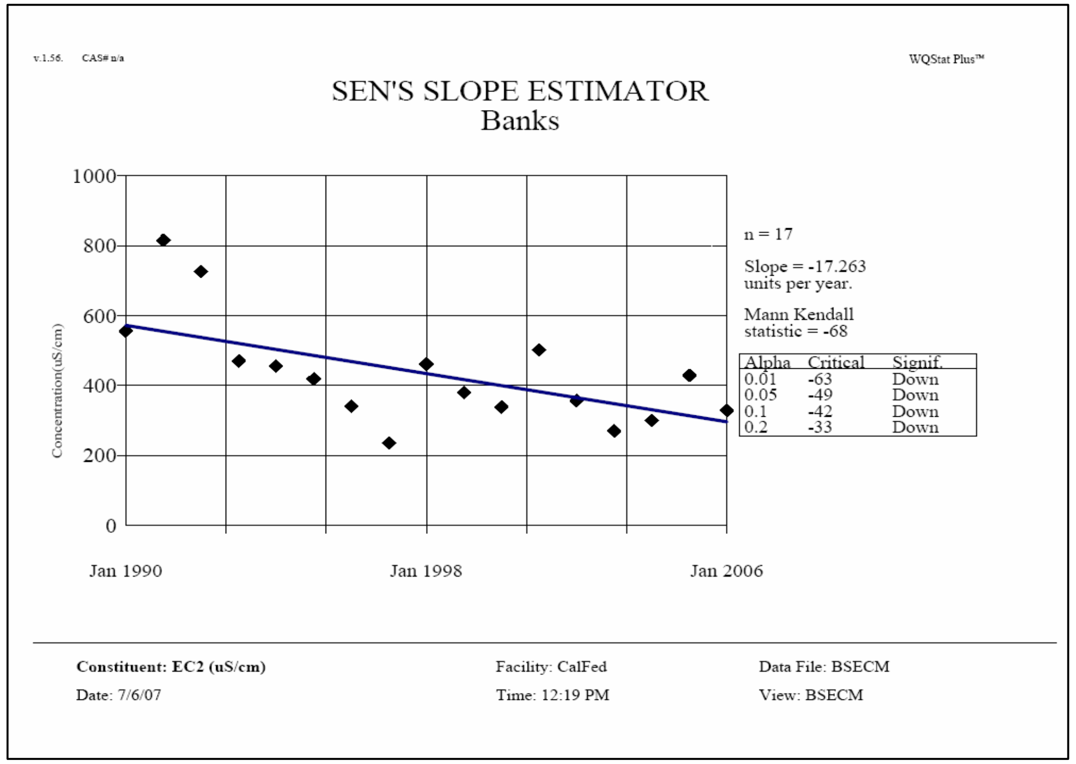
Mann Kendall statistic = -60

Alpha	Critical	Signif.
0.01	-63	No
0.05	-49	Down
0.1	-42	Down
0.2	-33	Down

Constituent: EC1 (uS/cm) Facility: CalFed Data File: BSECM

Date: 7/6/07 Time: 12:18 PM View: BSECM

FEBRUARY



n = 17

Slope = -17.263 units per year.

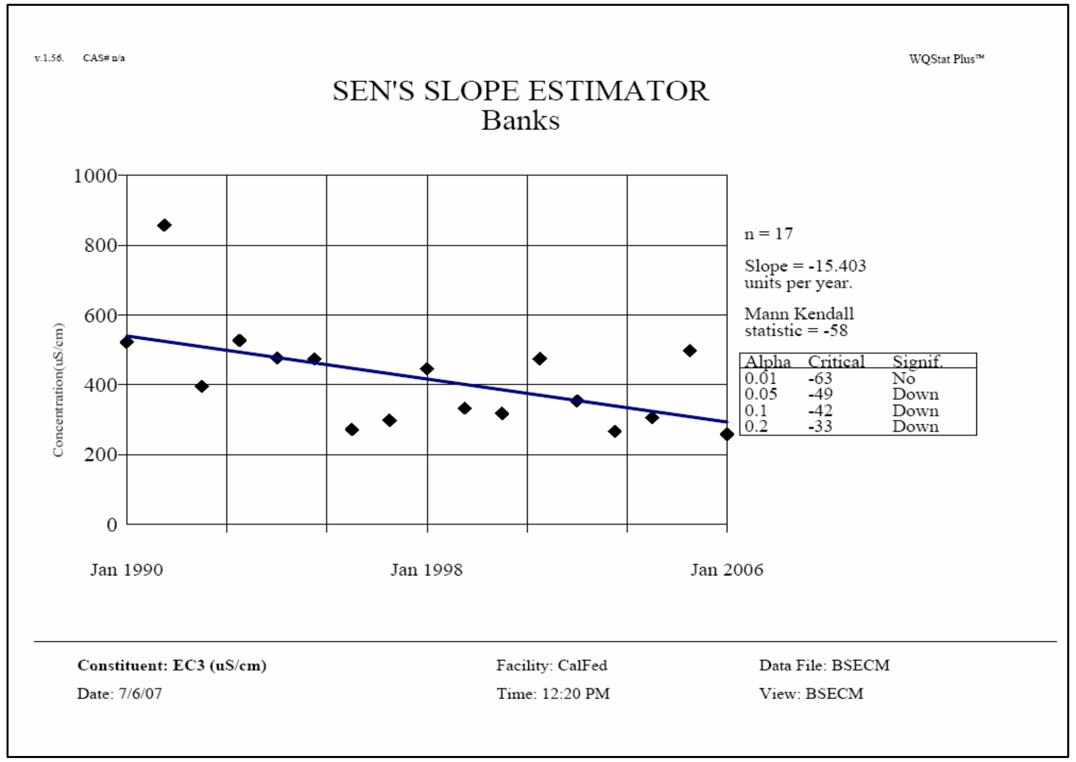
Mann Kendall statistic = -68

Alpha	Critical	Signif.
0.01	-63	Down
0.05	-49	Down
0.1	-42	Down
0.2	-33	Down

Constituent: EC2 (uS/cm) Facility: CalFed Data File: BSECM

Date: 7/6/07 Time: 12:19 PM View: BSECM

MARCH



n = 17

Slope = -15.403 units per year.

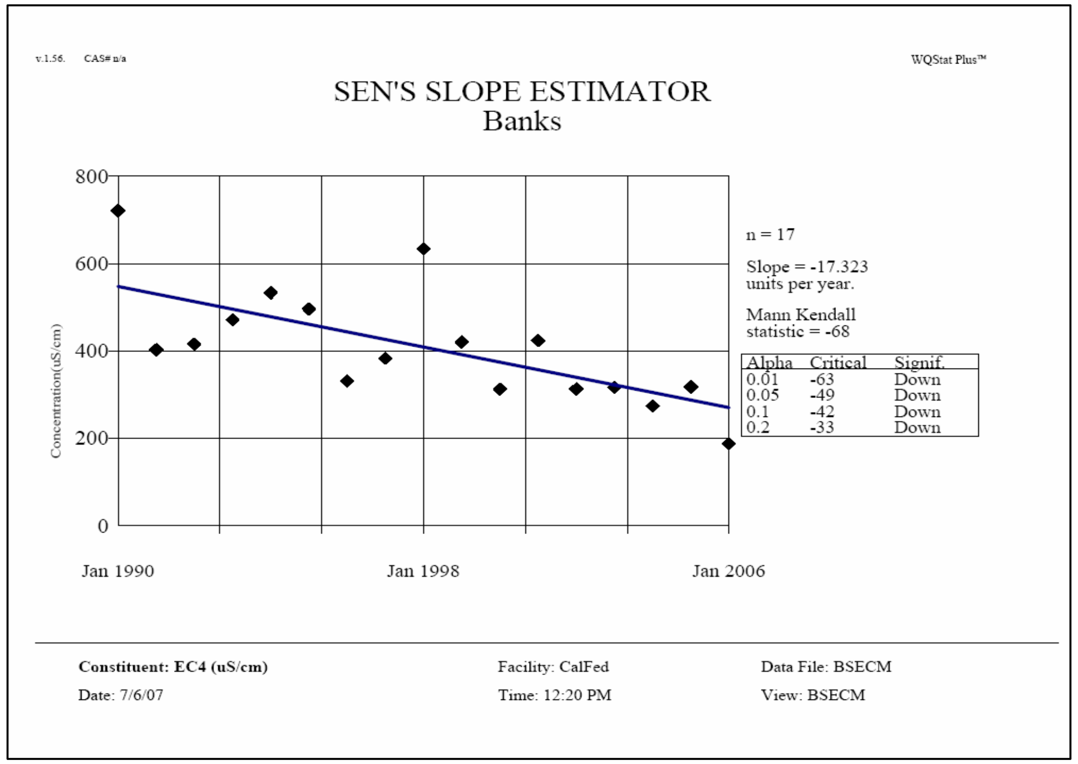
Mann Kendall statistic = -58

Alpha	Critical	Signif.
0.01	-63	No
0.05	-49	Down
0.1	-42	Down
0.2	-33	Down

Constituent: EC3 (uS/cm) Facility: CalFed Data File: BSECM

Date: 7/6/07 Time: 12:20 PM View: BSECM

APRIL



n = 17

Slope = -17.323 units per year.

Mann Kendall statistic = -68

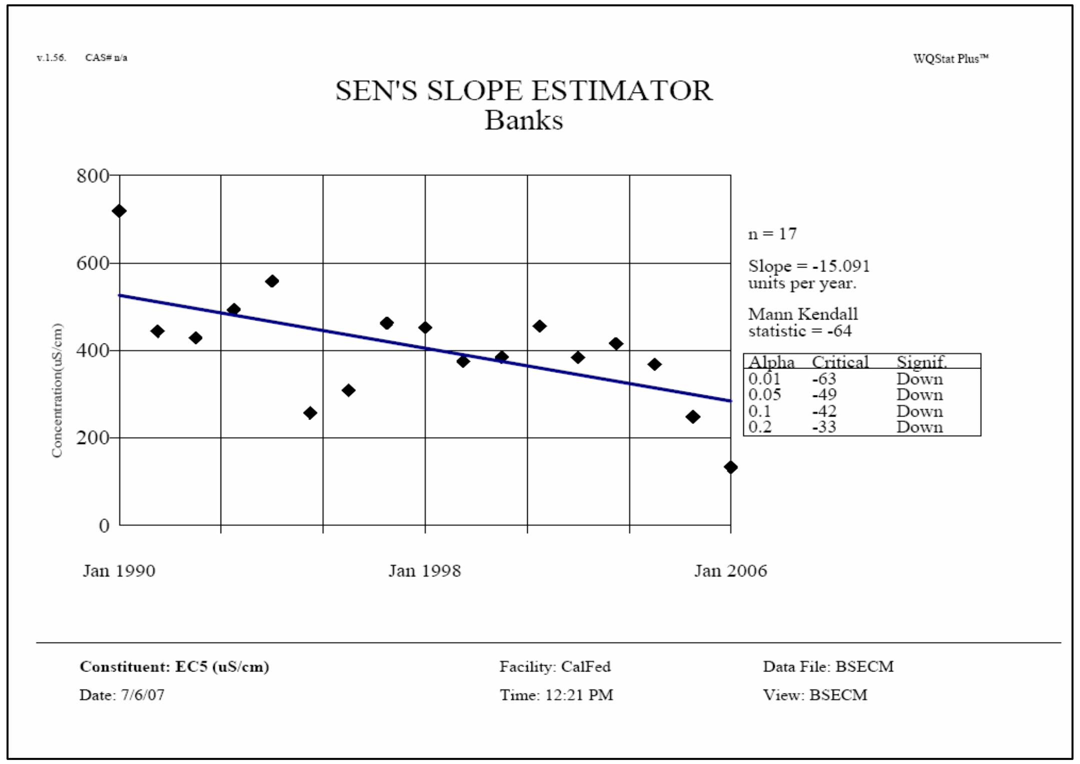
Alpha	Critical	Signif.
0.01	-63	Down
0.05	-49	Down
0.1	-42	Down
0.2	-33	Down

Constituent: EC4 (uS/cm) Facility: CalFed Data File: BSECM

Date: 7/6/07 Time: 12:20 PM View: BSECM

Figure 3. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Banks

MAY



SEN'S SLOPE ESTIMATOR
Banks

n = 17

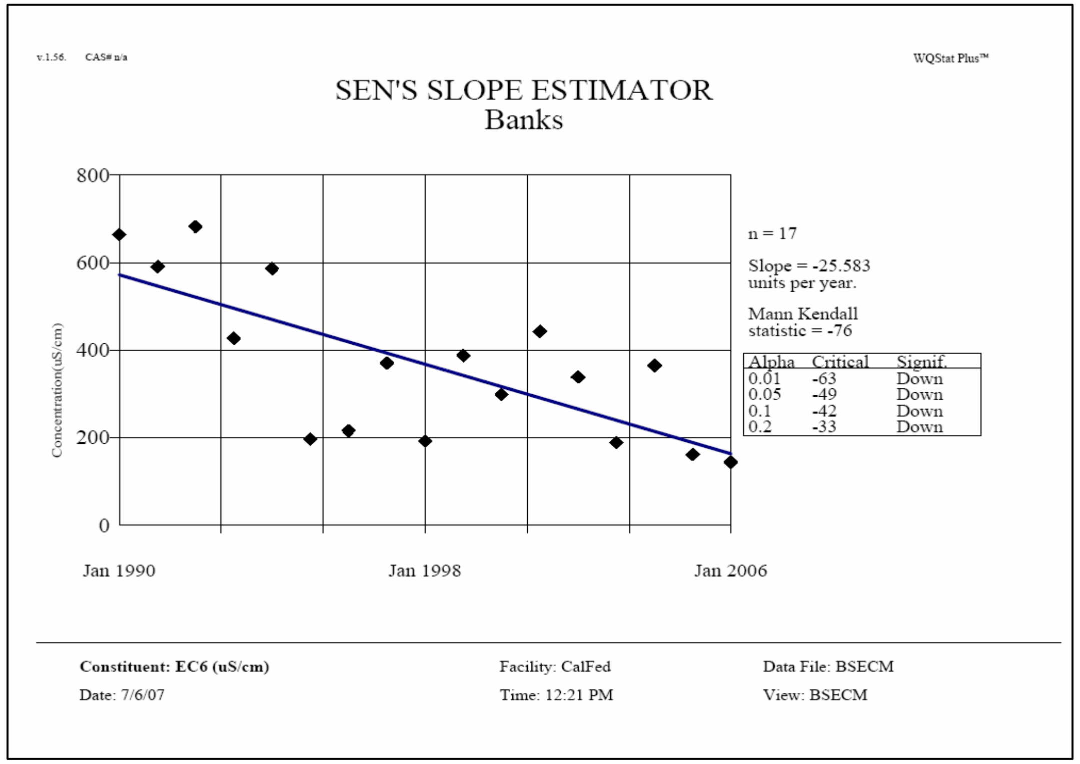
Slope = -15.091
units per year.

Mann Kendall
statistic = -64

Alpha	Critical	Signif.
0.01	-63	Down
0.05	-49	Down
0.1	-42	Down
0.2	-33	Down

Constituent: EC5 (uS/cm) Facility: CalFed Data File: BSECM
Date: 7/6/07 Time: 12:21 PM View: BSECM

JUNE



SEN'S SLOPE ESTIMATOR
Banks

n = 17

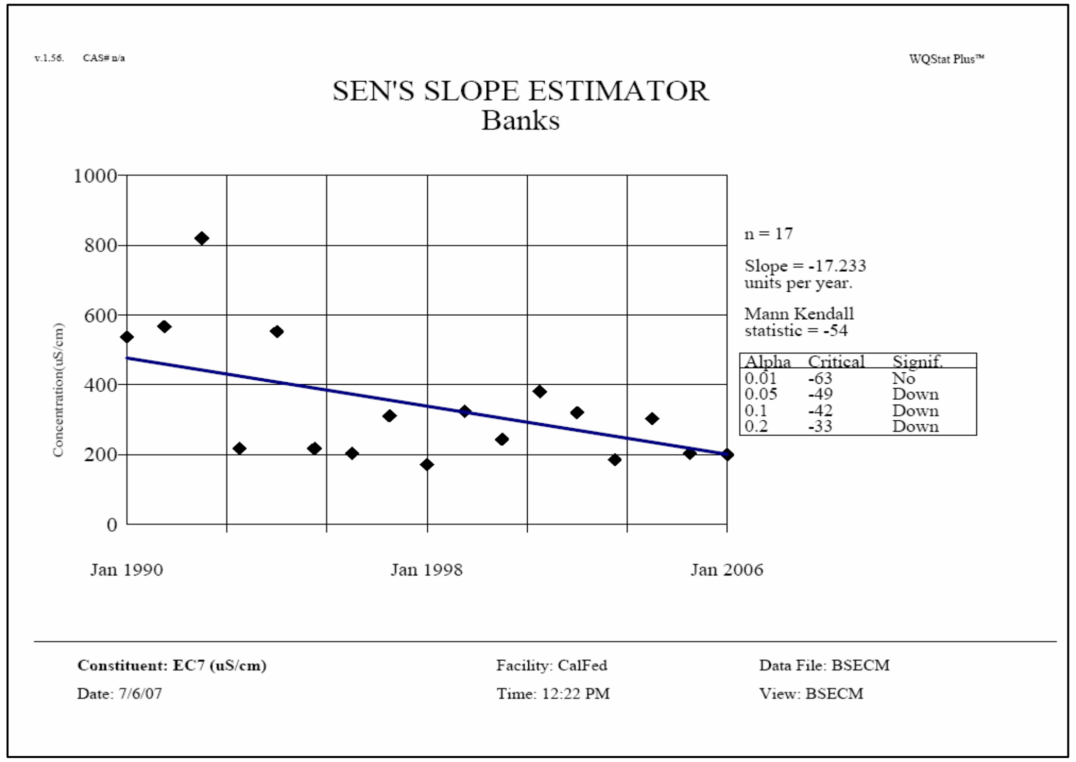
Slope = -25.583
units per year.

Mann Kendall
statistic = -76

Alpha	Critical	Signif.
0.01	-63	Down
0.05	-49	Down
0.1	-42	Down
0.2	-33	Down

Constituent: EC6 (uS/cm) Facility: CalFed Data File: BSECM
Date: 7/6/07 Time: 12:21 PM View: BSECM

JULY



SEN'S SLOPE ESTIMATOR
Banks

n = 17

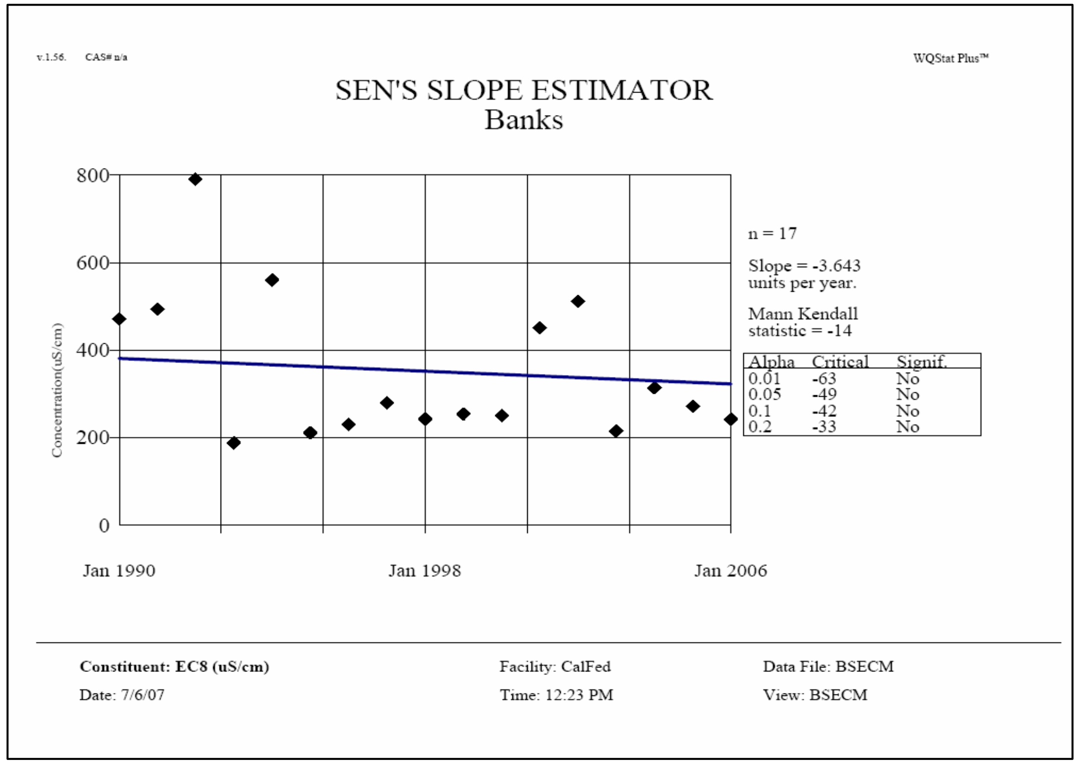
Slope = -17.233
units per year.

Mann Kendall
statistic = -54

Alpha	Critical	Signif.
0.01	-63	No
0.05	-49	Down
0.1	-42	Down
0.2	-33	Down

Constituent: EC7 (uS/cm) Facility: CalFed Data File: BSECM
Date: 7/6/07 Time: 12:22 PM View: BSECM

AUGUST



SEN'S SLOPE ESTIMATOR
Banks

n = 17

Slope = -3.643
units per year.

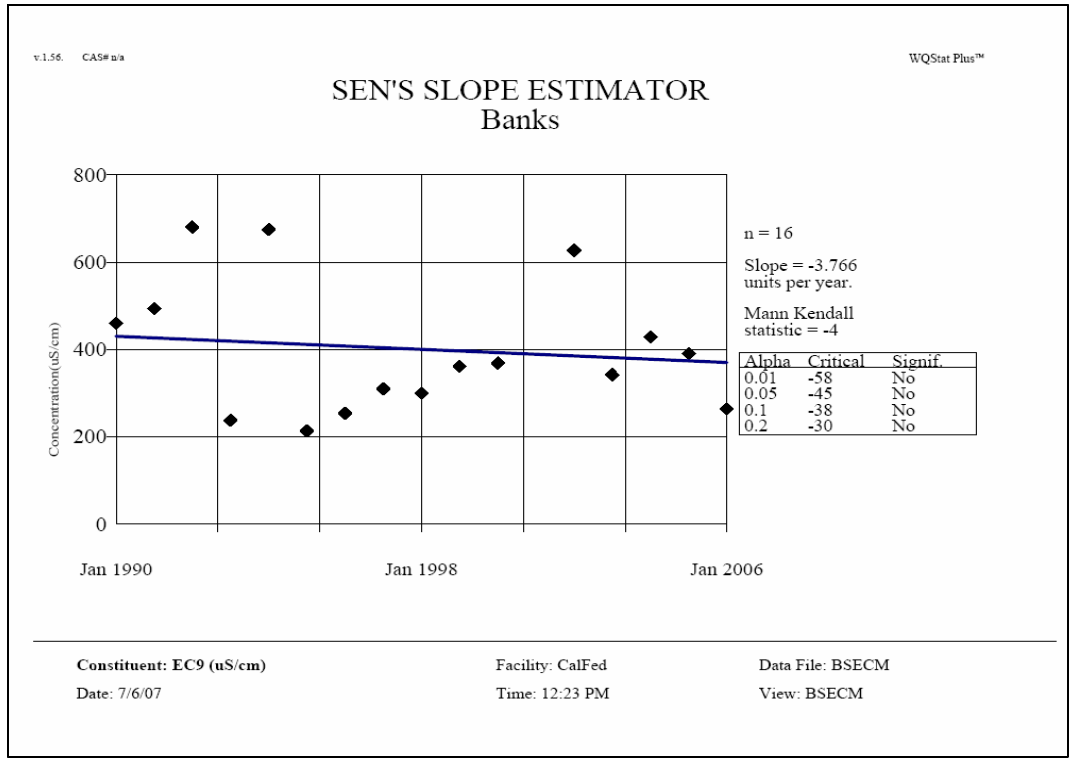
Mann Kendall
statistic = -14

Alpha	Critical	Signif.
0.01	-63	No
0.05	-49	No
0.1	-42	No
0.2	-33	No

Constituent: EC8 (uS/cm) Facility: CalFed Data File: BSECM
Date: 7/6/07 Time: 12:23 PM View: BSECM

Figure 3. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Banks

SEPTEMBER



n = 16

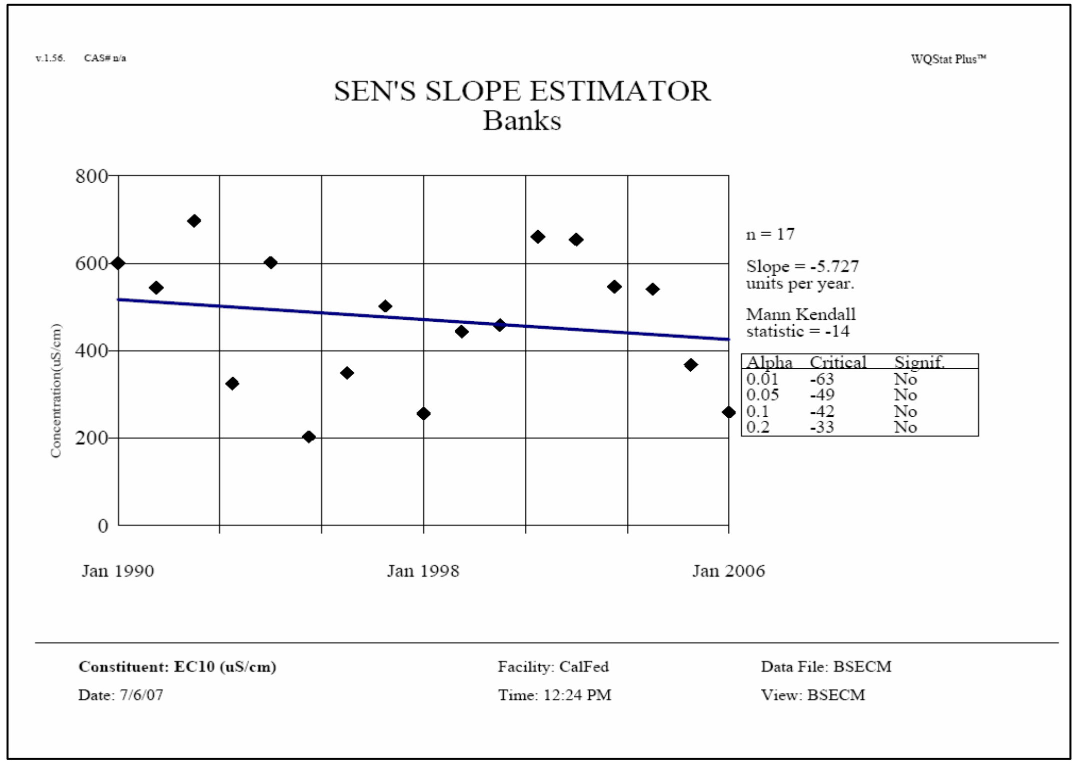
Slope = -3.766 units per year.

Mann Kendall statistic = -4

Alpha	Critical	Signif.
0.01	-58	No
0.05	-45	No
0.1	-38	No
0.2	-30	No

Constituent: EC9 (uS/cm) Facility: CalFed Data File: BSECM
Date: 7/6/07 Time: 12:23 PM View: BSECM

OCTOBER



n = 17

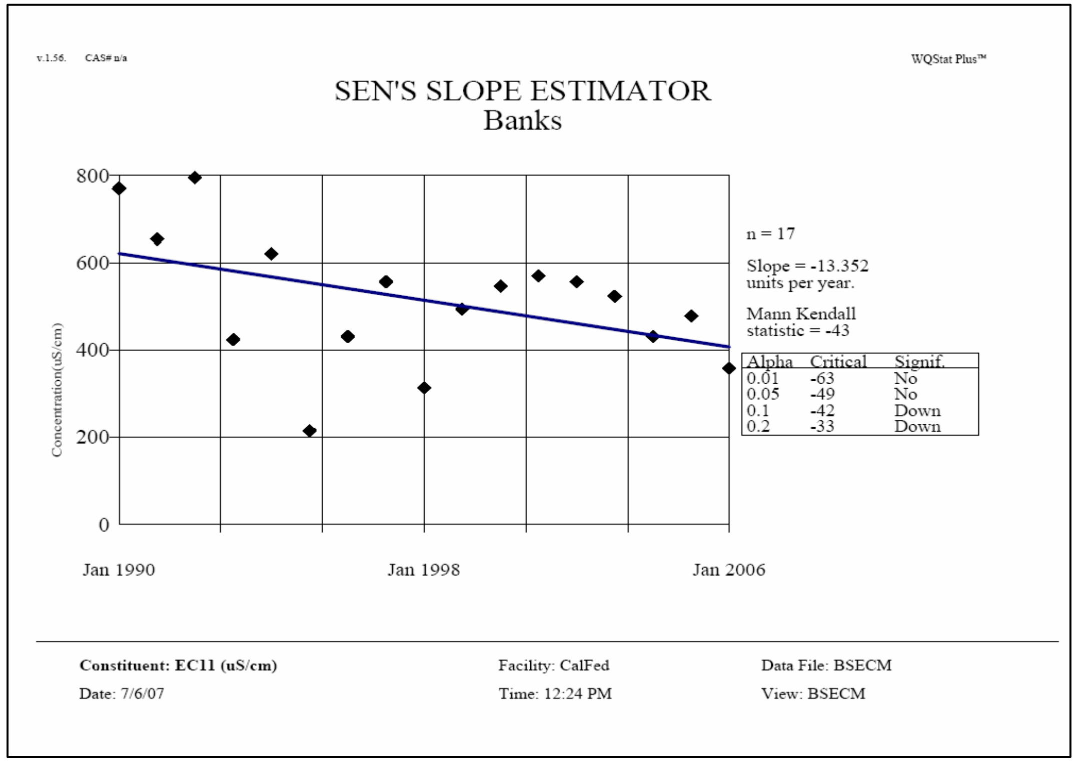
Slope = -5.727 units per year.

Mann Kendall statistic = -14

Alpha	Critical	Signif.
0.01	-63	No
0.05	-49	No
0.1	-42	No
0.2	-33	No

Constituent: EC10 (uS/cm) Facility: CalFed Data File: BSECM
Date: 7/6/07 Time: 12:24 PM View: BSECM

NOVEMBER



n = 17

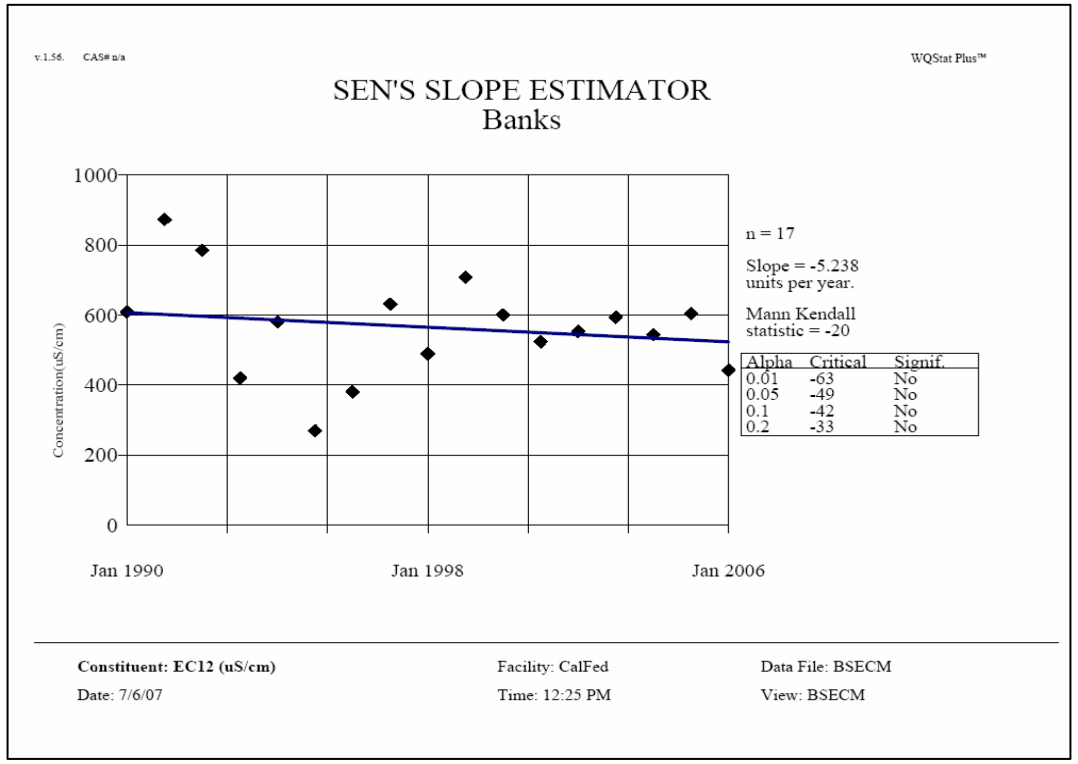
Slope = -13.352 units per year.

Mann Kendall statistic = -43

Alpha	Critical	Signif.
0.01	-63	No
0.05	-49	No
0.1	-42	Down
0.2	-33	Down

Constituent: EC11 (uS/cm) Facility: CalFed Data File: BSECM
Date: 7/6/07 Time: 12:24 PM View: BSECM

DECEMBER



n = 17

Slope = -5.238 units per year.

Mann Kendall statistic = -20

Alpha	Critical	Signif.
0.01	-63	No
0.05	-49	No
0.1	-42	No
0.2	-33	No

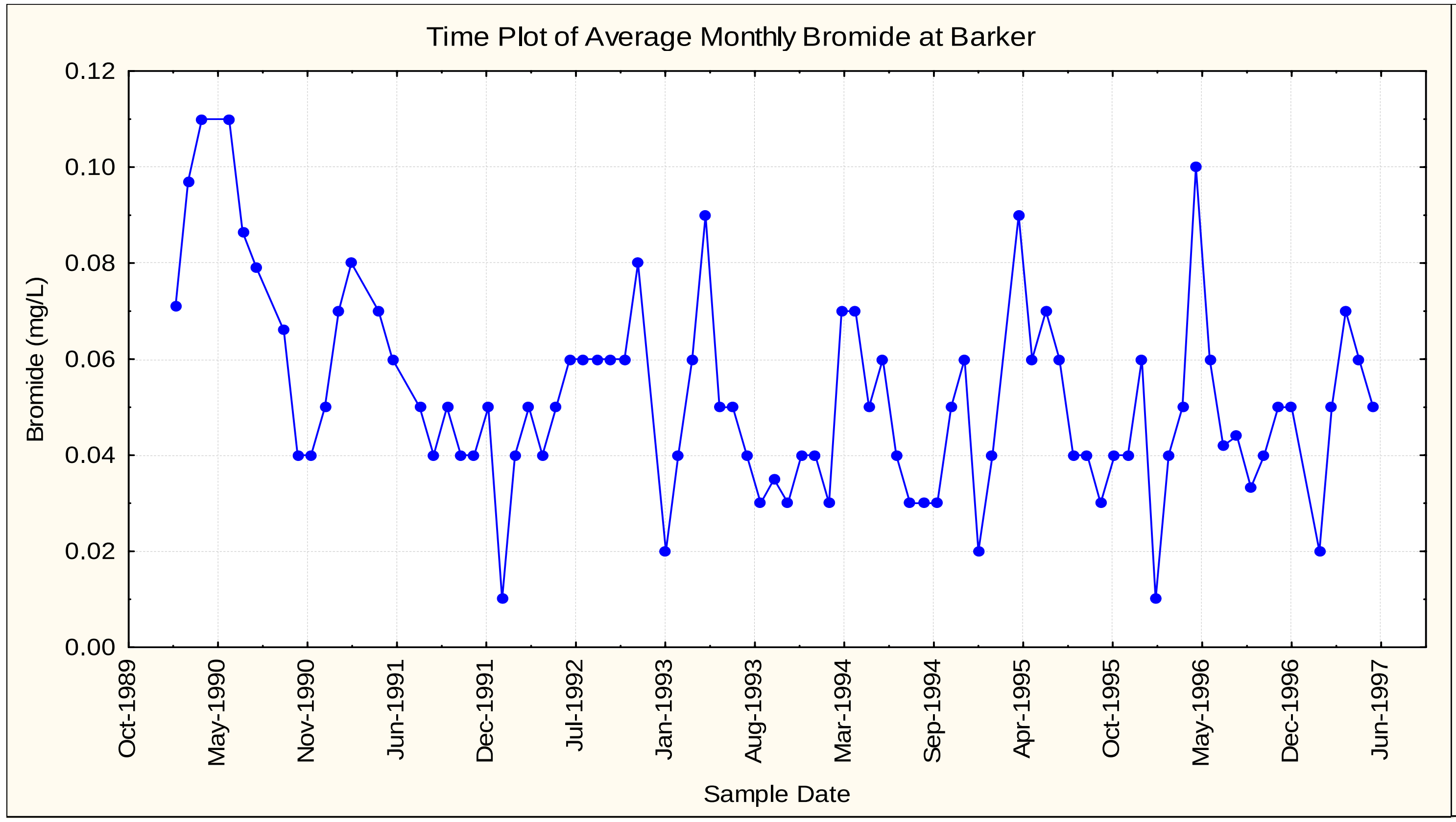
Constituent: EC12 (uS/cm) Facility: CalFed Data File: BSECM
Date: 7/6/07 Time: 12:25 PM View: BSECM

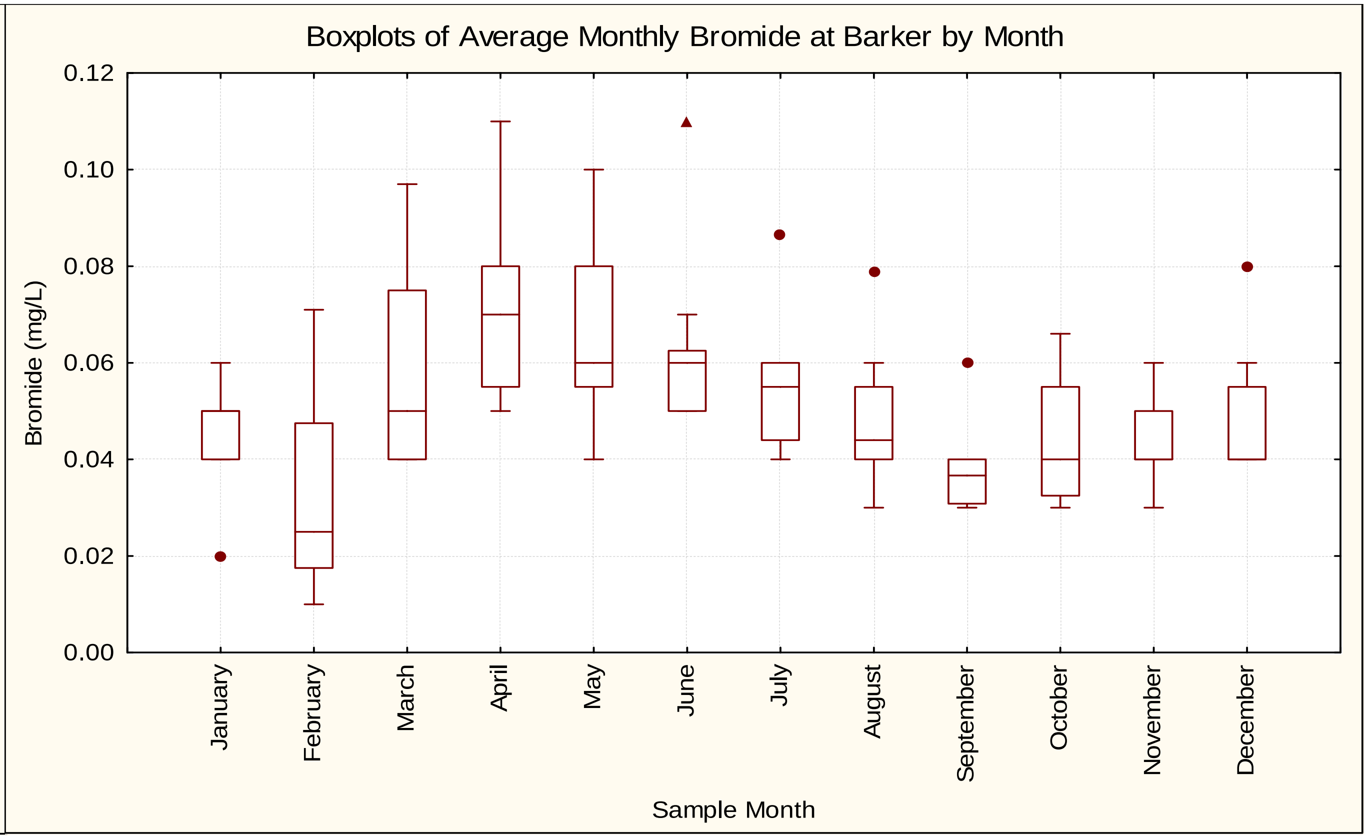
Figure 3. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Banks

DATA USED IN TREND ANALYSIS - AVERAGE MONTHLY MEASUREMENTS OF ELECTRICAL CONDUCTIVITY (µS/CM)												
Sample Year	January	February	March	April	May	June	July	August	September	October	November	December
1990	721.9	555.5	521.7	721.6	718.8	664.2	536.7	471.8	460.2	599.5	770.4	608.9
1991	755.2	815.5	857.5	402.1	443.6	590.5	566.7	493.6	494.0	543.8	654.3	872.9
1992	743.5	726.0	395.0	415.8	428.1	682.0	820.4	790.6	680.6	696.9	795.2	785.6
1993	528.4	470.3	526.9	470.8	492.9	427.2	217.9	187.3	237.5	324.4	423.2	420.1
1994	426.0	455.3	476.6	532.7	558.2	586.3	552.8	560.0	674.5	601.5	620.3	580.2
1995	453.9	418.9	473.5	496.0	256.4	196.3	217.2	210.6	212.8	202.6	214.3	269.3
1996	303.7	340.4	271.0	331.0	308.2	215.5	203.0	230.4	253.9	349.0	430.8	380.6
1997	225.2	235.7	298.3	383.2	462.3	370.3	310.7	279.5	309.5	501.7	556.4	631.3
1998	523.2	460.6	446.1	633.6	452.4	192.3	170.2	242.4	299.3	255.3	312.5	489.2
1999	525.5	379.7	332.9	420.3	374.5	387.1	324.0	253.4	360.9	443.6	493.1	708.3
2000	434.9	338.0	318.1	312.0	384.4	298.0	243.6	250.3	368.5	458.4	546.4	600.7
2001	668.4	501.5	475.3	423.7	455.3	442.5	380.6	450.8		660.3	569.5	523.7
2002	370.7	357.2	353.7	312.8	383.7	338.1	320.2	511.3	627.1	654.1	556.4	553.0
2003	345.5	270.5	266.9	316.3	415.3	188.9	184.7	214.5	341.8	546.3	523.1	593.2
2004	343.1	300.4	305.2	273.7	367.4	364.4	302.2	313.4	429.0	540.9	430.6	544.0
2005	477.3	429.4	497.7	317.6	247.8	161.2	202.8	271.5	390.1	367.2	478.3	604.1
2006	282.3	328.4	258.0	187.4	132.4	143.3	199.8	241.8	263.4	258.7	358.0	442.6

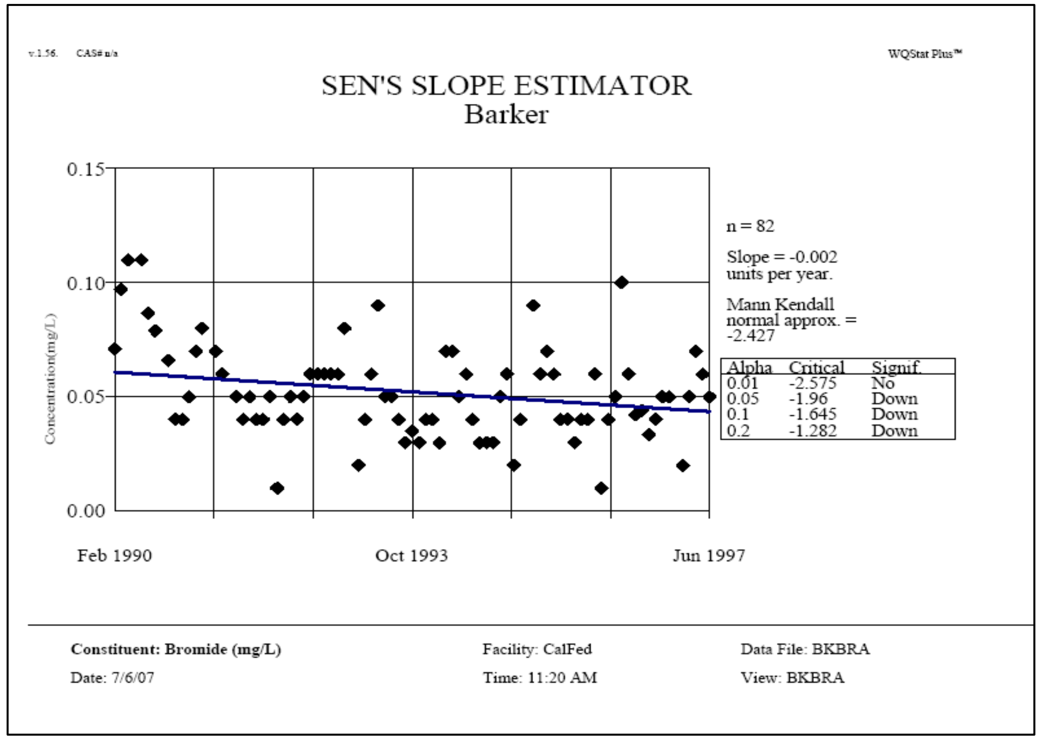
SUMMARY OF TREND ANALYSIS RESULTS													
	Electrical Conductivity												
	January	February	March	April	May	June	July	August	September	October	November	December	All Months
Number of Observations:	17	17	17	17	17	17	17	17	16	17	17	17	203
Significance													
Alpha													
0.01	no	down	no	down	down	down	no	no	no	no	no	no	down
0.05	down	down	down	down	down	down	down	no	no	no	no	no	down
0.1	down	down	down	down	down	down	down	no	no	no	down	no	down
0.2	down	down	down	down	down	down	down	no	no	no	down	no	down

Figure 4. Trend Analysis Using Average Monthly Concentrations of Bromide at Barker


Time Plot of Average Monthly Bromide at Barker


Boxplots of Average Monthly Bromide at Barker by Month

ALL DATA


v.1.56. CAS# n/a

WQStat Plus™

SEN'S SLOPE ESTIMATOR
Barker

n = 82

Slope = -0.002
units per year.

Mann Kendall
normal approx. =
-2.427

Alpha	Critical	Signif.
0.01	-2.575	No
0.05	-1.96	Down
0.1	-1.645	Down
0.2	-1.282	Down

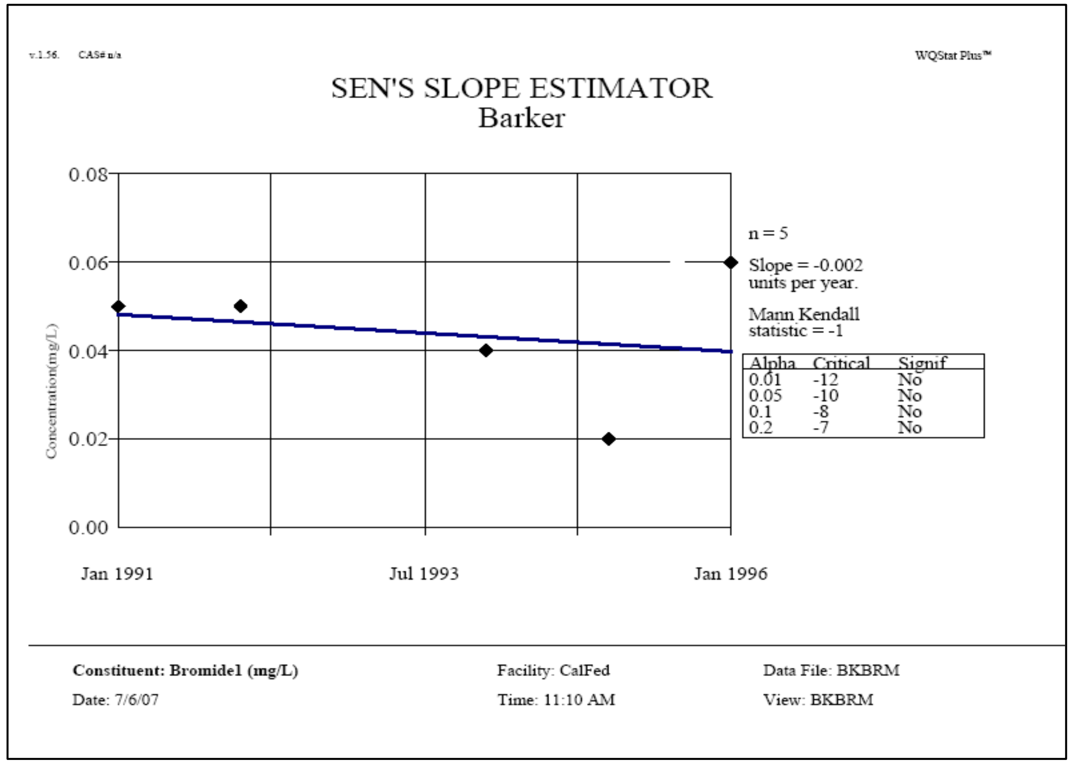
Constituent: Bromide (mg/L)
Date: 7/6/07

Facility: CalFed
Time: 11:20 AM

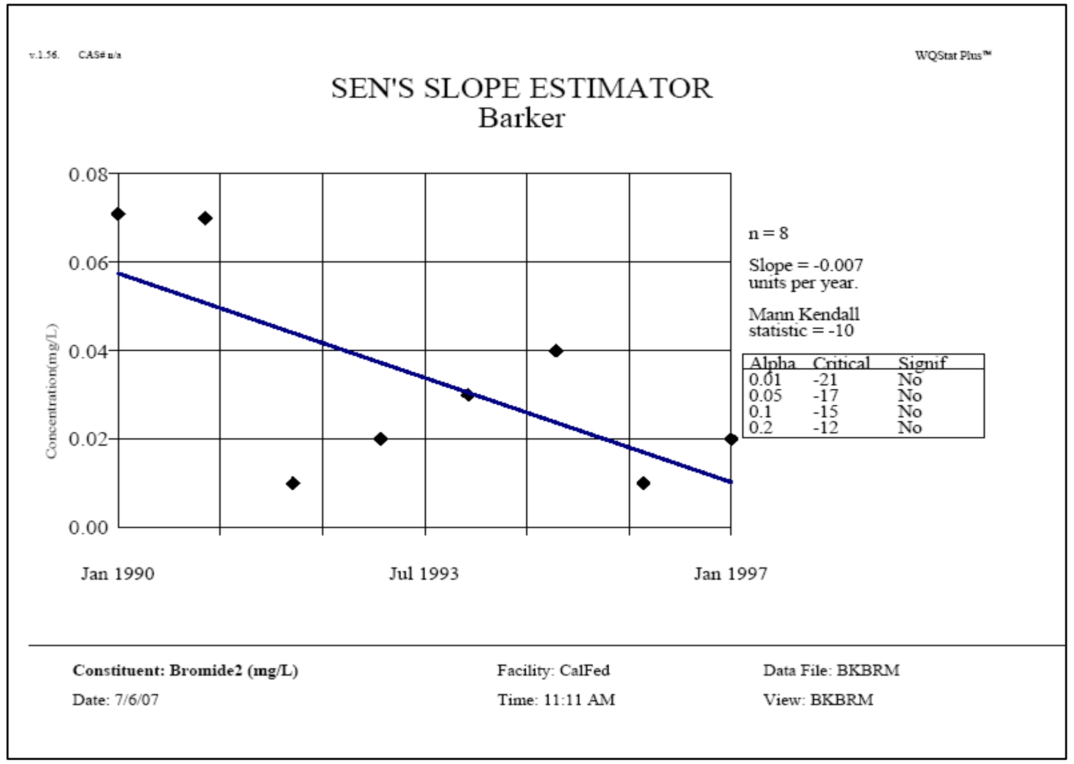
Data File: BKBRA
View: BKBRA

Figure 4. Trend Analysis Using Average Monthly Concentrations of Bromide at Barker

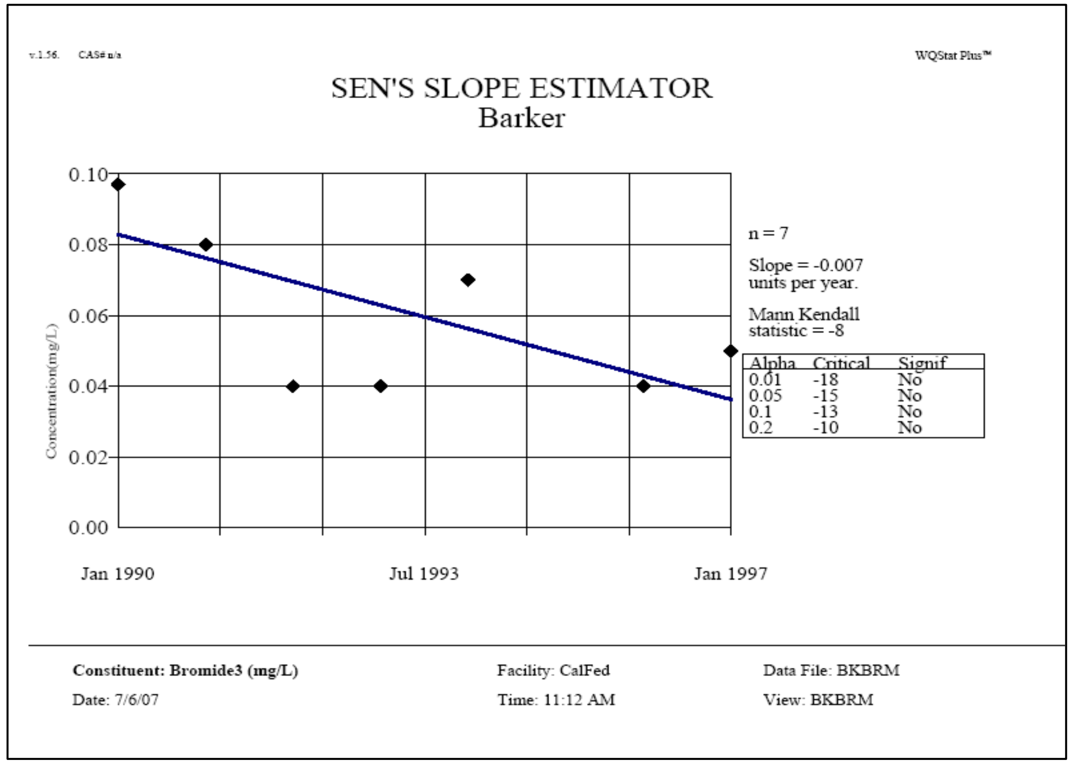
JANUARY



FEBRUARY



MARCH



APRIL

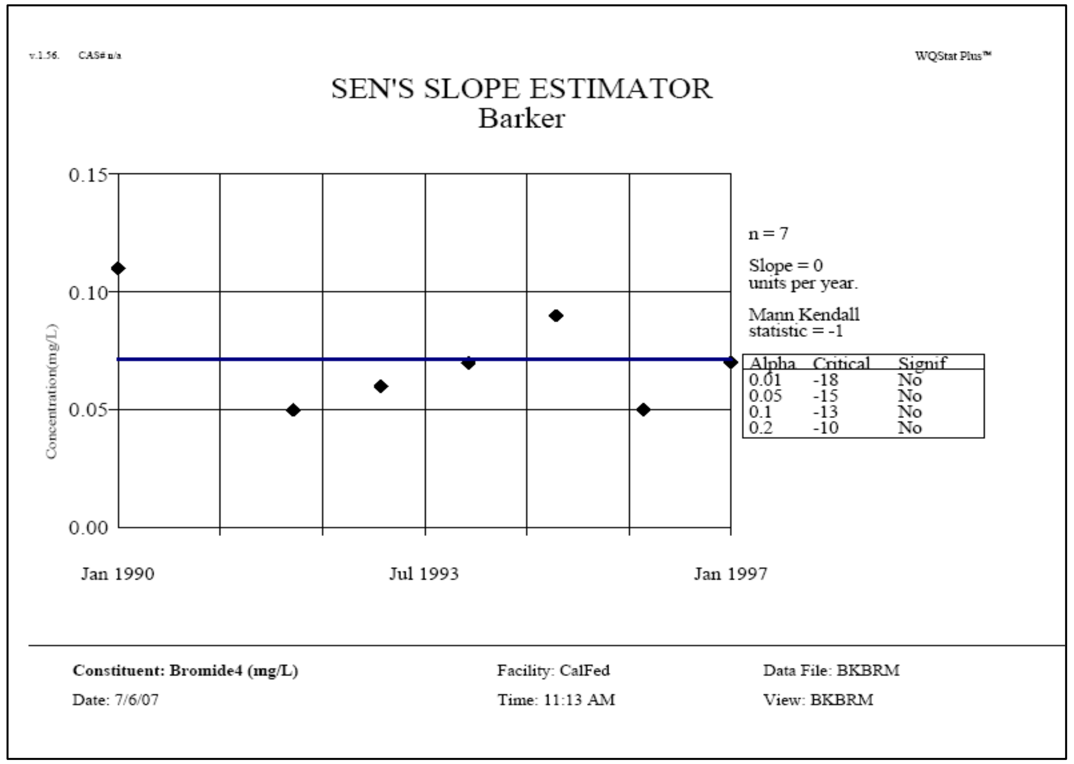
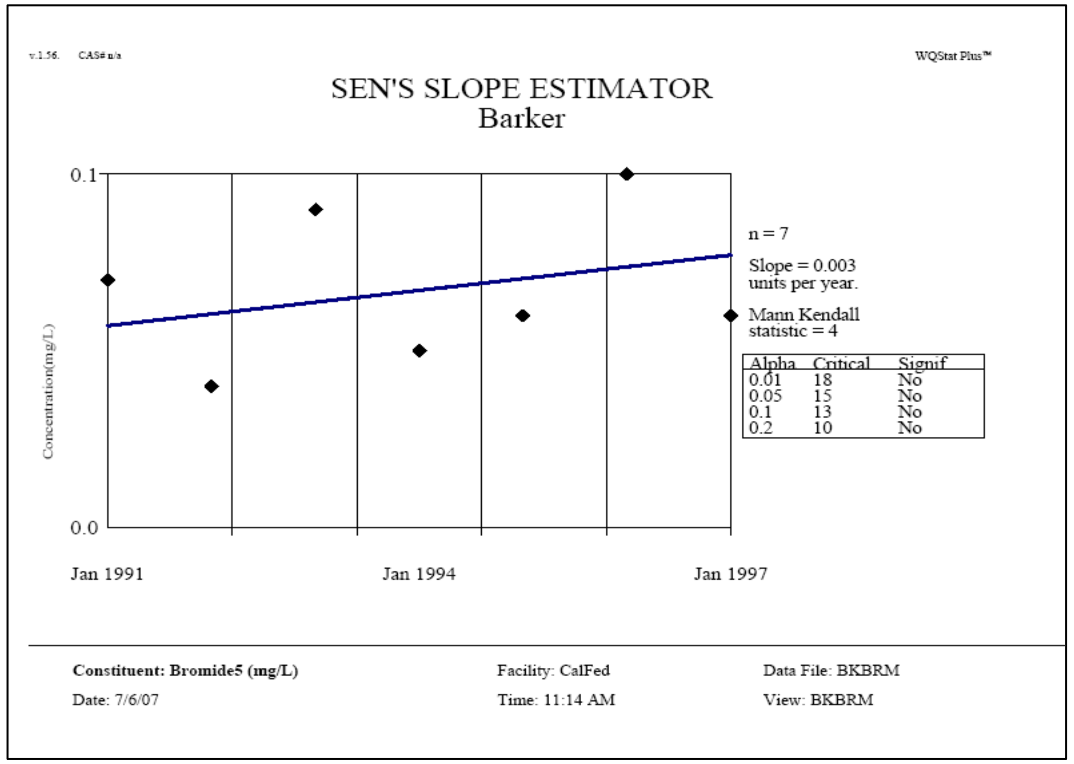
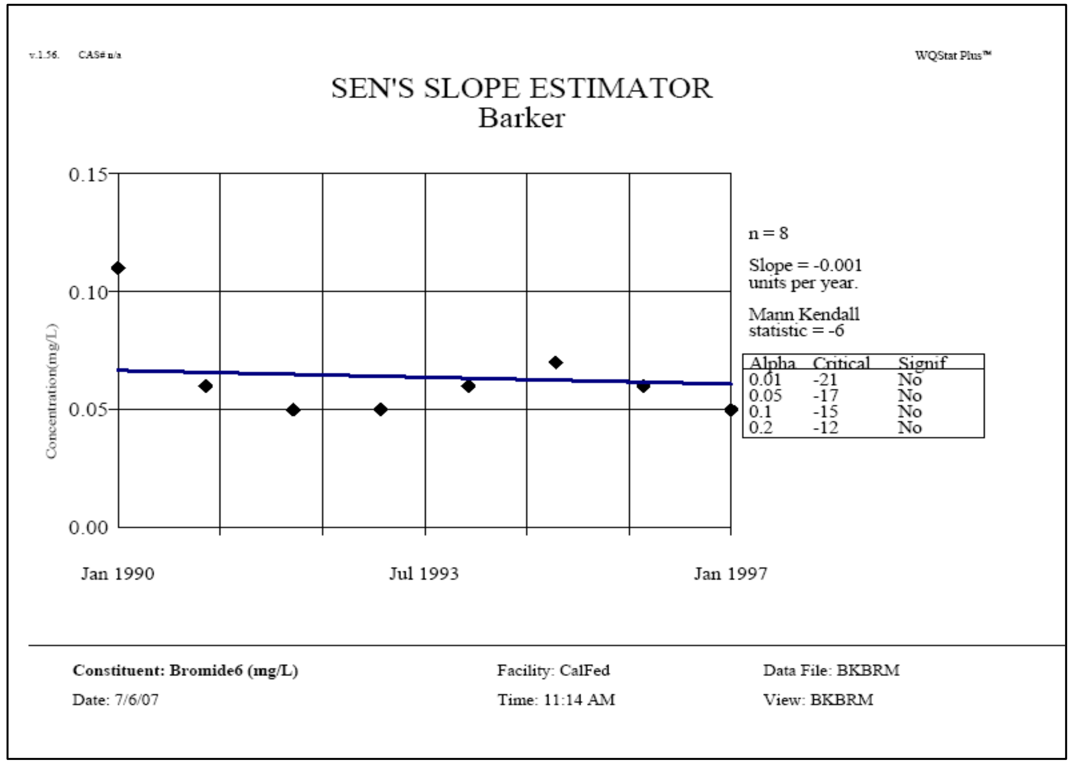


Figure 4. Trend Analysis Using Average Monthly Concentrations of Bromide at Barker

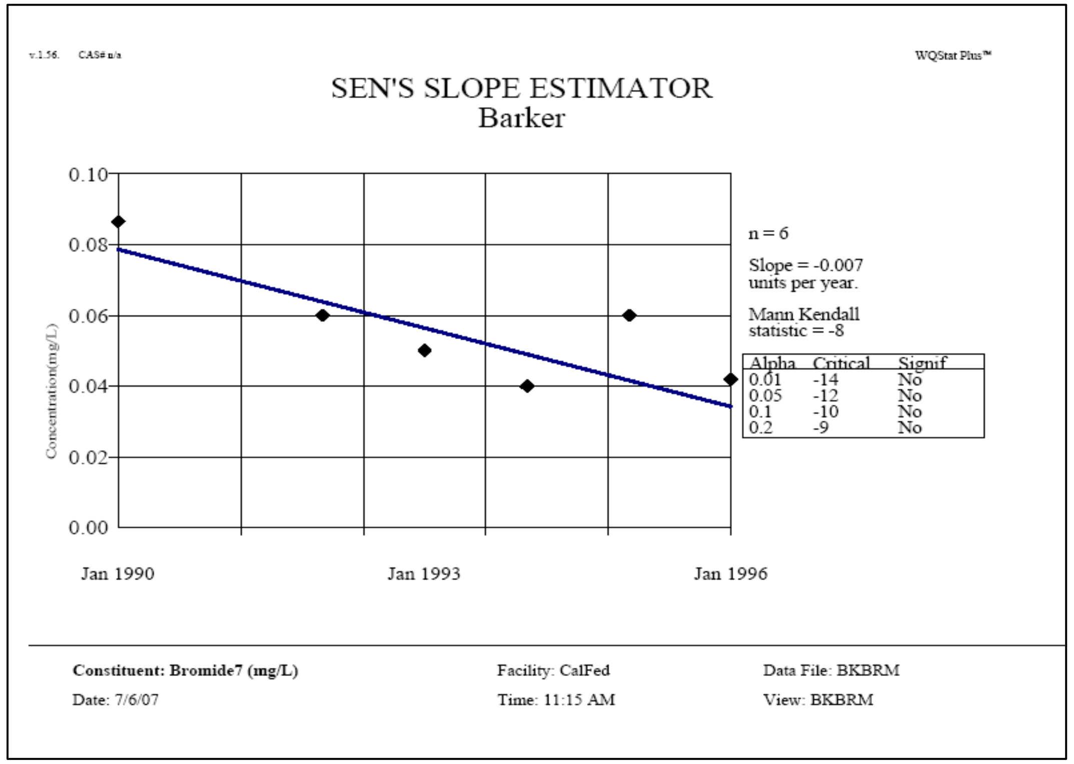
MAY



JUNE



JULY



AUGUST

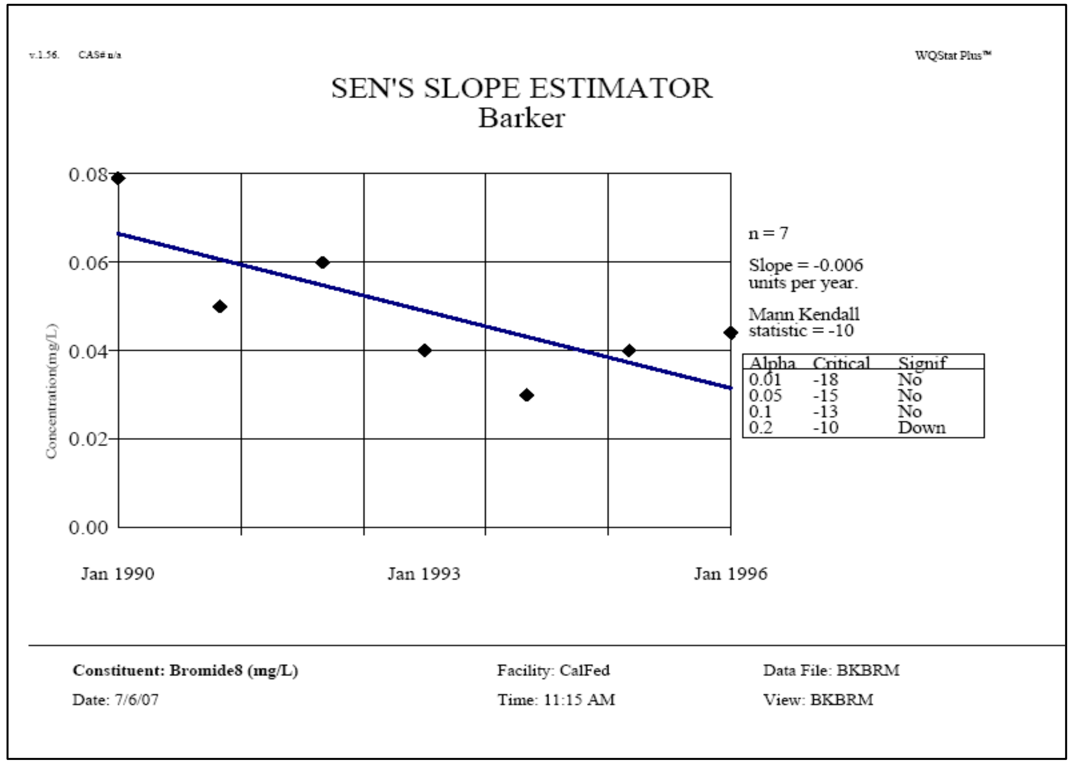
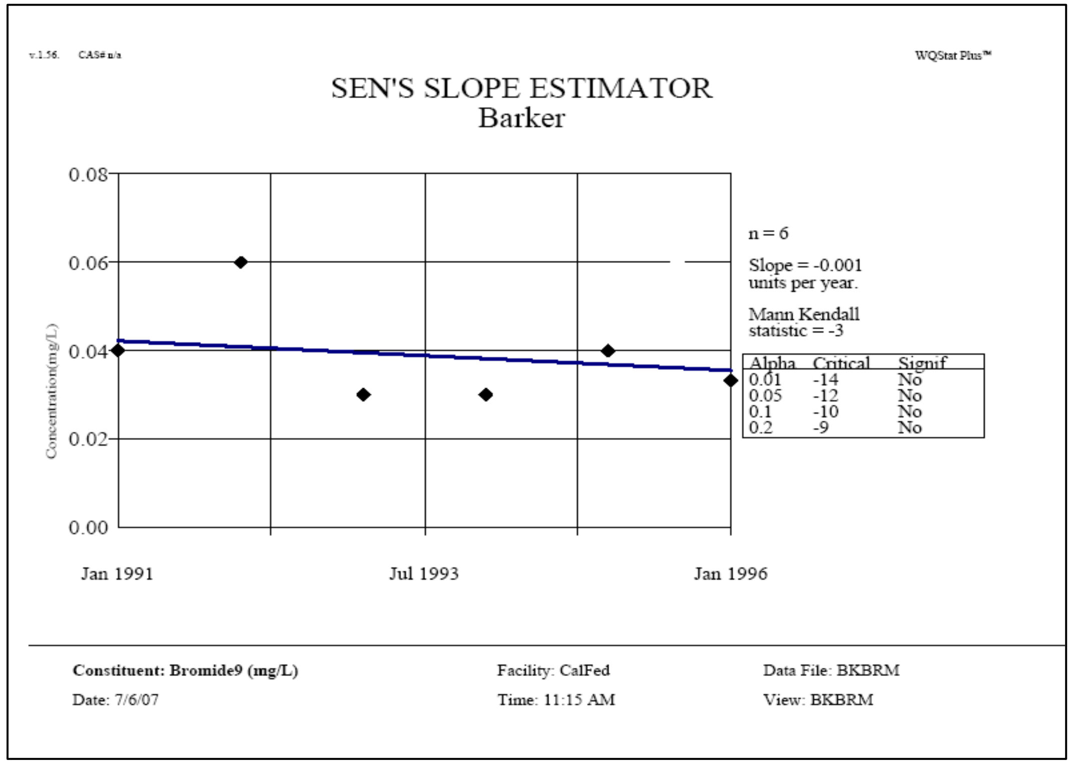
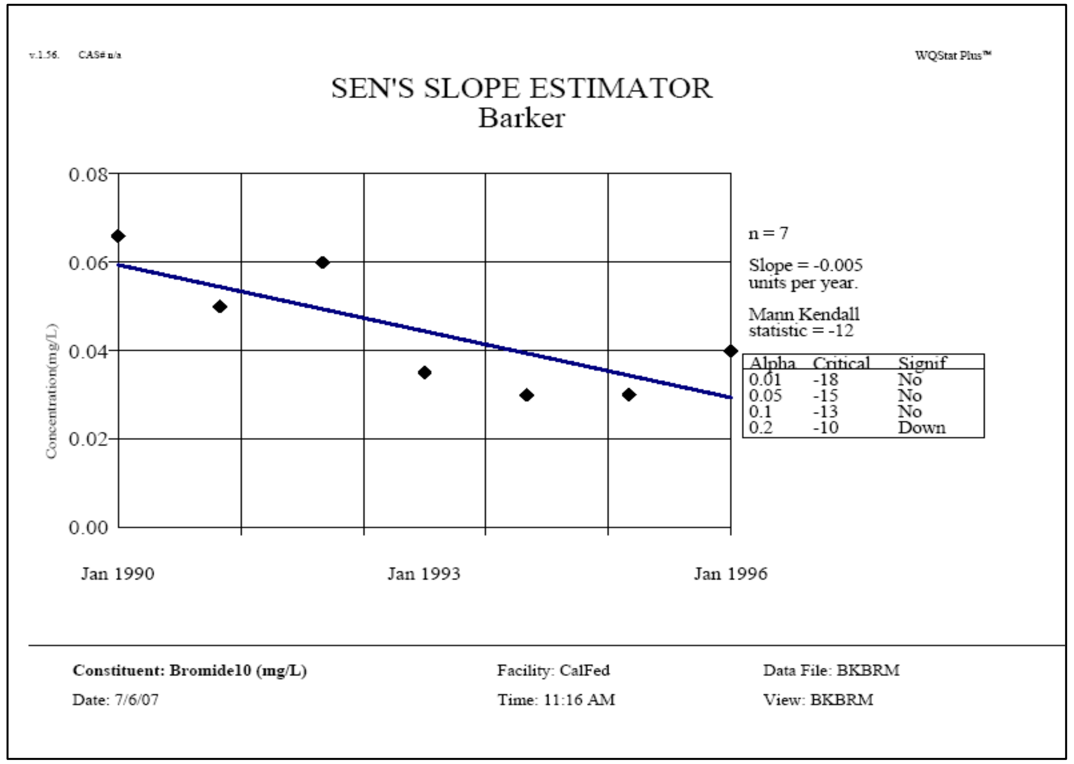


Figure 4. Trend Analysis Using Average Monthly Concentrations of Bromide at Barker

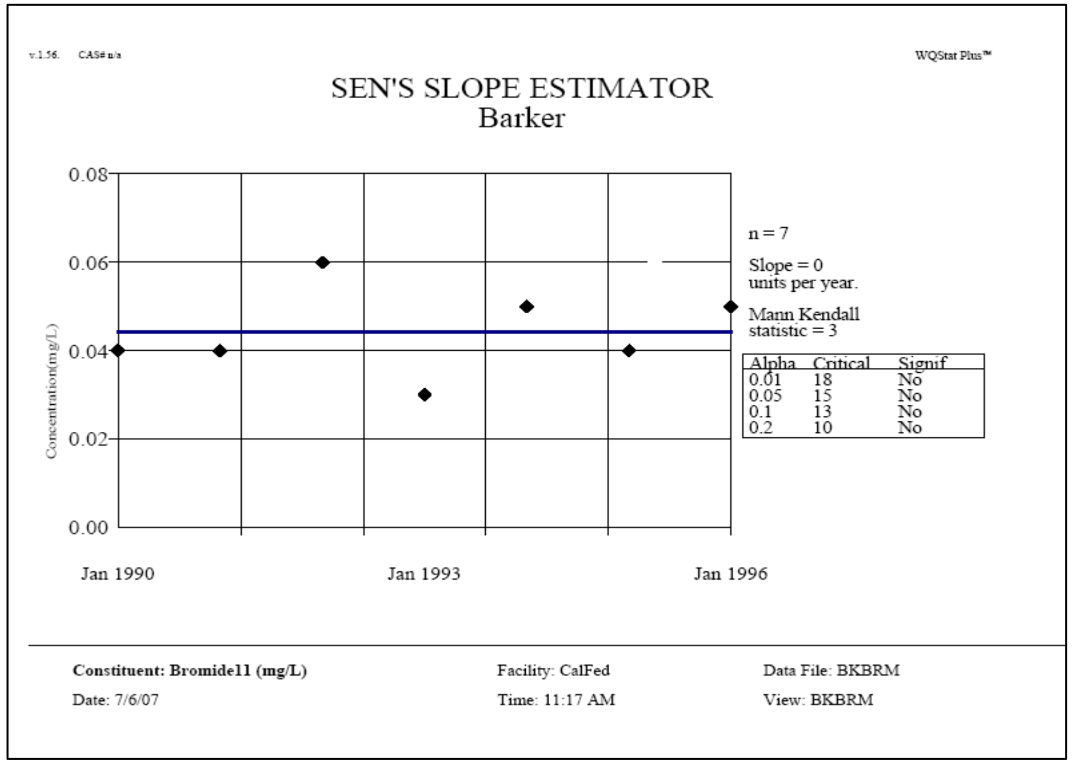
SEPTEMBER



OCTOBER



NOVEMBER



DECEMBER

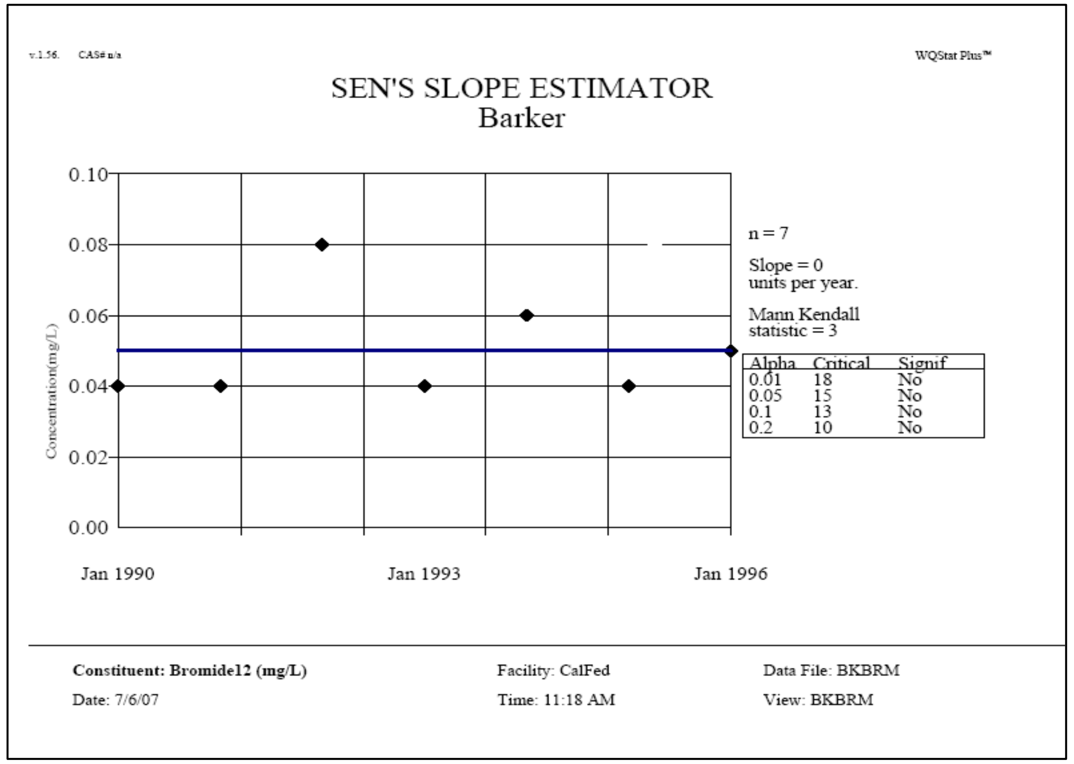
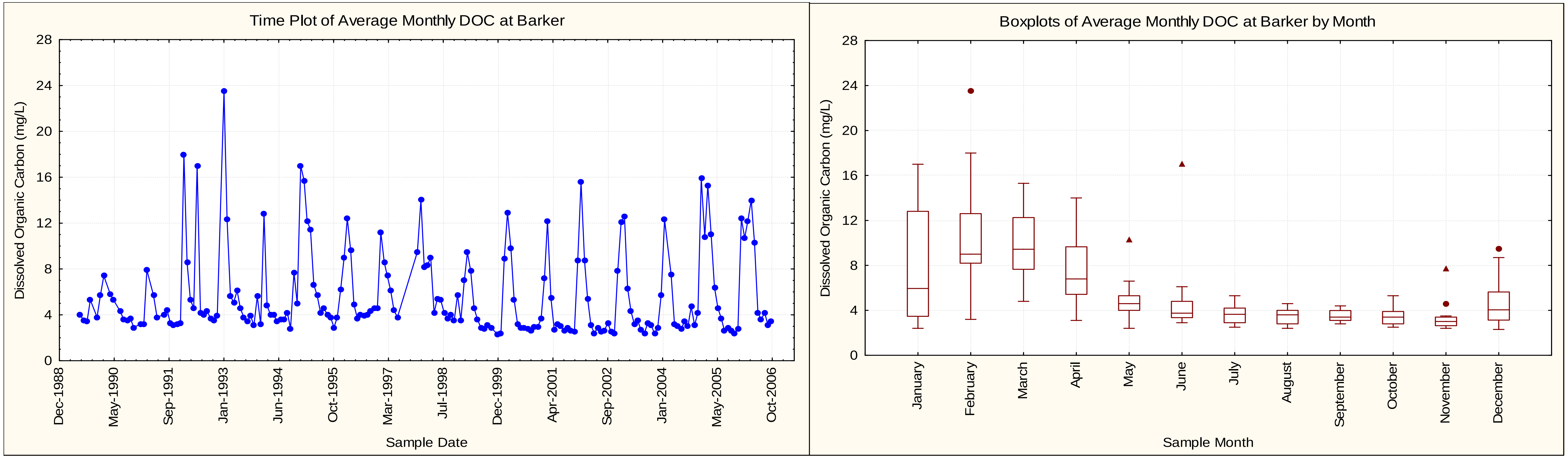


Figure 4. Trend Analysis Using Average Monthly Concentrations of Bromide at Barker

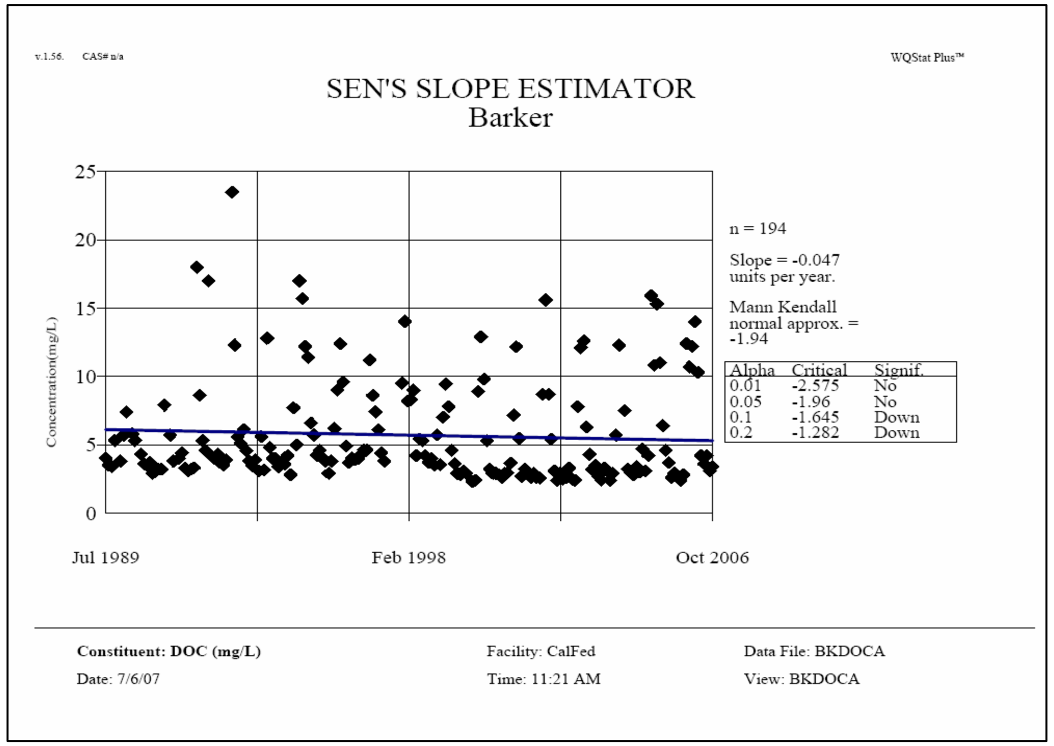
DATA USED IN TREND ANALYSIS - AVERAGE MONTHLY CONCENTRATIONS OF BROMIDE (MG/L)												
Sample Year	January	February	March	April	May	June	July	August	September	October	November	December
1990		0.0710	0.0970	0.1100		0.1100	0.0865	0.0790		0.0660	0.0400	0.0400
1991	0.0500	0.0700	0.0800		0.0700	0.0600		0.0500	0.0400	0.0500	0.0400	0.0400
1992	0.0500	0.0100	0.0400	0.0500	0.0400	0.0500	0.0600	0.0600	0.0600	0.0600	0.0600	0.0800
1993		0.0200	0.0400	0.0600	0.0900	0.0500	0.0500	0.0400	0.0300	0.0350	0.0300	0.0400
1994	0.0400	0.0300	0.0700	0.0700	0.0500	0.0600	0.0400	0.0300	0.0300	0.0300	0.0500	0.0600
1995	0.0200	0.0400		0.0900	0.0600	0.0700	0.0600	0.0400	0.0400	0.0300	0.0400	0.0400
1996	0.0600	0.0100	0.0400	0.0500	0.1000	0.0600	0.0420	0.0440	0.0333	0.0400	0.0500	0.0500
1997		0.0200	0.0500	0.0700	0.0600	0.0500						

SUMMARY OF TREND ANALYSIS RESULTS													
	Bromide												
	January	February	March	April	May	June	July	August	September	October	November	December	All Months
Number of Observations:	5	8	7	7	7	8	6	7	6	7	7	7	82
Significance													
Alpha													
0.01	no	no	no	no	no	no	no	no	no	no	no	no	no
0.05	no	no	no	no	no	no	no	no	no	no	no	no	down
0.1	no	no	no	no	no	no	no	no	no	no	no	no	down
0.2	no	no	no	no	no	no	no	down	no	down	no	no	down

Figure 5. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at Barker



ALL DATA



v.1.56. CAS# n/a

WQStat Plus™

SEN'S SLOPE ESTIMATOR
Barker

n = 194

Slope = -0.047
units per year.

Mann Kendall
normal approx. =
-1.94

Alpha	Critical	Signif.
0.01	-2.575	No
0.05	-1.96	No
0.1	-1.645	Down
0.2	-1.282	Down

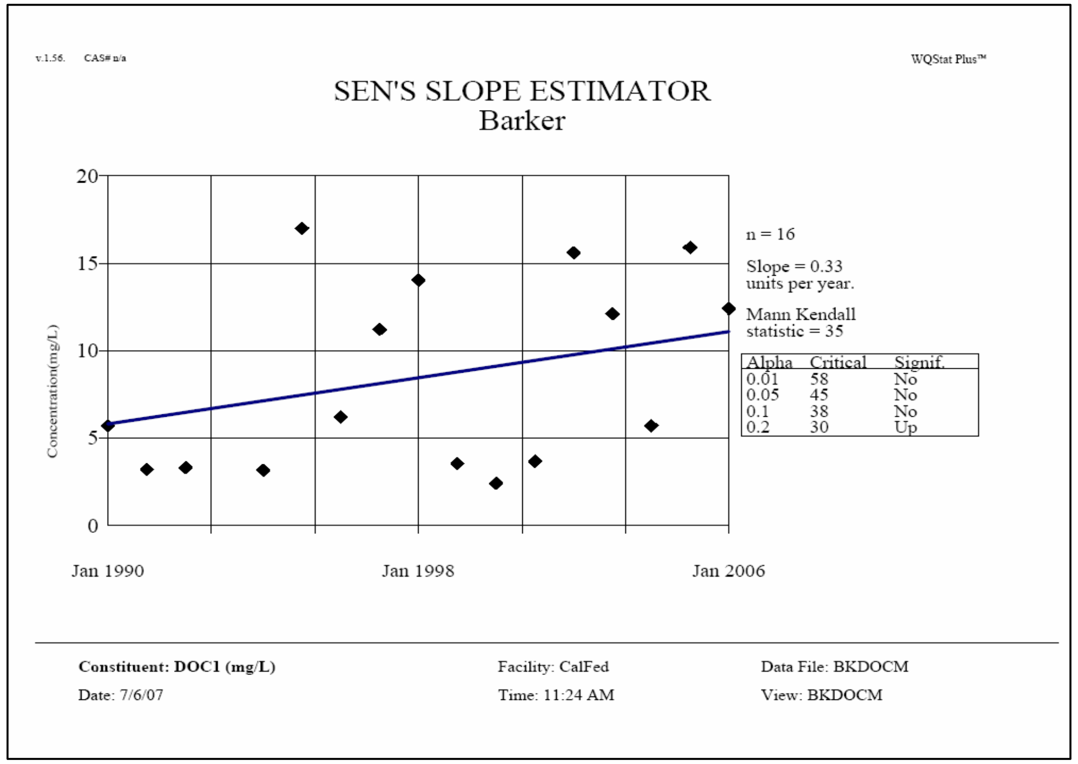
Constituent: DOC (mg/L)
Date: 7/6/07

Facility: CalFed
Time: 11:21 AM

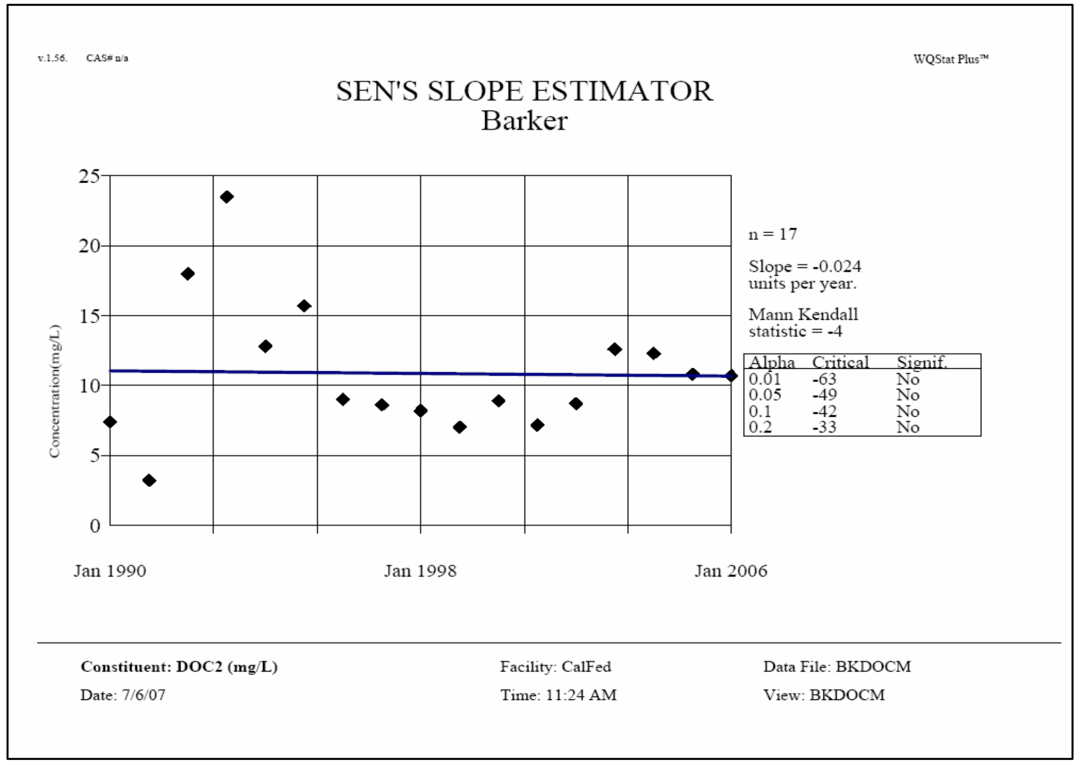
Data File: BKDOCA
View: BKDOCA

Figure 5. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at Barker

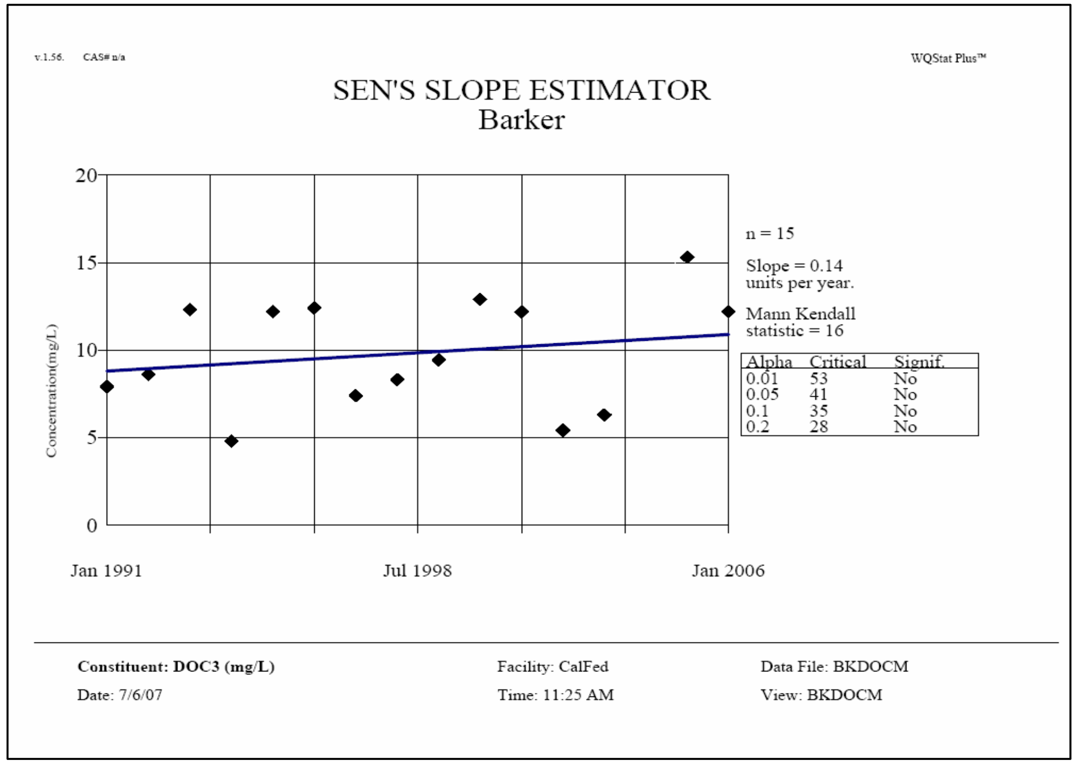
JANUARY



FEBRUARY



MARCH



APRIL

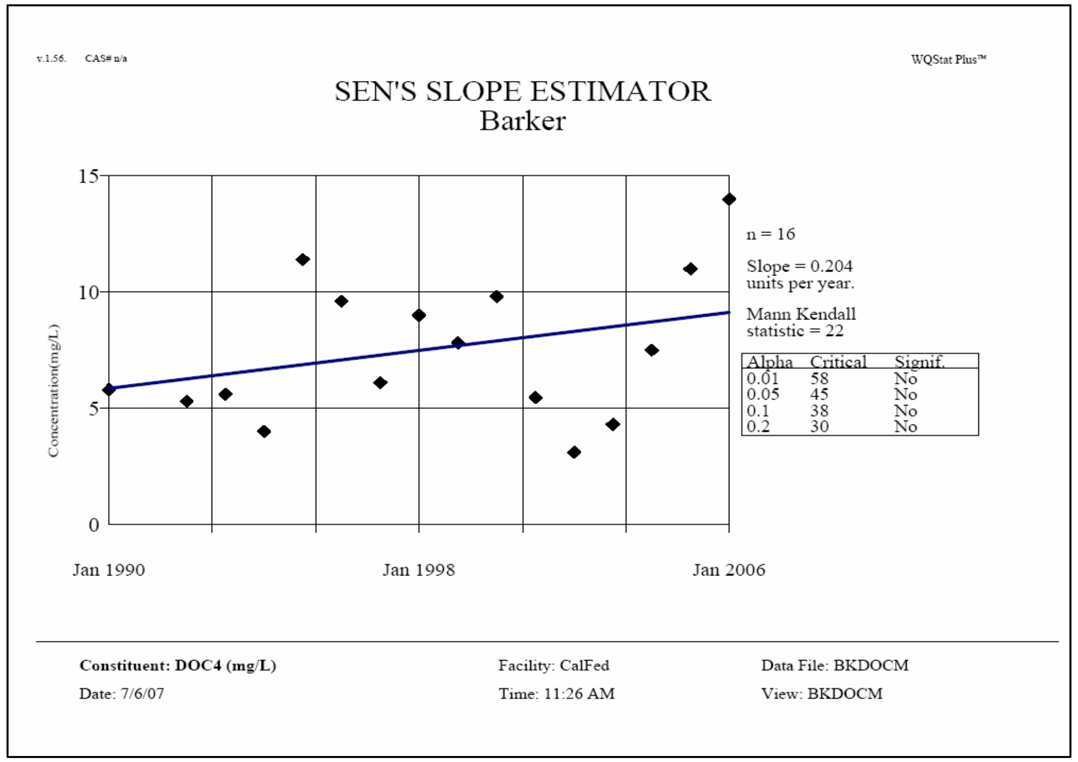
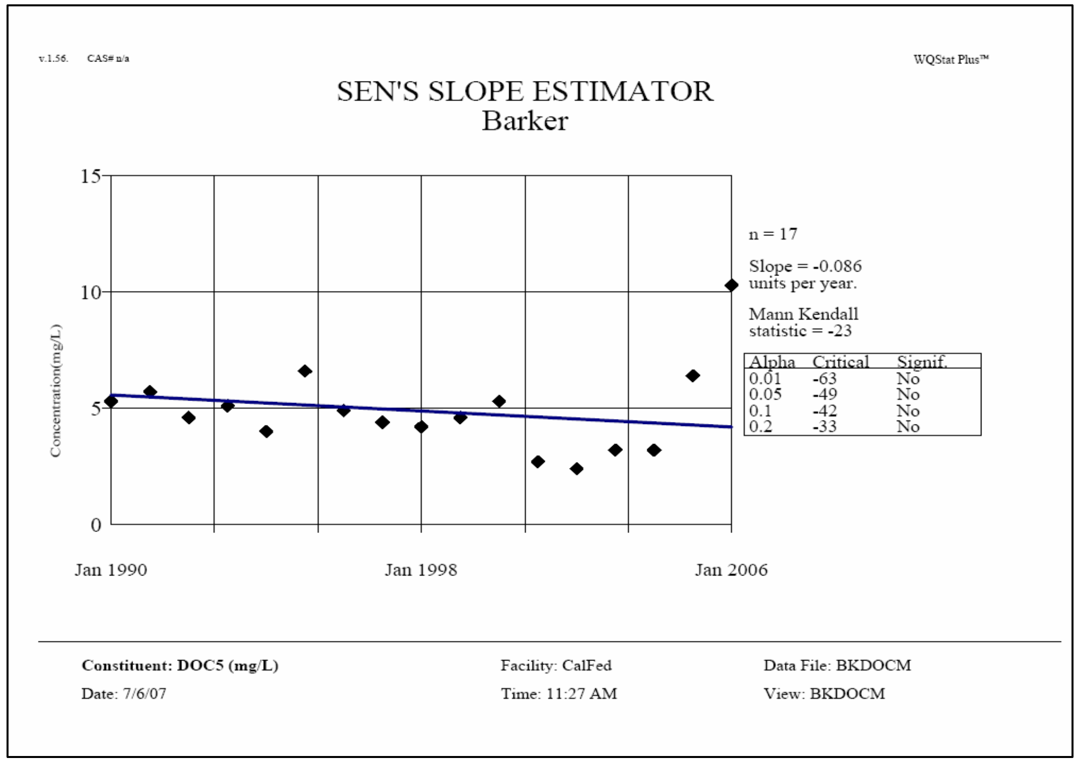
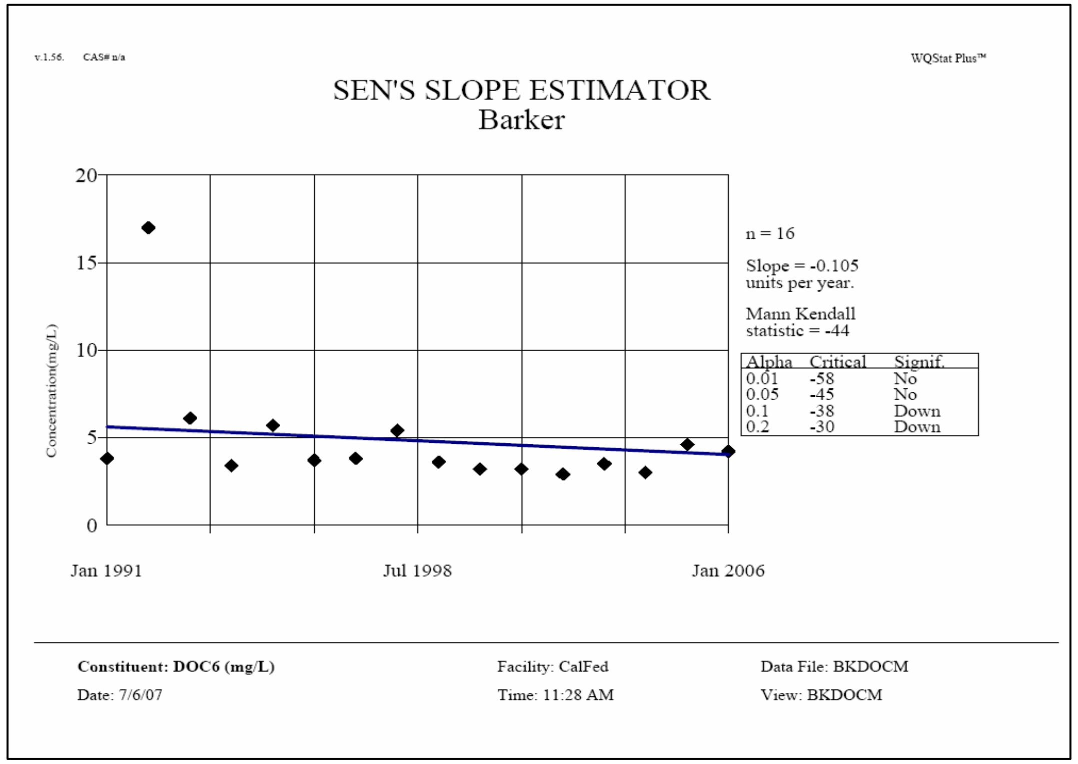


Figure 5. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at Barker

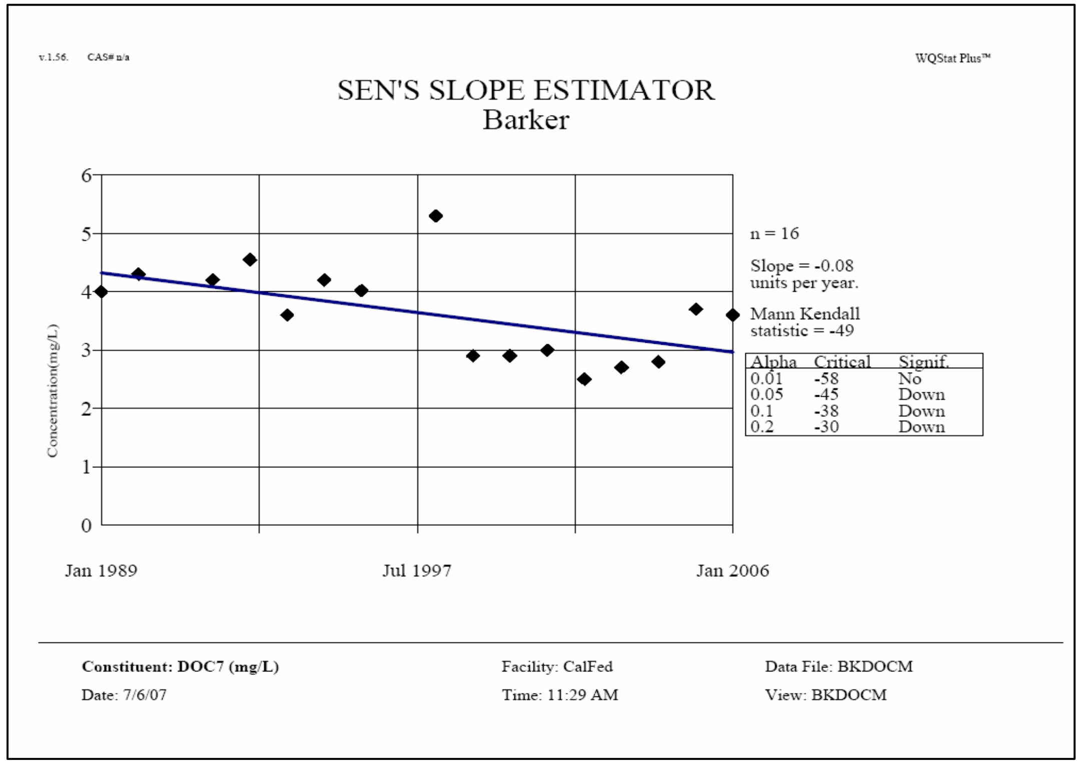
MAY



JUNE



JULY



AUGUST

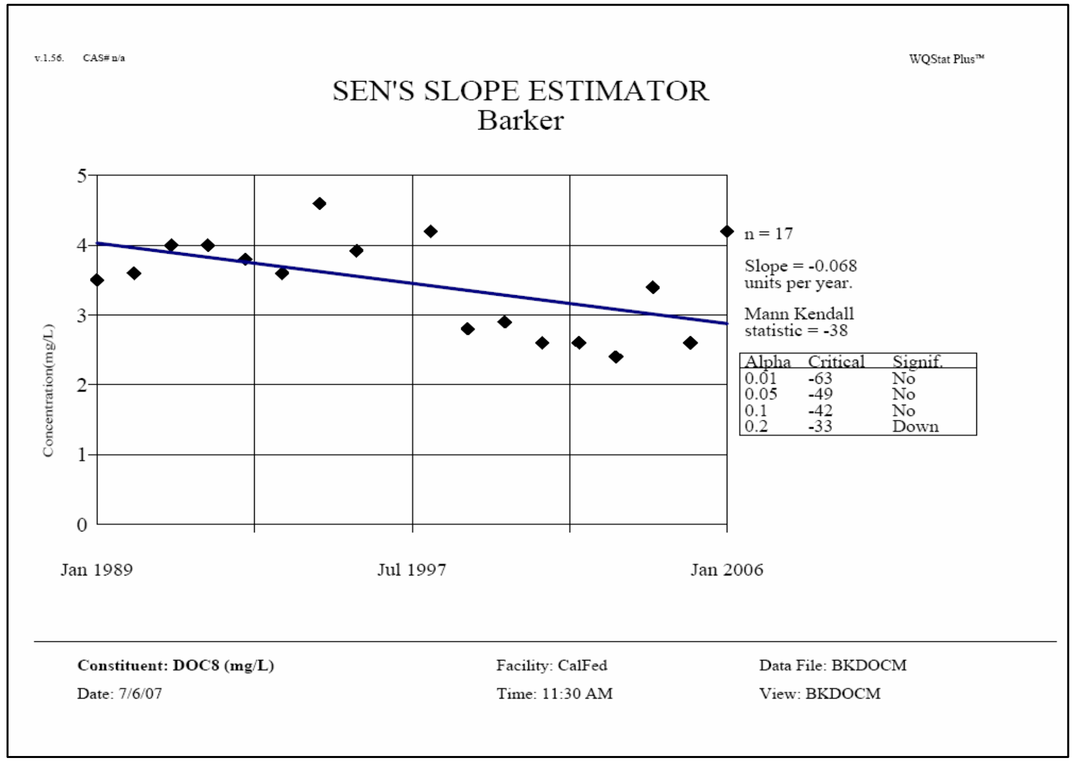
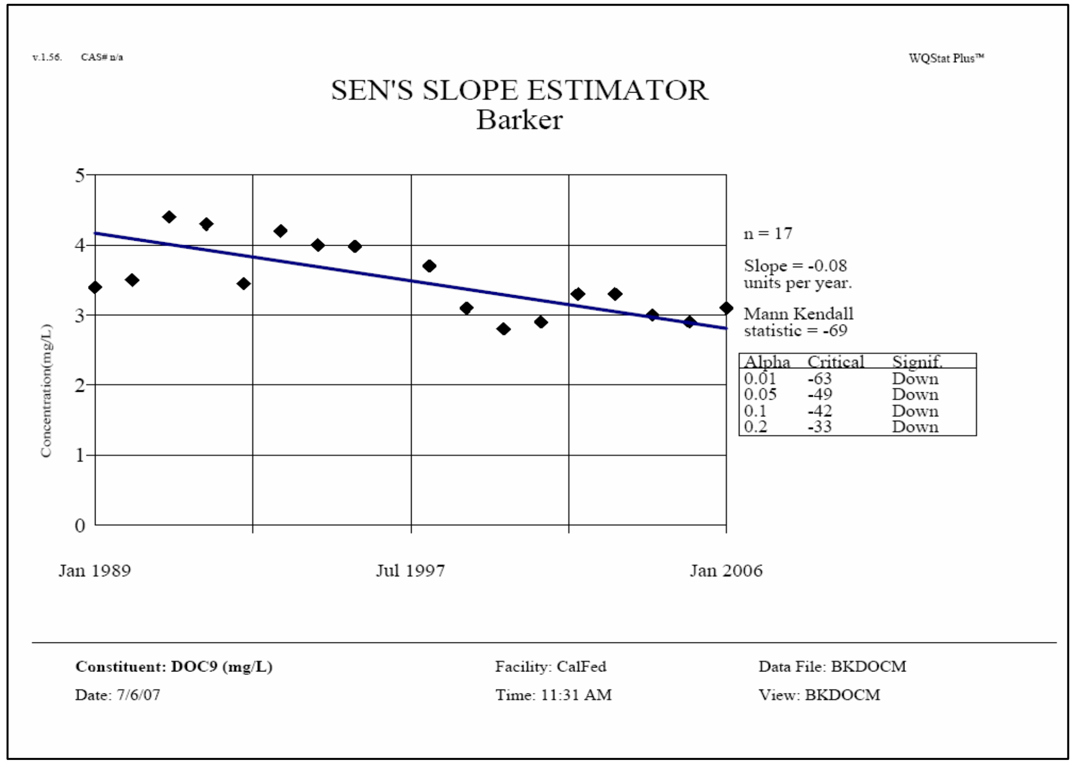
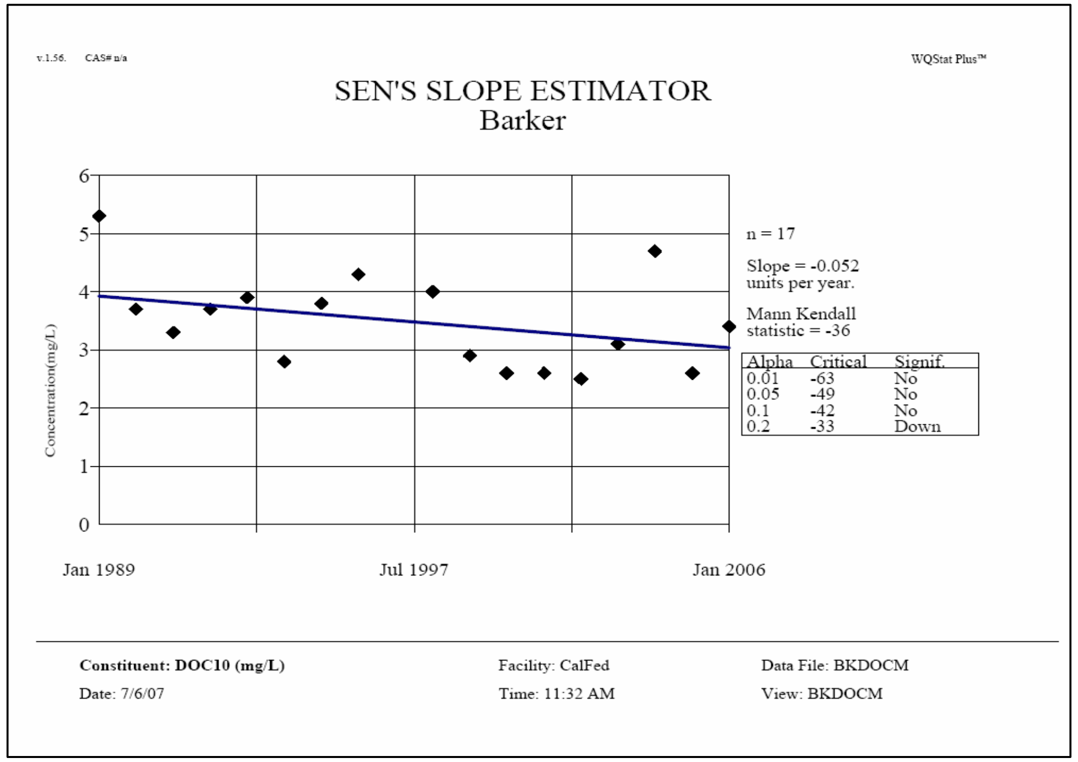


Figure 5. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at Barker

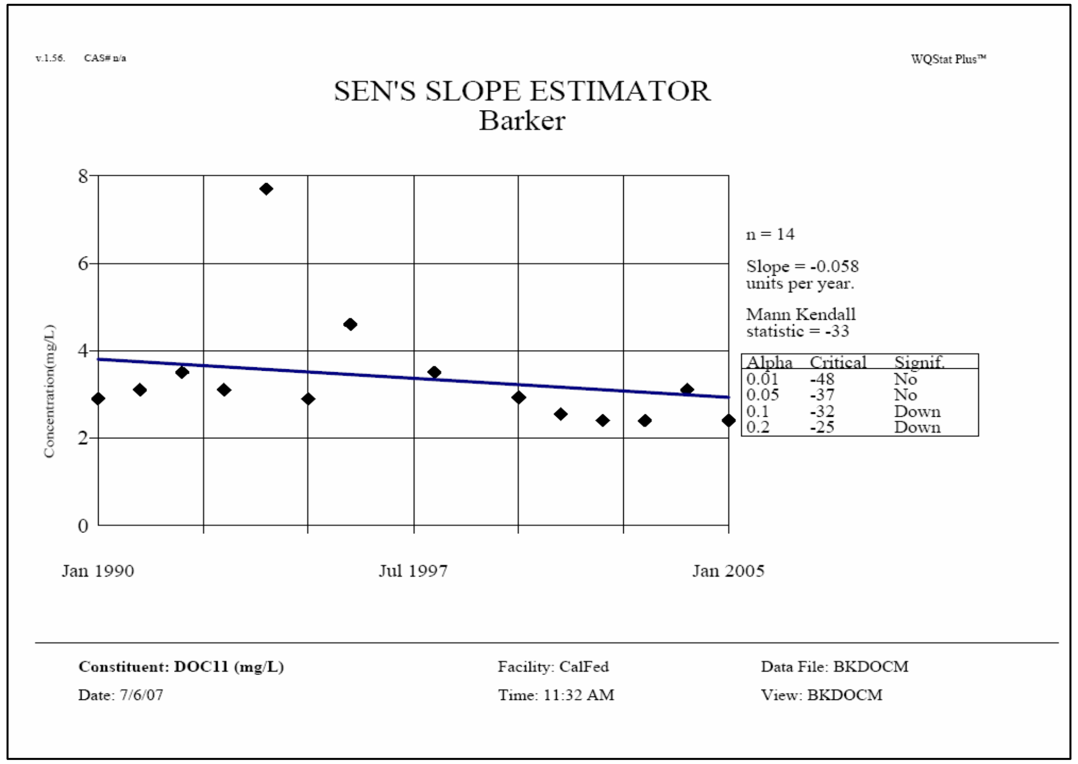
SEPTEMBER



OCTOBER



NOVEMBER



DECEMBER

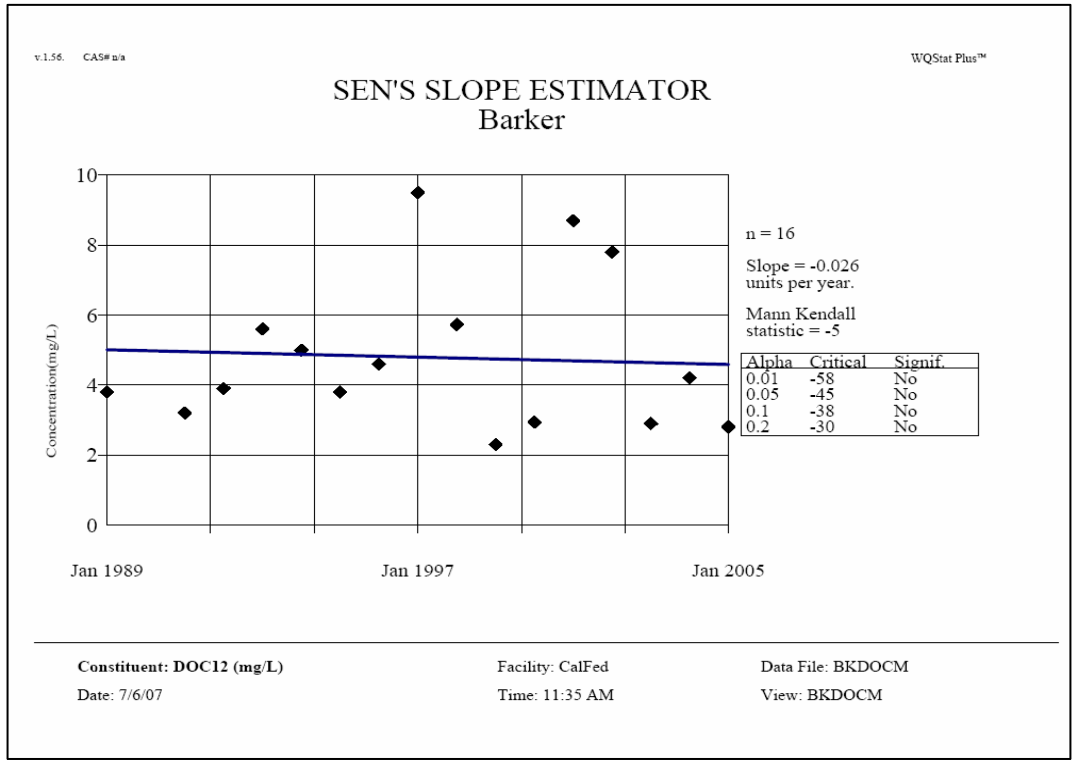


Figure 5. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at Barker

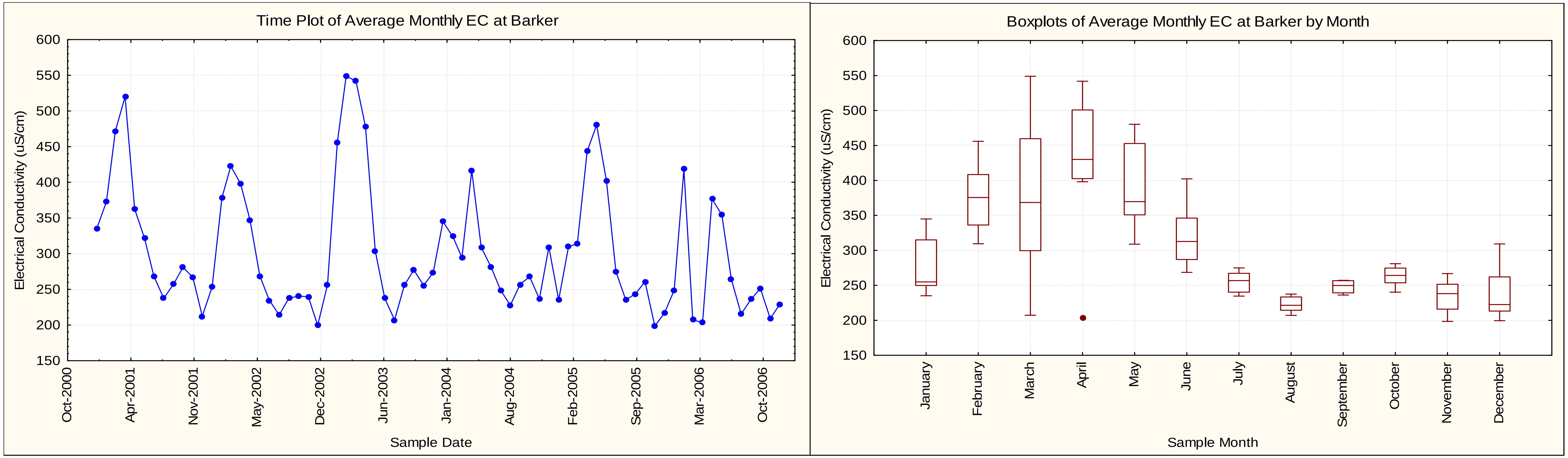
DATA USED IN TREND ANALYSIS - AVERAGE MONTHLY CONCENTRATIONS OF DISSOLVED ORGANIC CARBON (MG/L)

Sample Year	January	February	March	April	May	June	July	August	September	October	November	December
1989							4.00	3.50	3.40	5.30		3.80
1990	5.70	7.40		5.80	5.30		4.30	3.60	3.50	3.70	2.90	
1991	3.20	3.20	7.90		5.70	3.80		4.00	4.40	3.30	3.10	3.20
1992	3.30	18.00	8.60	5.30	4.60	17.00	4.20	4.00	4.30	3.70	3.50	3.90
1993		23.50	12.30	5.60	5.10	6.10	4.55	3.80	3.45	3.90	3.10	5.60
1994	3.15	12.80	4.80	4.00	4.00	3.40	3.60	3.60	4.20	2.80	7.70	5.00
1995	17.00	15.70	12.20	11.40	6.60	5.70	4.20	4.60	4.00	3.80	2.90	3.80
1996	6.20	9.00	12.40	9.60	4.90	3.70	4.02	3.92	3.98	4.30	4.60	4.60
1997	11.20	8.60	7.40	6.10	4.40	3.80						9.50
1998	14.03	8.20	8.30	9.00	4.20	5.40	5.30	4.20	3.70	4.00	3.50	5.73
1999	3.53	7.02	9.44	7.80	4.60	3.60	2.90	2.80	3.10	2.90		2.30
2000	2.40	8.90	12.90	9.80	5.30	3.20	2.90	2.90	2.80	2.60	2.93	2.94
2001	3.66	7.18	12.18	5.46	2.70	3.20	3.00	2.60	2.90	2.60	2.55	8.70
2002	15.60	8.70	5.40	3.10	2.40	2.90	2.50	2.60	3.30	2.50	2.40	7.80
2003	12.10	12.60	6.30	4.30	3.20	3.50	2.70	2.40	3.30	3.10	2.40	2.90
2004	5.70	12.30		7.50	3.20	3.00	2.80	3.40	3.00	4.70	3.10	4.20
2005	15.90	10.80	15.30	11.00	6.40	4.60	3.70	2.60	2.90	2.60	2.40	2.80
2006	12.40	10.70	12.20	14.00	10.30	4.20	3.60	4.20	3.10	3.40		

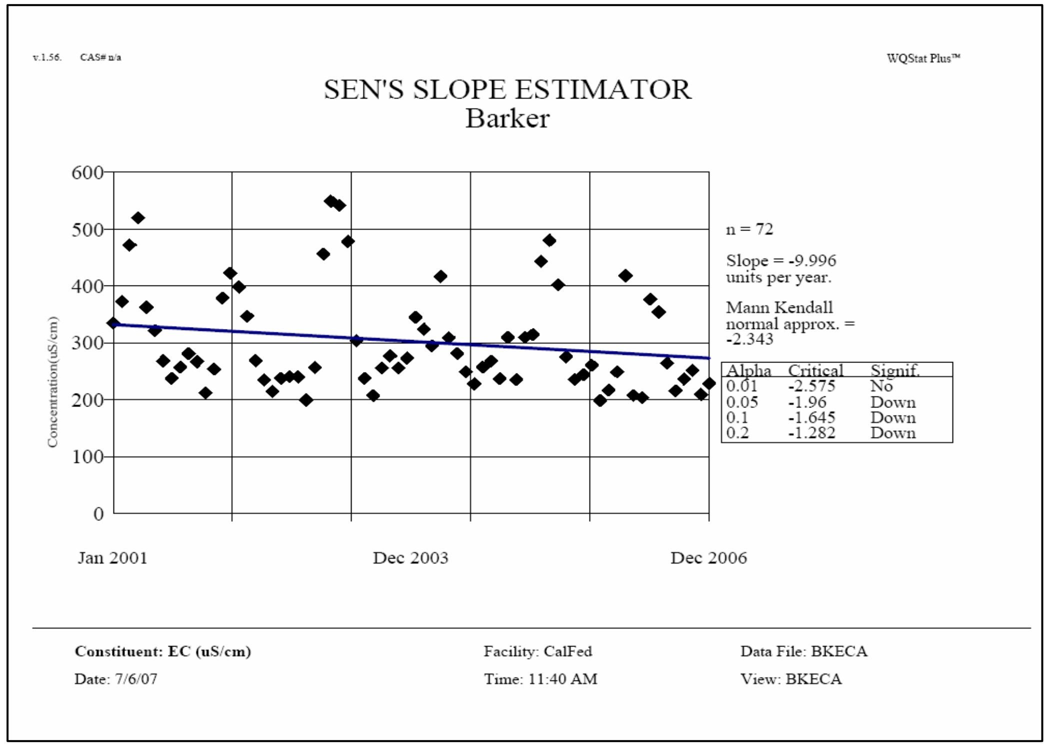
SUMMARY OF TREND ANALYSIS RESULTS

	Dissolved Organic Carbon												
	January	February	March	April	May	June	July	August	September	October	November	December	All Months
Number of Observations:	16	17	15	16	17	16	16	17	17	17	14	16	194
Significance													
Alpha													
0.01	no	no	no	no	no	no	no	no	down	no	no	no	no
0.05	no	no	no	no	no	no	down	no	down	no	no	no	no
0.1	no	no	no	no	no	down	down	no	down	no	down	no	down
0.2	up	no	no	no	no	down	down	down	down	down	down	no	down

Figure 6. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Barker



ALL DATA



v.1.56. CAS# n/a

WQStat Plus™

SEN'S SLOPE ESTIMATOR
Barker

n = 72

Slope = -9.996
units per year.

Mann Kendall
normal approx. =
-2.343

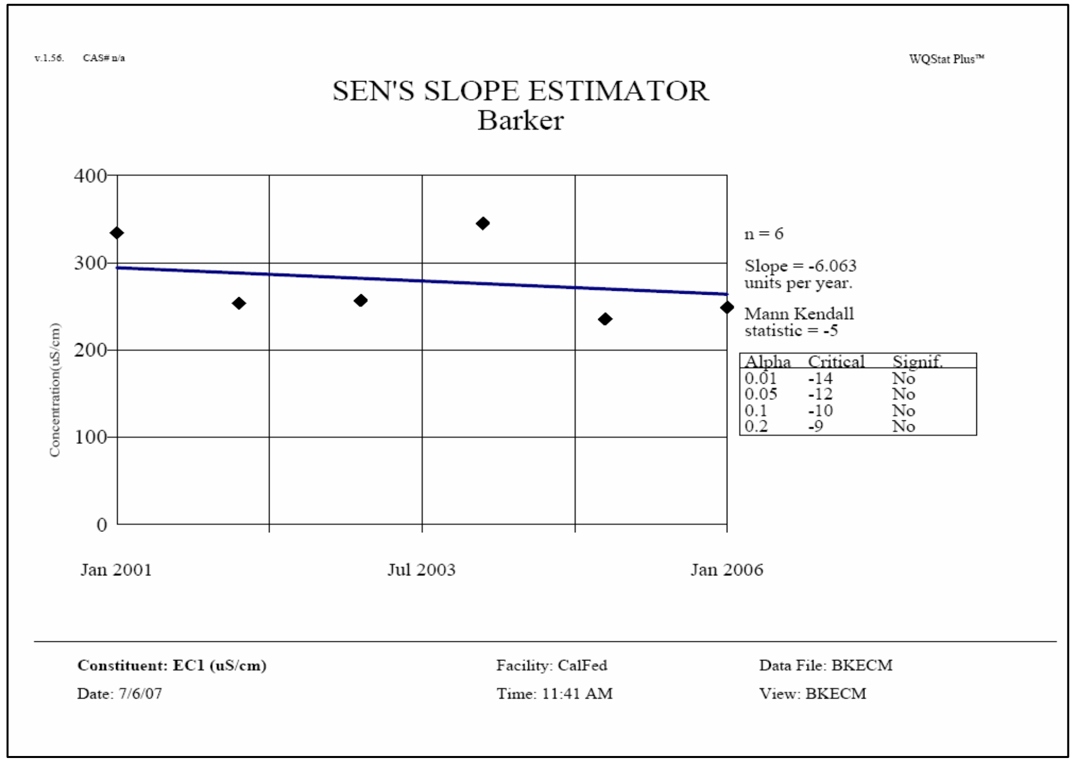
Alpha	Critical	Signif.
0.01	-2.575	No
0.05	-1.96	Down
0.1	-1.645	Down
0.2	-1.282	Down

Constituent: EC (uS/cm) Facility: CalFed Data File: BKECA

Date: 7/6/07 Time: 11:40 AM View: BKECA

Figure 6. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Barker

JANUARY



n = 6

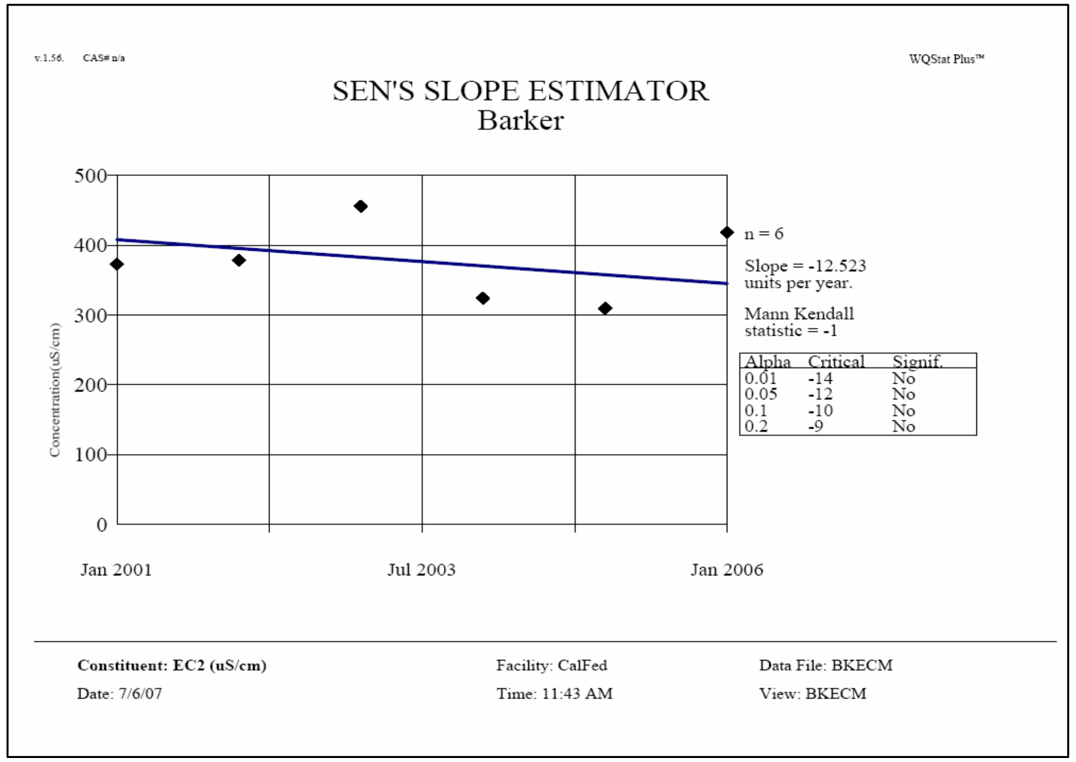
Slope = -6.063 units per year.

Mann Kendall statistic = -5

Alpha	Critical	Signif.
0.01	-14	No
0.05	-12	No
0.1	-10	No
0.2	-9	No

Constituent: EC1 (uS/cm) Facility: CalFed Data File: BKECM
Date: 7/6/07 Time: 11:41 AM View: BKECM

FEBRUARY



n = 6

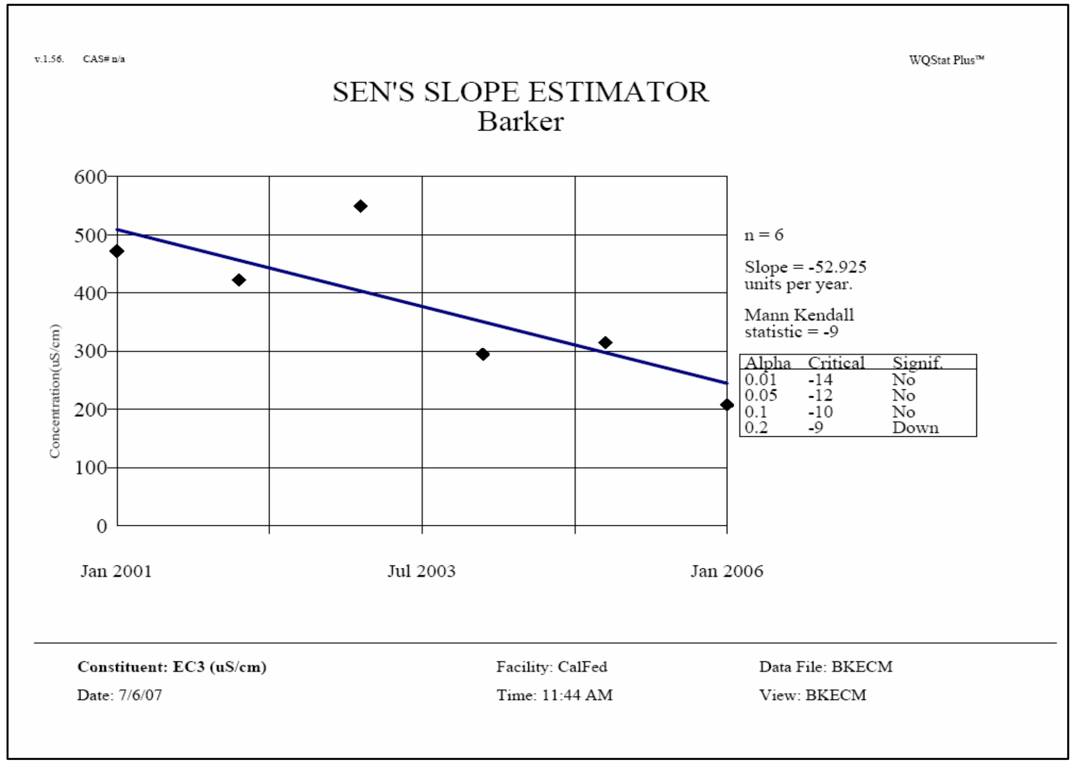
Slope = -12.523 units per year.

Mann Kendall statistic = -1

Alpha	Critical	Signif.
0.01	-14	No
0.05	-12	No
0.1	-10	No
0.2	-9	No

Constituent: EC2 (uS/cm) Facility: CalFed Data File: BKECM
Date: 7/6/07 Time: 11:43 AM View: BKECM

MARCH



n = 6

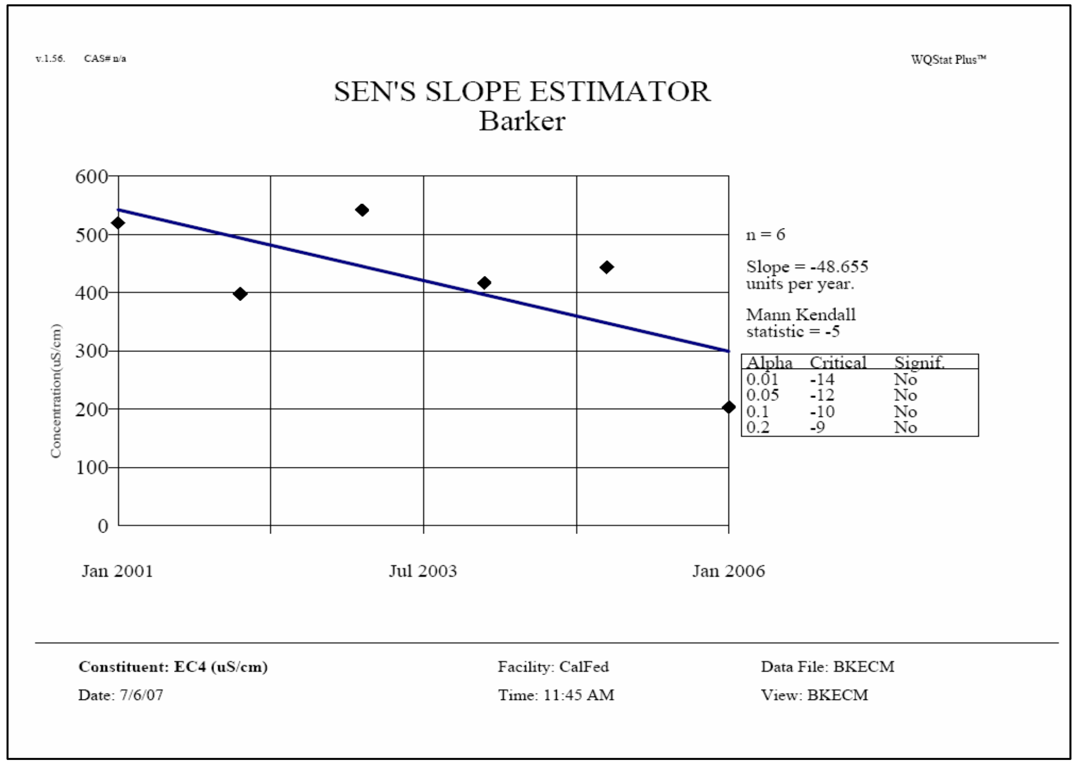
Slope = -52.925 units per year.

Mann Kendall statistic = -9

Alpha	Critical	Signif.
0.01	-14	No
0.05	-12	No
0.1	-10	No
0.2	-9	Down

Constituent: EC3 (uS/cm) Facility: CalFed Data File: BKECM
Date: 7/6/07 Time: 11:44 AM View: BKECM

APRIL



n = 6

Slope = -48.655 units per year.

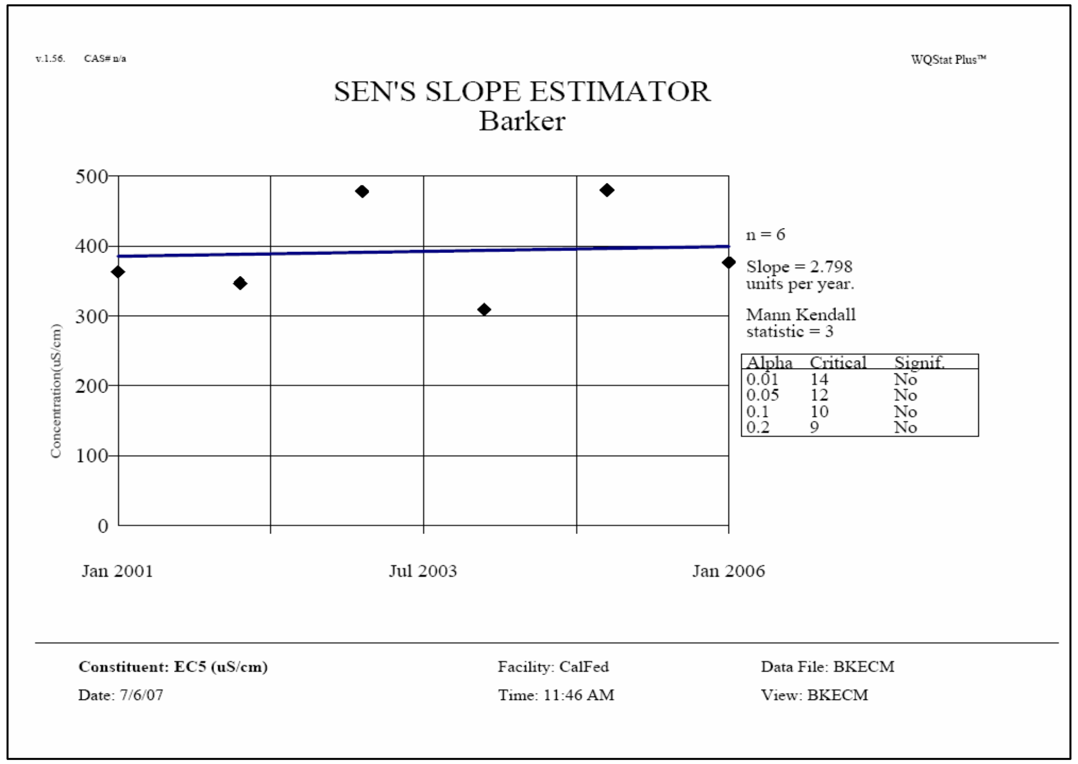
Mann Kendall statistic = -5

Alpha	Critical	Signif.
0.01	-14	No
0.05	-12	No
0.1	-10	No
0.2	-9	No

Constituent: EC4 (uS/cm) Facility: CalFed Data File: BKECM
Date: 7/6/07 Time: 11:45 AM View: BKECM

Figure 6. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Barker

MAY



SEN'S SLOPE ESTIMATOR
Barker

n = 6

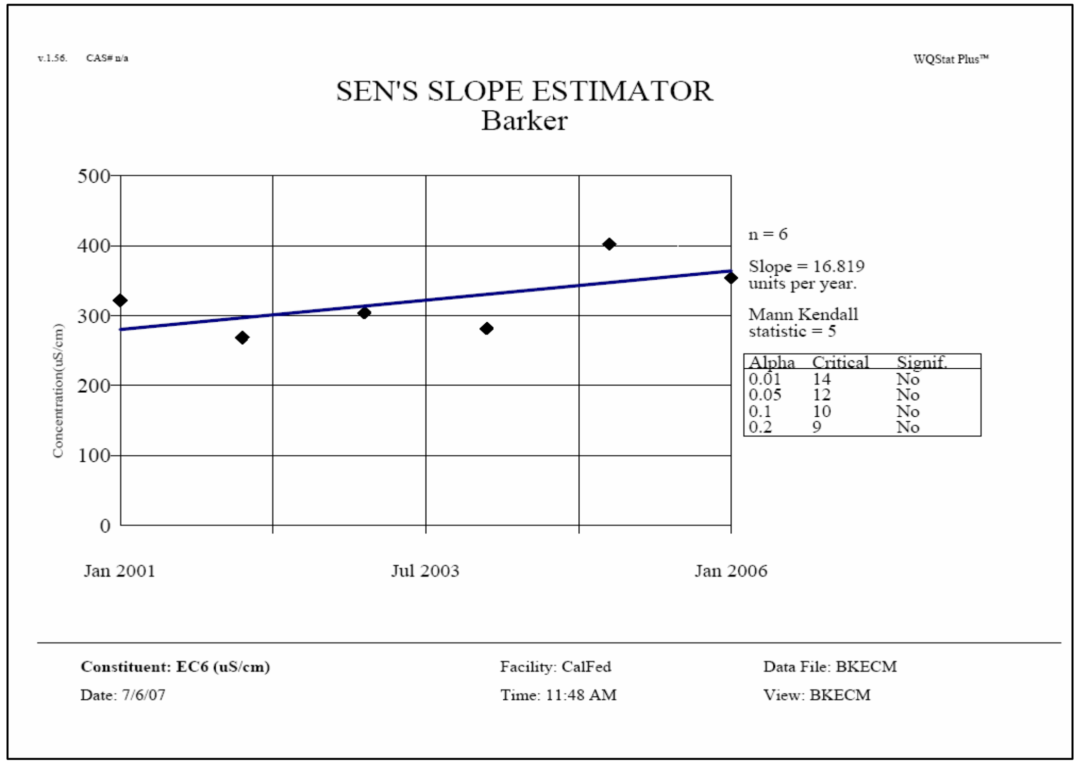
Slope = 2.798
units per year.

Mann Kendall
statistic = 3

Alpha	Critical	Signif.
0.01	14	No
0.05	12	No
0.1	10	No
0.2	9	No

Constituent: EC5 (uS/cm) Facility: CalFed Data File: BKECM
Date: 7/6/07 Time: 11:46 AM View: BKECM

JUNE



SEN'S SLOPE ESTIMATOR
Barker

n = 6

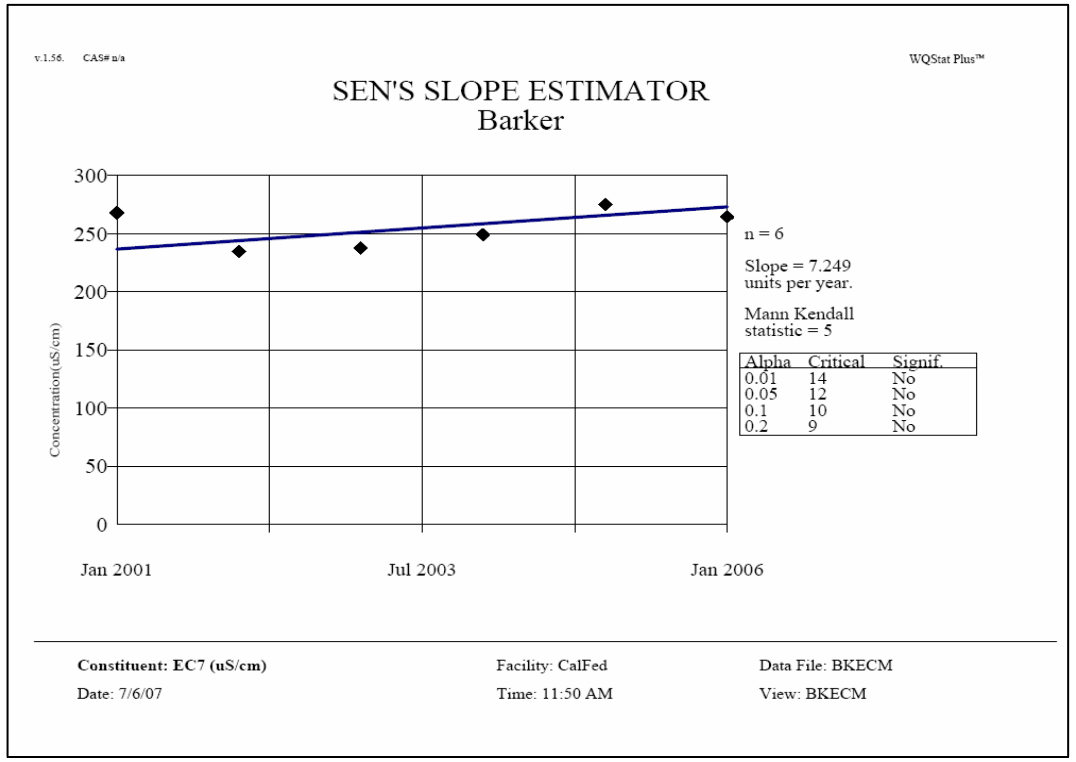
Slope = 16.819
units per year.

Mann Kendall
statistic = 5

Alpha	Critical	Signif.
0.01	14	No
0.05	12	No
0.1	10	No
0.2	9	No

Constituent: EC6 (uS/cm) Facility: CalFed Data File: BKECM
Date: 7/6/07 Time: 11:48 AM View: BKECM

JULY



SEN'S SLOPE ESTIMATOR
Barker

n = 6

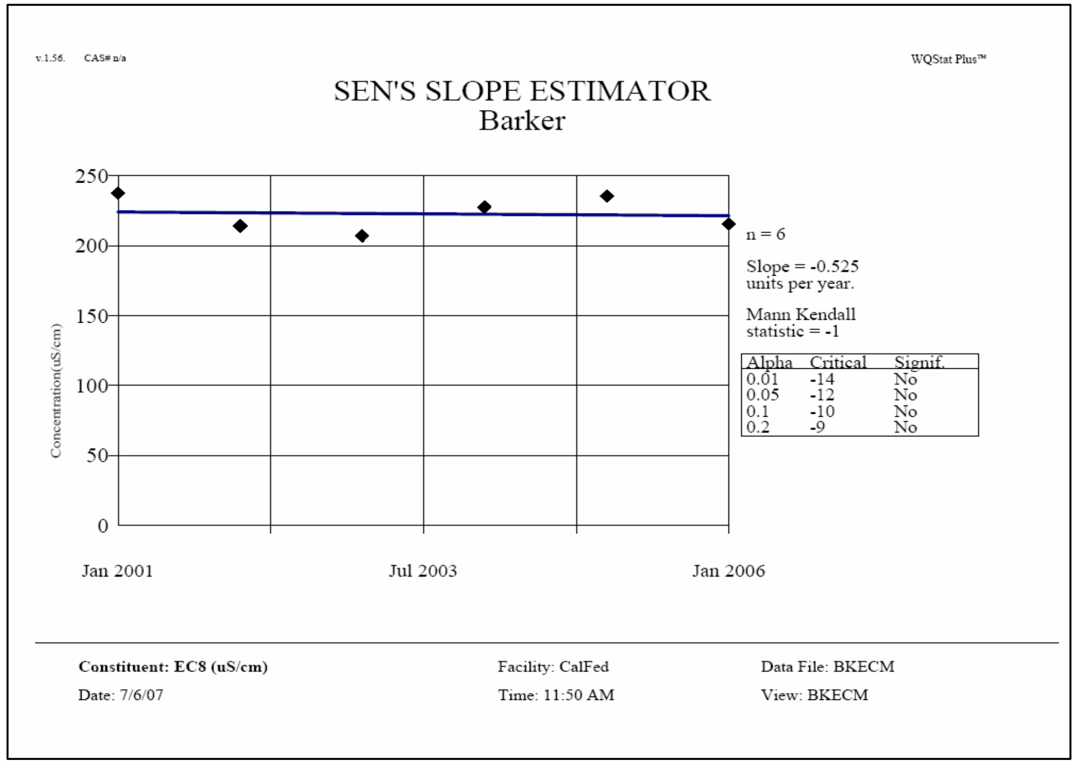
Slope = 7.249
units per year.

Mann Kendall
statistic = 5

Alpha	Critical	Signif.
0.01	14	No
0.05	12	No
0.1	10	No
0.2	9	No

Constituent: EC7 (uS/cm) Facility: CalFed Data File: BKECM
Date: 7/6/07 Time: 11:50 AM View: BKECM

AUGUST



SEN'S SLOPE ESTIMATOR
Barker

n = 6

Slope = -0.525
units per year.

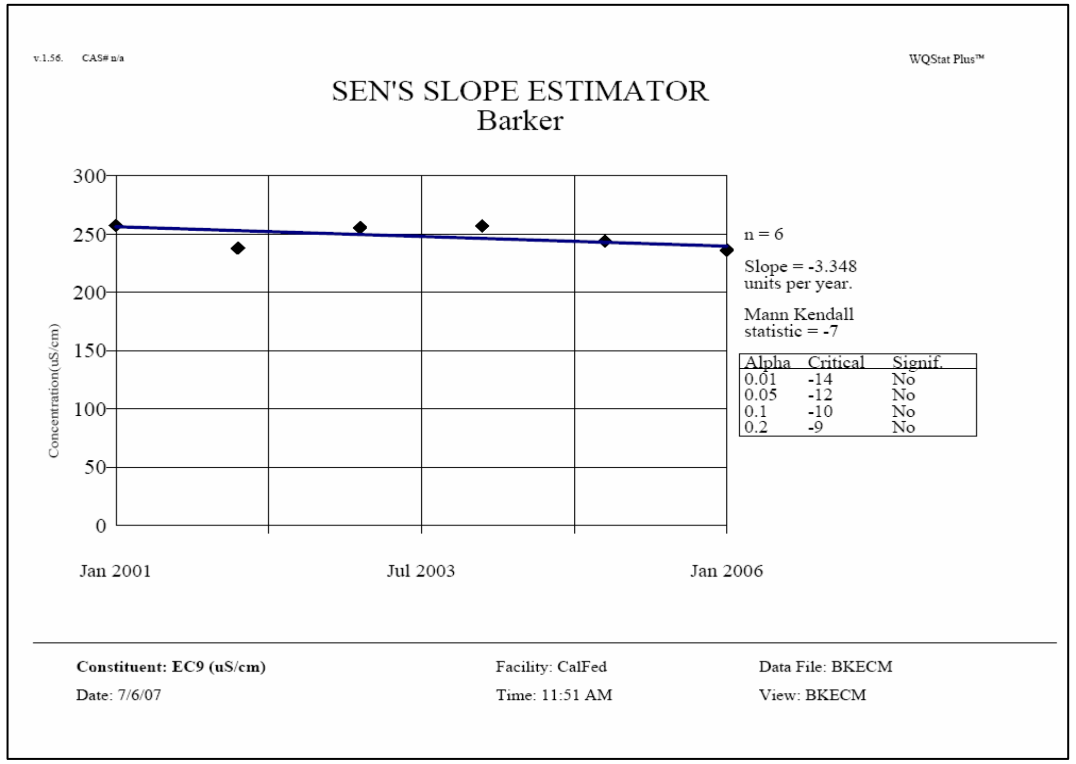
Mann Kendall
statistic = -1

Alpha	Critical	Signif.
0.01	-14	No
0.05	-12	No
0.1	-10	No
0.2	-9	No

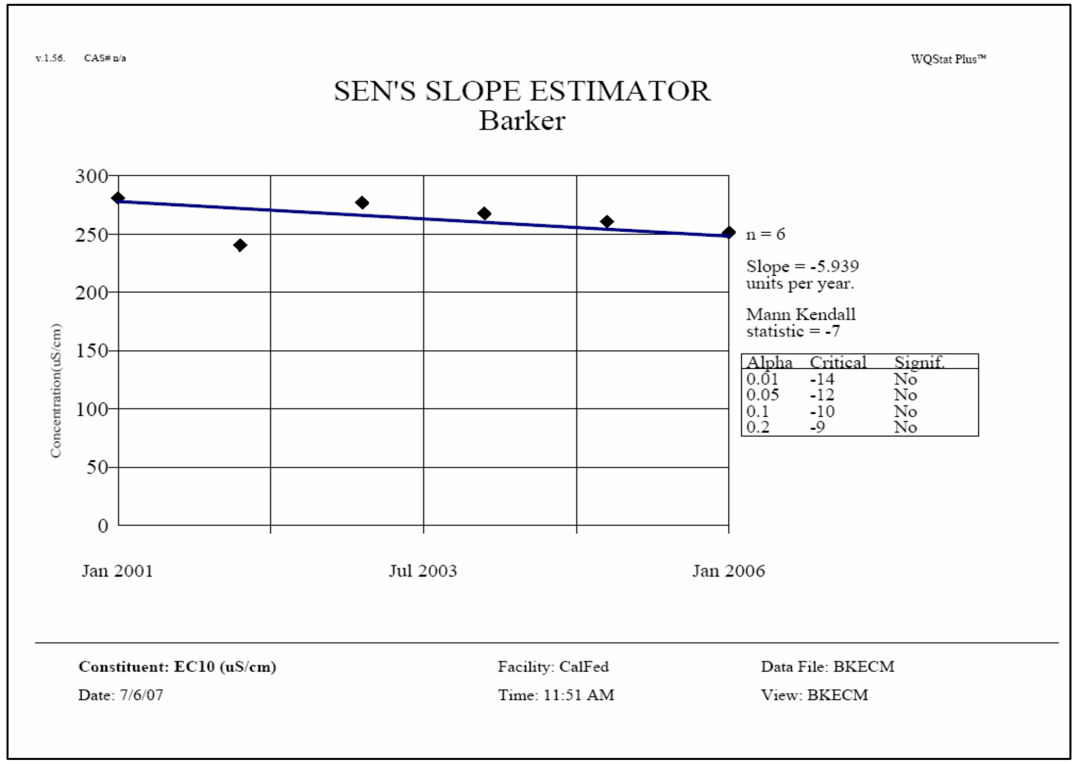
Constituent: EC8 (uS/cm) Facility: CalFed Data File: BKECM
Date: 7/6/07 Time: 11:50 AM View: BKECM

Figure 6. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Barker

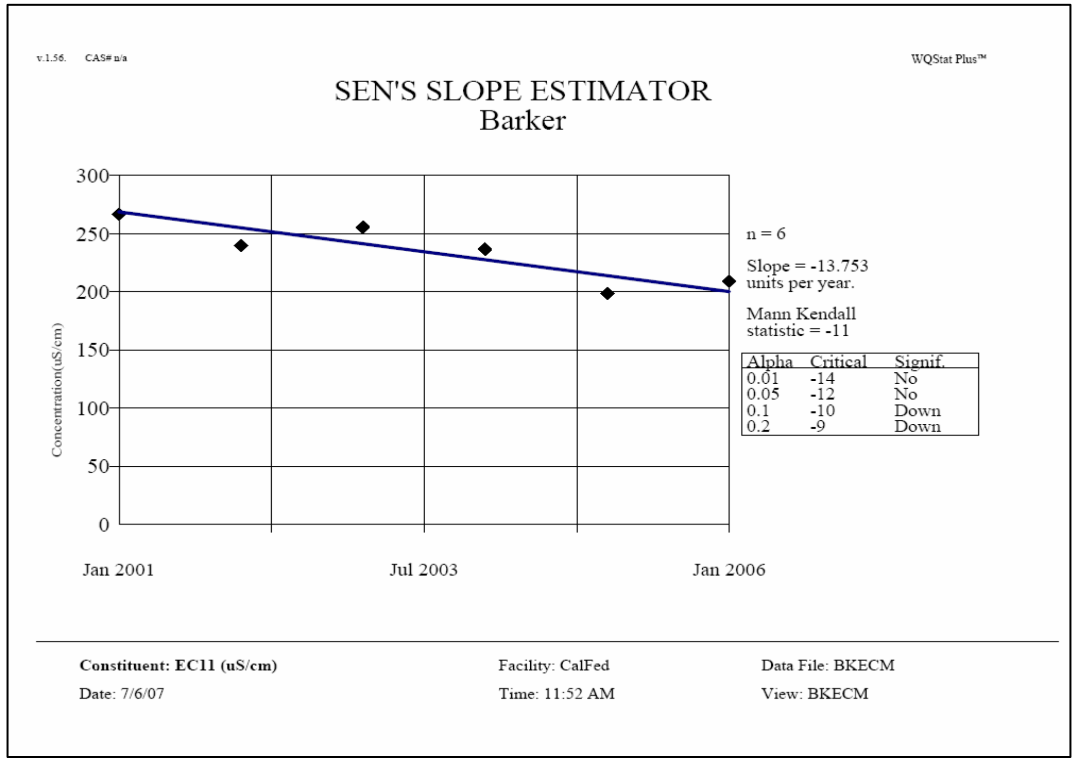
SEPTEMBER



OCTOBER



NOVEMBER



DECEMBER

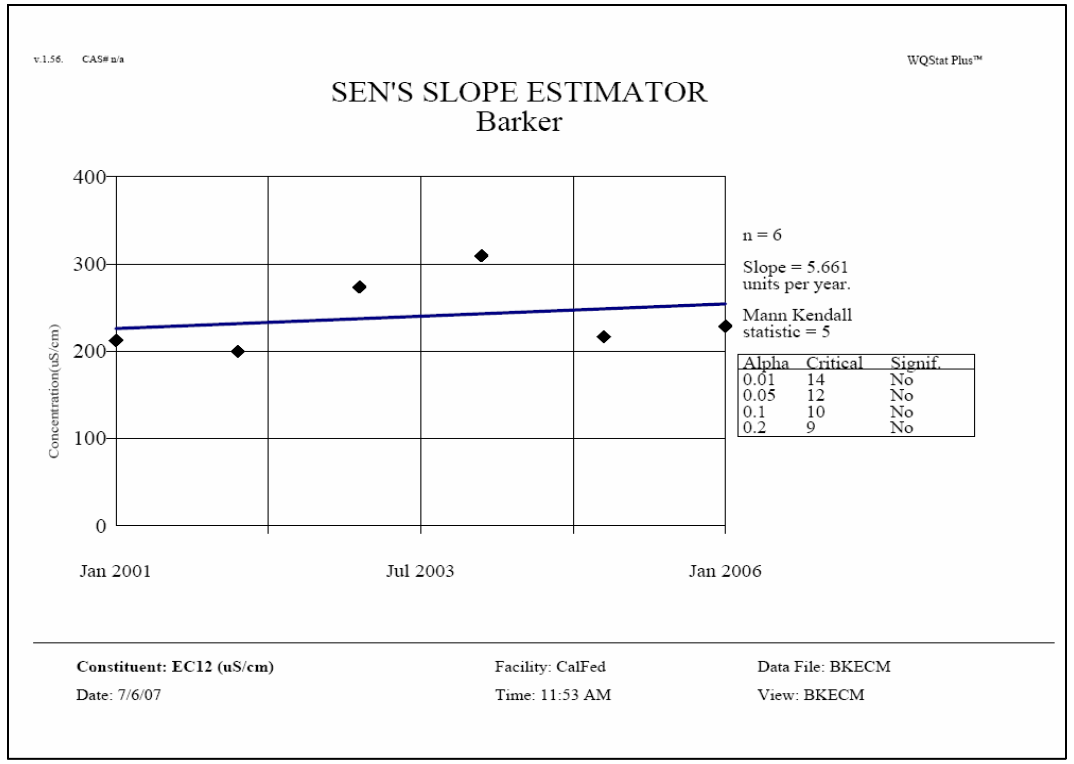
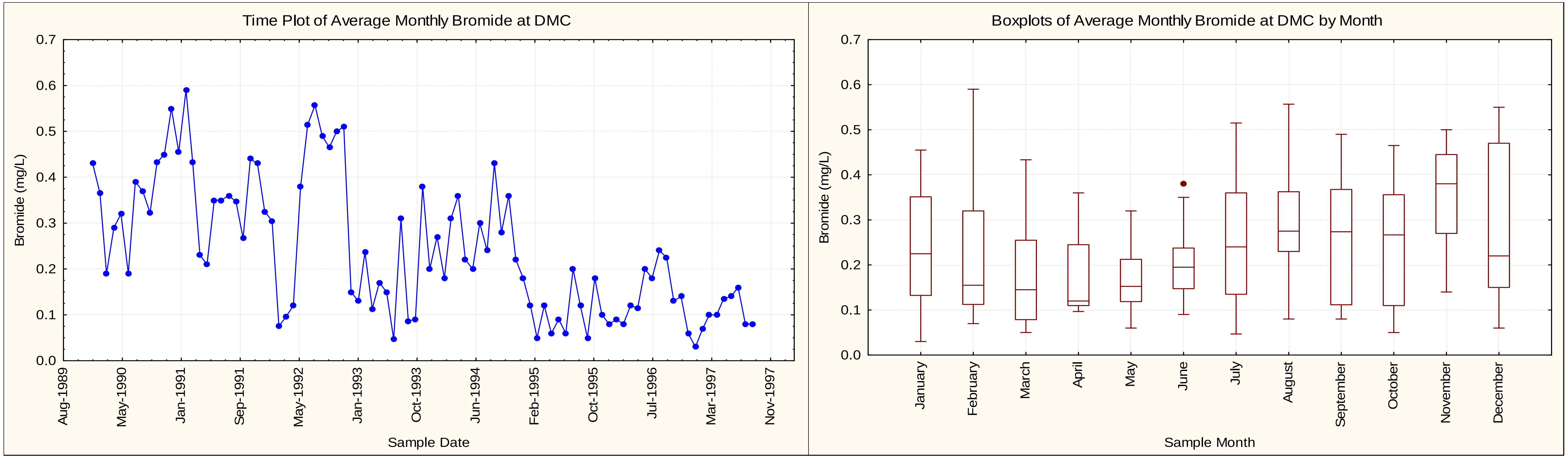


Figure 6. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Barker

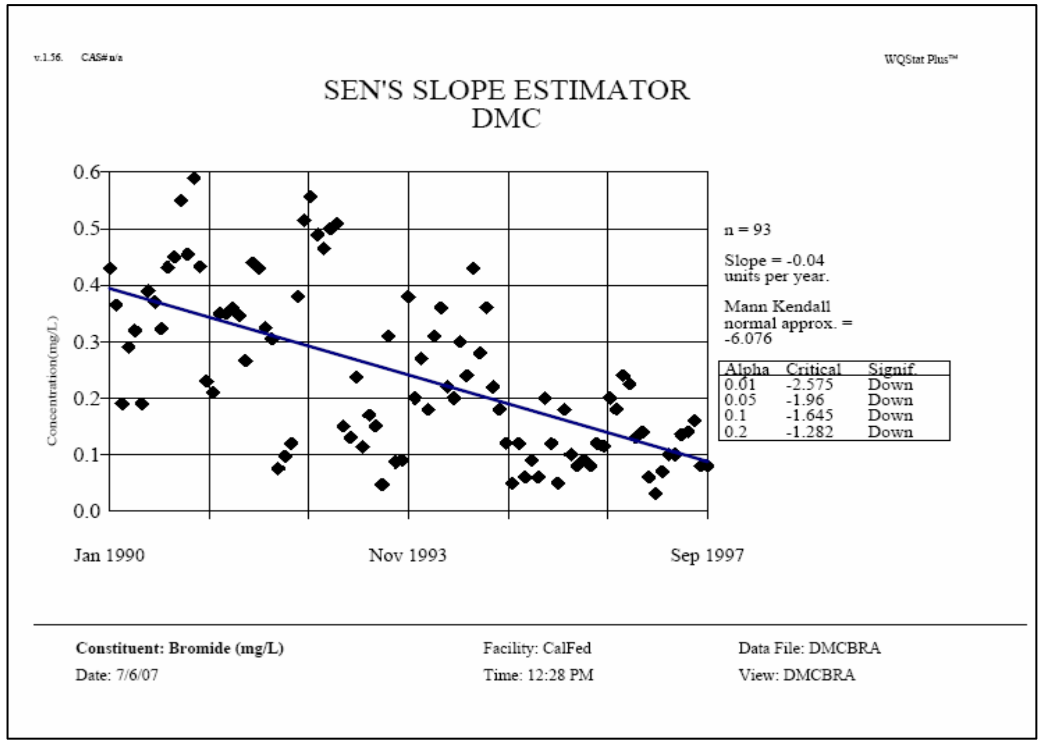
DATA USED IN TREND ANALYSIS - AVERAGE MONTHLY MEASUREMENTS OF ELECTRICAL CONDUCTIVITY (µS/CM)												
Sample Year	January	February	March	April	May	June	July	August	September	October	November	December
2001	334.5	372.8	472.1	519.9	362.7	321.8	268.1	237.5	257.2	281.0	266.8	212.3
2002	253.4	378.5	422.7	398.1	346.8	268.6	234.6	214.1	237.8	240.4	239.8	199.5
2003	256.5	456.0	549.0	541.8	478.2	303.8	237.5	207.1	255.7	277.1	255.6	273.3
2004	345.0	324.1	294.7	416.7	308.9	281.5	249.1	227.7	257.0	267.7	236.7	309.3
2005	235.2	309.5	314.3	443.5	480.3	402.2	275.0	235.4	243.8	260.8	198.5	216.5
2006	248.7	418.4	207.3	203.3	376.7	354.3	264.5	215.4	236.1	251.3	209.1	228.6

SUMMARY OF TREND ANALYSIS RESULTS													
	Electrical Conductivity												
	January	February	March	April	May	June	July	August	September	October	November	December	All Months
Number of Observations:	6	6	6	6	6	6	6	6	6	6	6	6	72
Significance													
Alpha													
0.01	no	no	no	no	no	no	no	no	no	no	no	no	no
0.05	no	no	no	no	no	no	no	no	no	no	no	no	down
0.1	no	no	no	no	no	no	no	no	no	no	down	no	down
0.2	no	no	down	no	no	no	no	no	no	no	down	no	down

Figure 7. Trend Analysis Using Average Monthly Concentrations of Bromide at DMC



ALL DATA



SEN'S SLOPE ESTIMATOR
DMC

n = 93

Slope = -0.04
units per year.

Mann Kendall
normal approx. =
-6.076

Alpha	Critical	Signif.
0.01	-2.575	Down
0.05	-1.96	Down
0.1	-1.645	Down
0.2	-1.282	Down

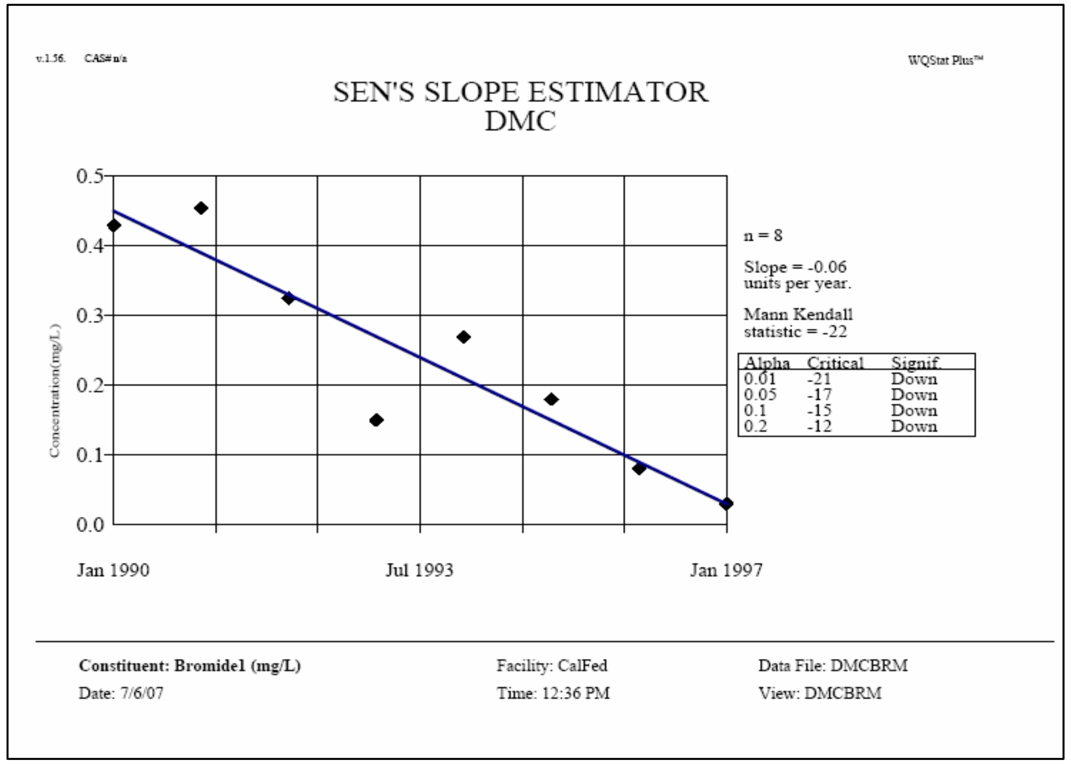
Constituent: Bromide (mg/L)
Date: 7/6/07

Facility: CalFed
Time: 12:28 PM

Data File: DMCBRA
View: DMCBRA

Figure 7. Trend Analysis Using Average Monthly Concentrations of Bromide at DMC

JANUARY



SEN'S SLOPE ESTIMATOR
DMC

n = 8

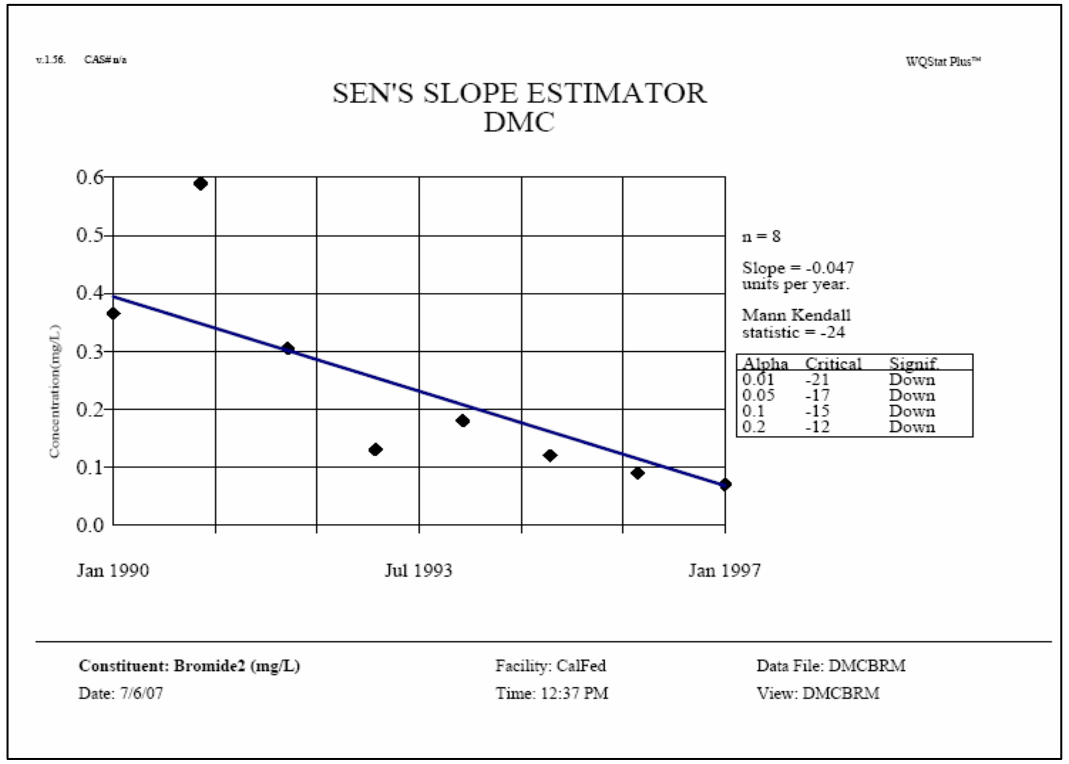
Slope = -0.06 units per year.

Mann Kendall statistic = -22

Alpha	Critical	Signif
0.01	-21	Down
0.05	-17	Down
0.1	-15	Down
0.2	-12	Down

Constituent: Bromide1 (mg/L) Facility: CalFed Data File: DMCBRM
Date: 7/6/07 Time: 12:36 PM View: DMCBRM

FEBRUARY



SEN'S SLOPE ESTIMATOR
DMC

n = 8

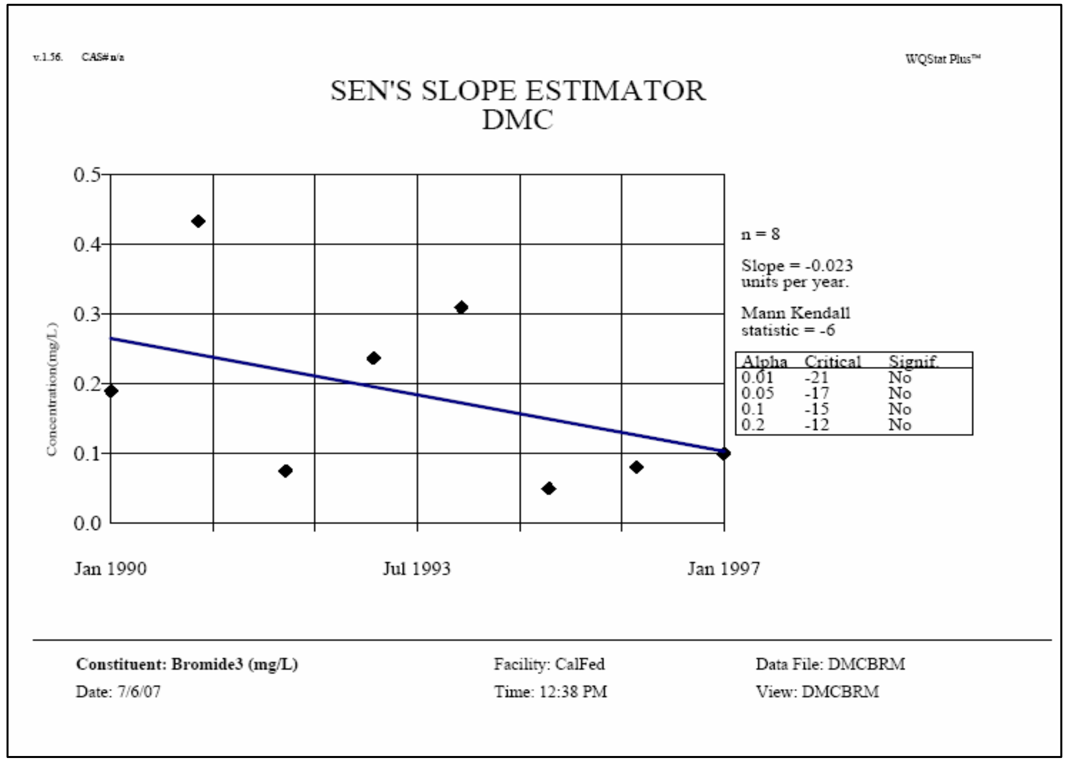
Slope = -0.047 units per year.

Mann Kendall statistic = -24

Alpha	Critical	Signif
0.01	-21	Down
0.05	-17	Down
0.1	-15	Down
0.2	-12	Down

Constituent: Bromide2 (mg/L) Facility: CalFed Data File: DMCBRM
Date: 7/6/07 Time: 12:37 PM View: DMCBRM

MARCH



SEN'S SLOPE ESTIMATOR
DMC

n = 8

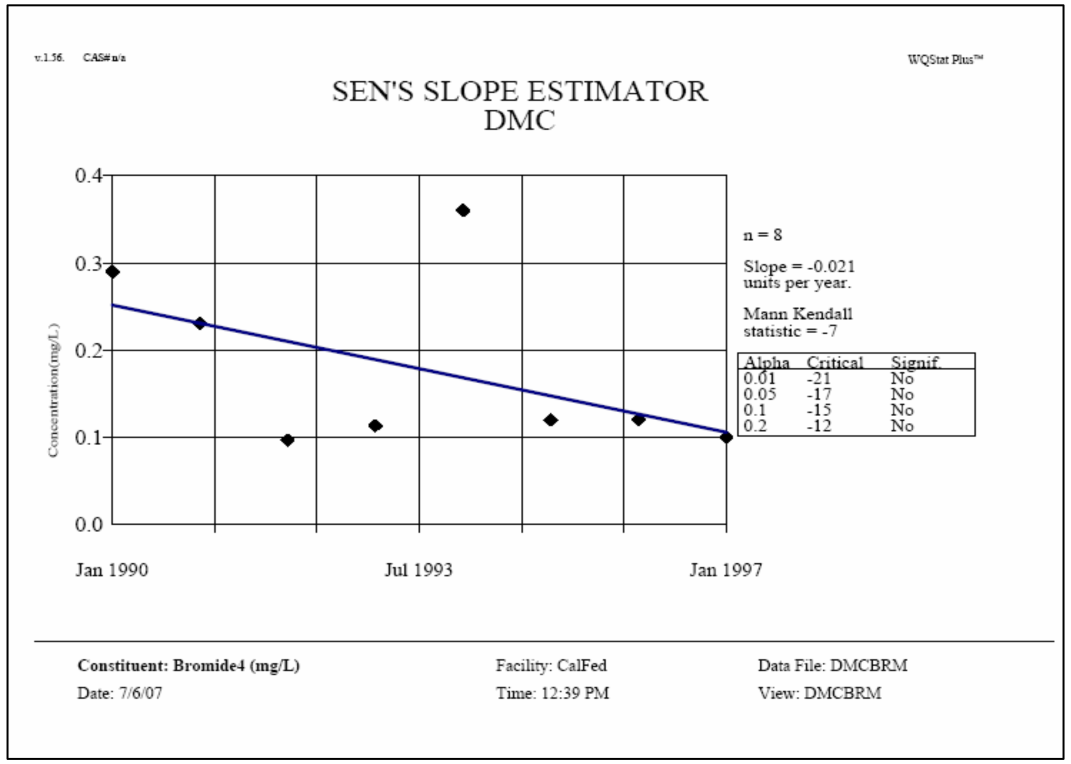
Slope = -0.023 units per year.

Mann Kendall statistic = -6

Alpha	Critical	Signif
0.01	-21	No
0.05	-17	No
0.1	-15	No
0.2	-12	No

Constituent: Bromide3 (mg/L) Facility: CalFed Data File: DMCBRM
Date: 7/6/07 Time: 12:38 PM View: DMCBRM

APRIL



SEN'S SLOPE ESTIMATOR
DMC

n = 8

Slope = -0.021 units per year.

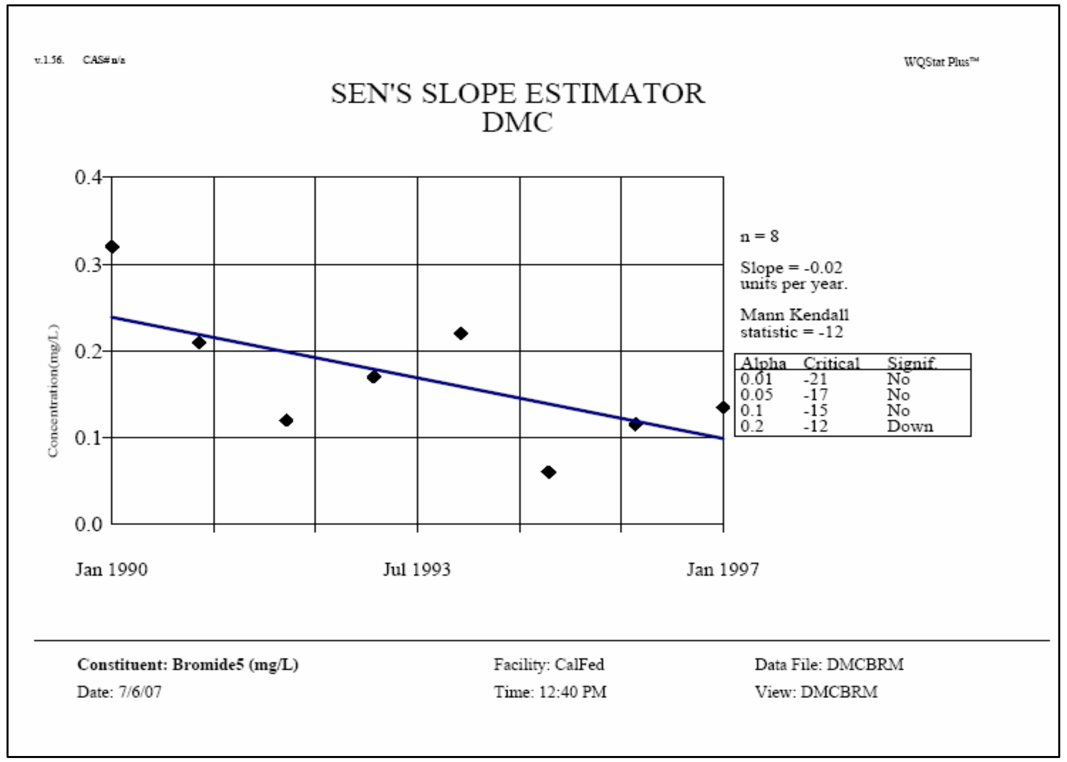
Mann Kendall statistic = -7

Alpha	Critical	Signif
0.01	-21	No
0.05	-17	No
0.1	-15	No
0.2	-12	No

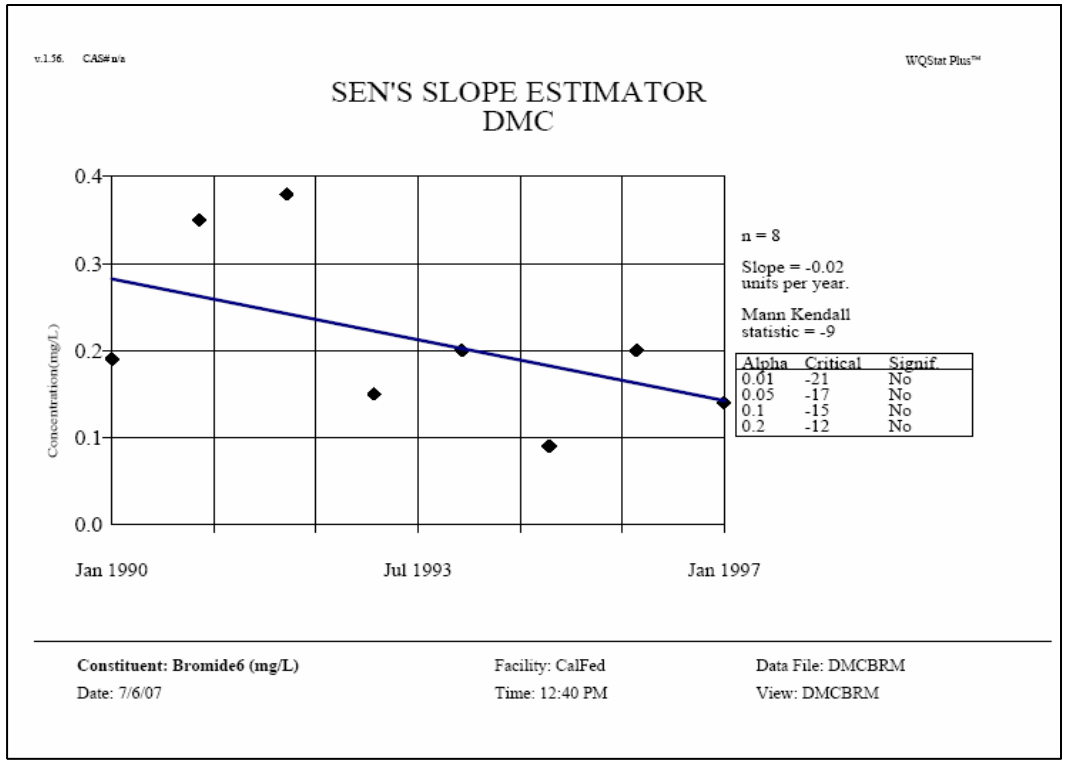
Constituent: Bromide4 (mg/L) Facility: CalFed Data File: DMCBRM
Date: 7/6/07 Time: 12:39 PM View: DMCBRM

Figure 7. Trend Analysis Using Average Monthly Concentrations of Bromide at DMC

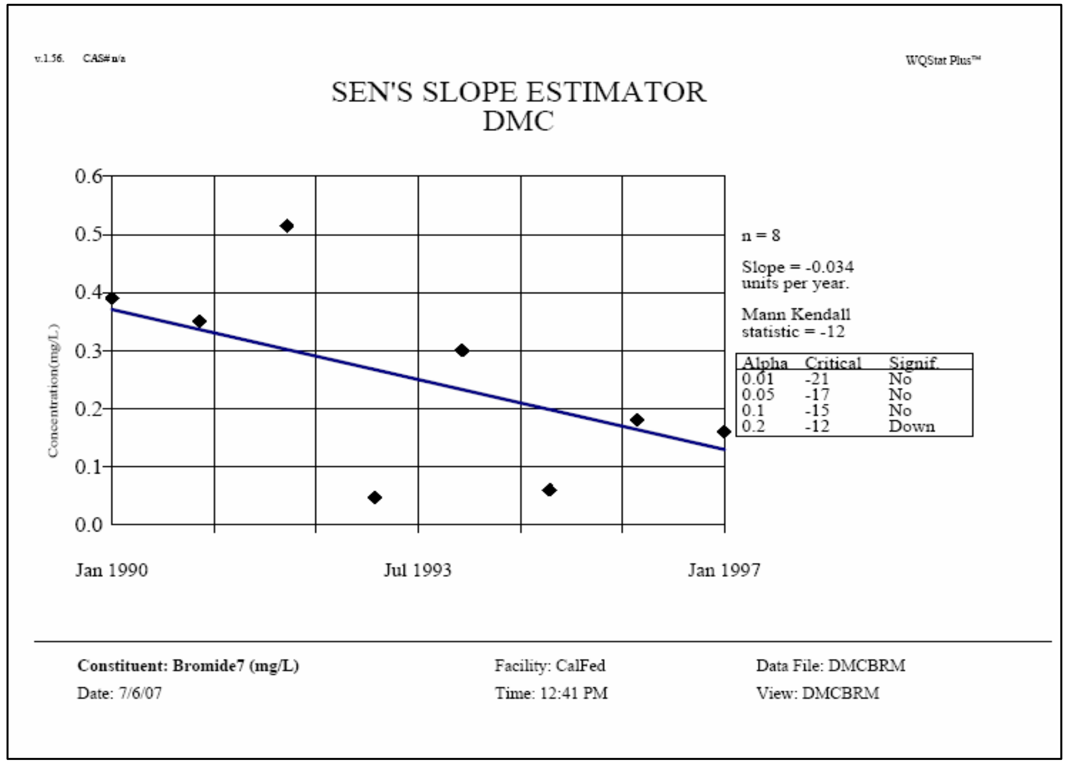
MAY



JUNE



JULY



AUGUST

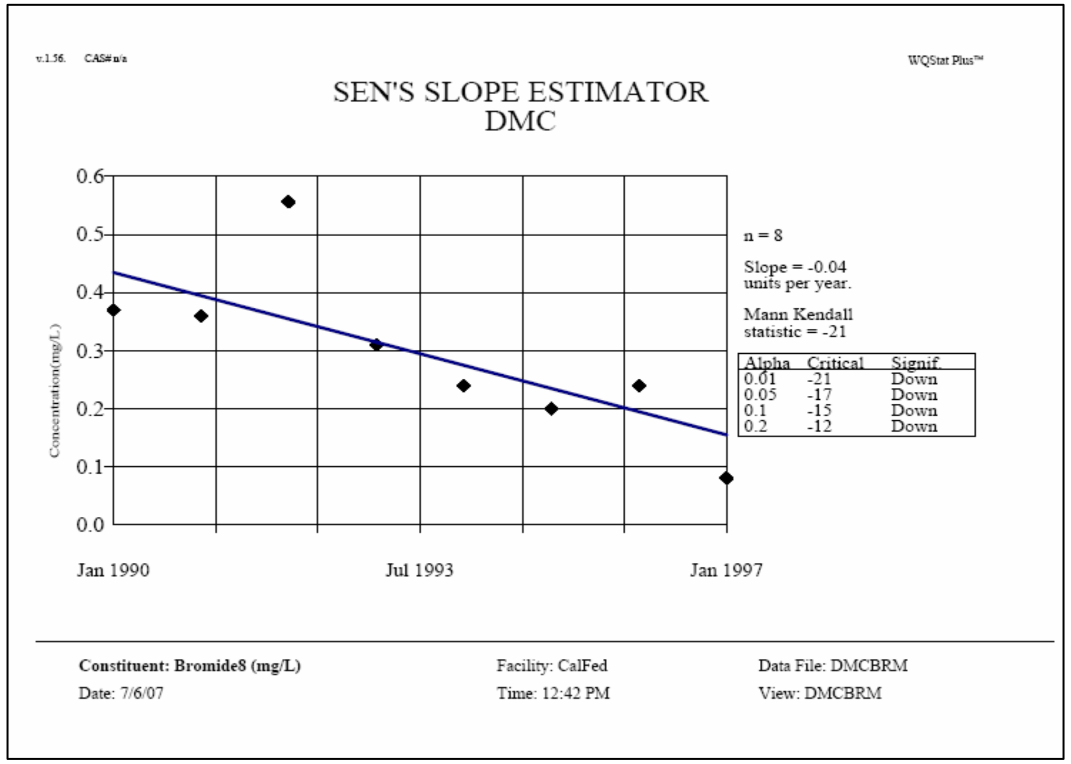
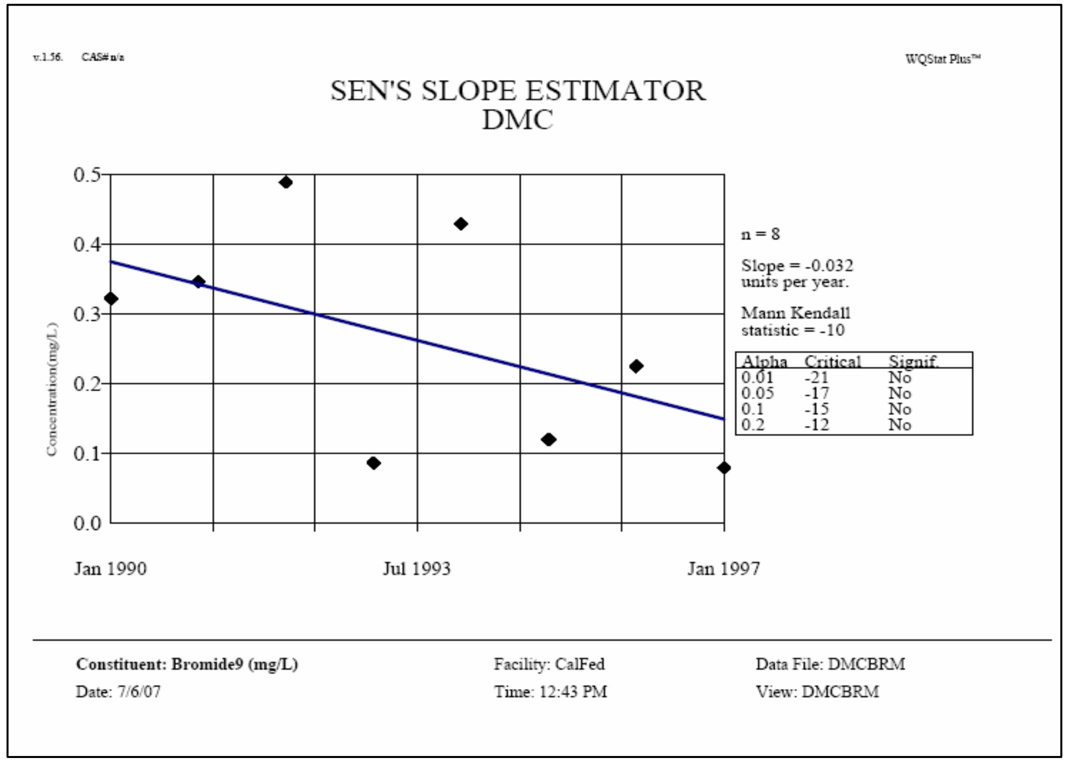
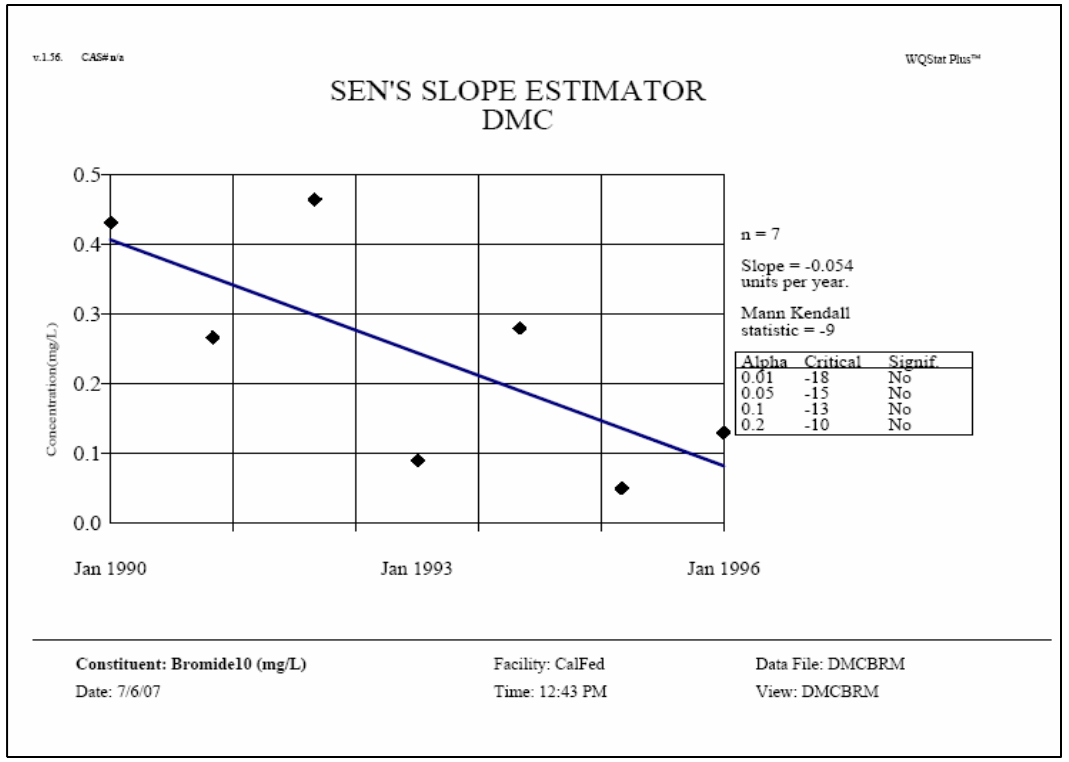


Figure 7. Trend Analysis Using Average Monthly Concentrations of Bromide at DMC

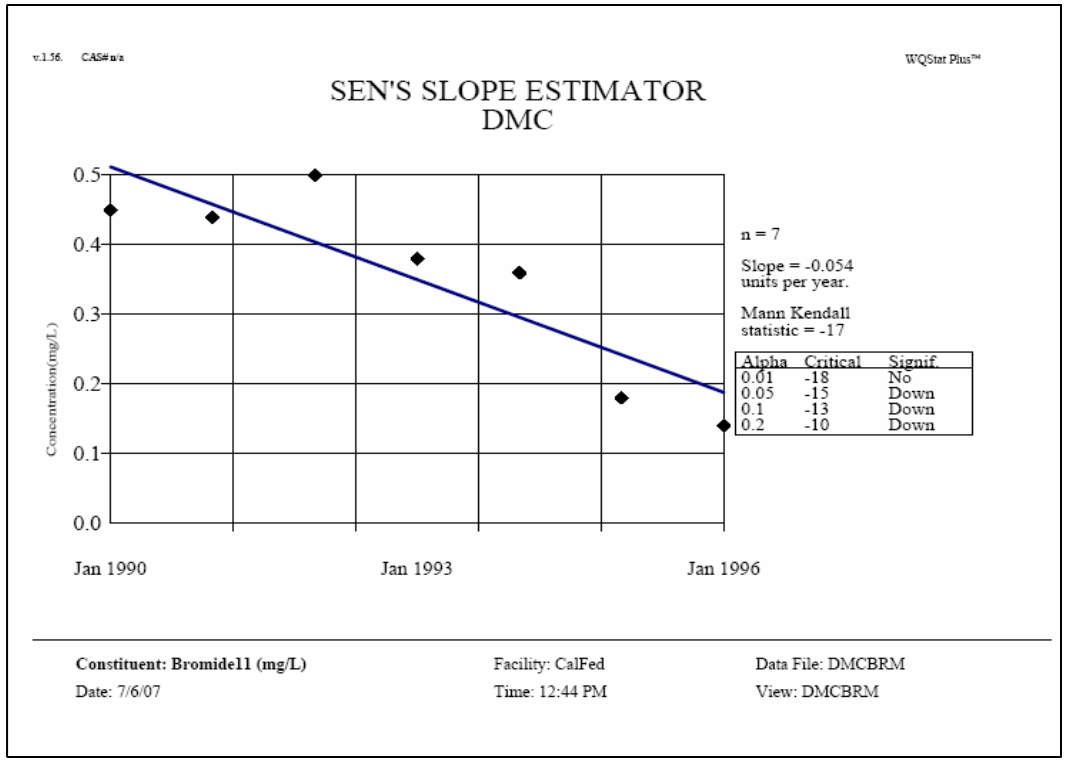
SEPTEMBER



OCTOBER



NOVEMBER



DECEMBER

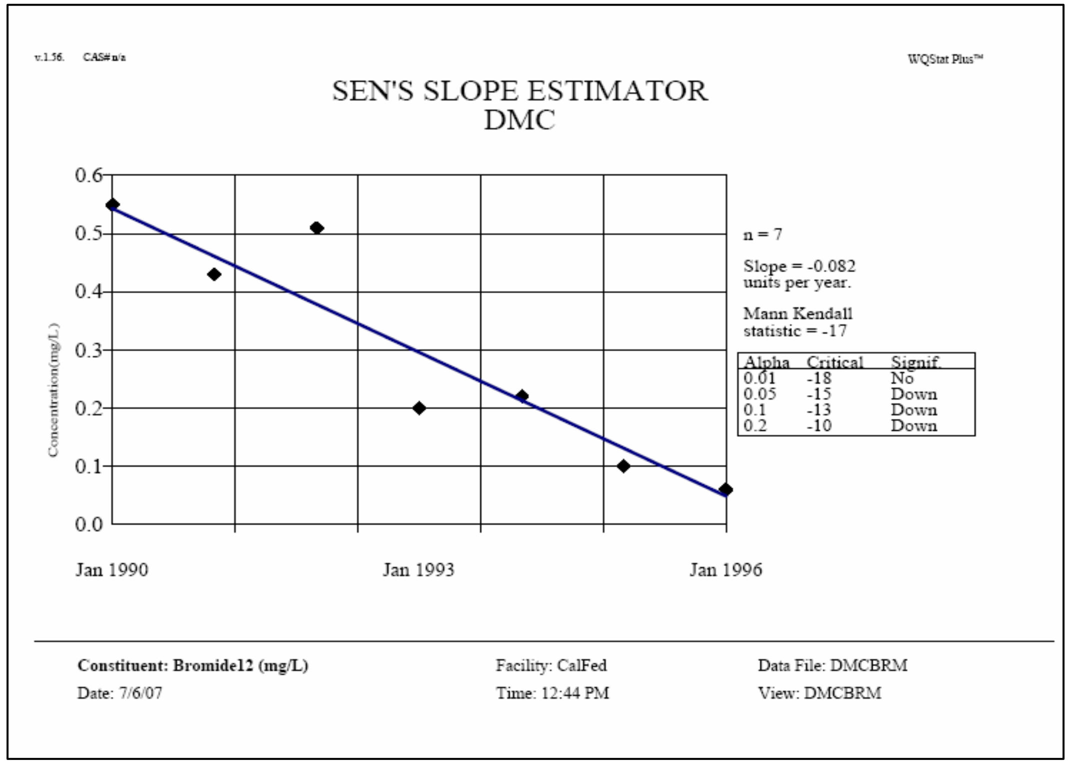
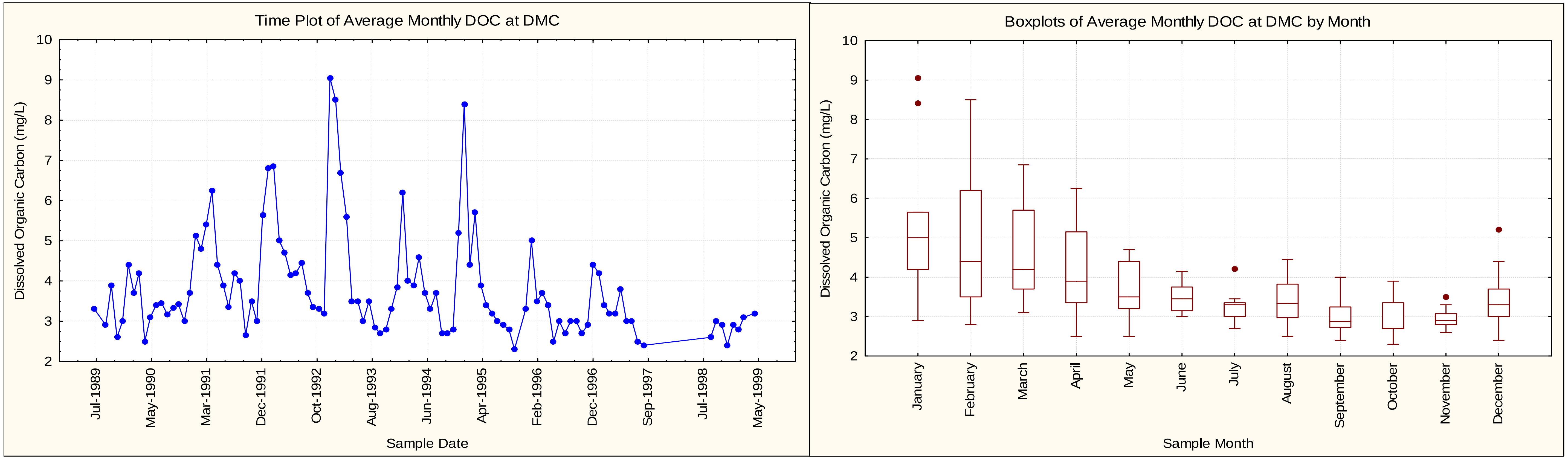


Figure 7. Trend Analysis Using Average Monthly Concentrations of Bromide at DMC

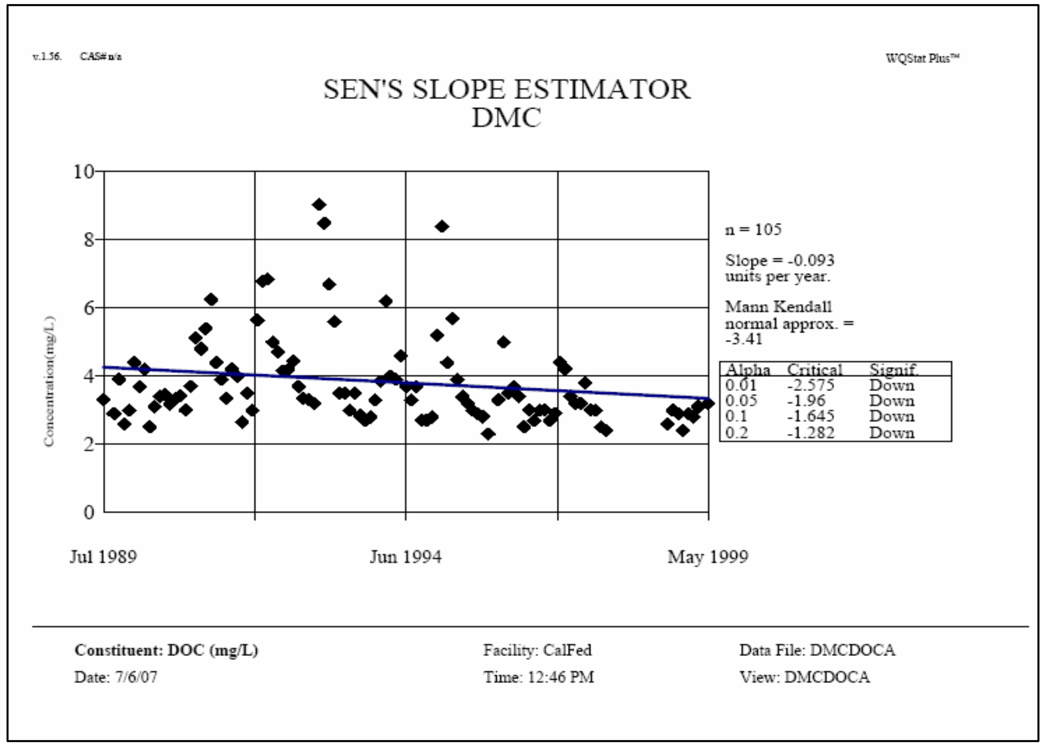
DATA USED IN TREND ANALYSIS - AVERAGE MONTHLY CONCENTRATIONS OF BROMIDE (MG/L)												
Sample Year	January	February	March	April	May	June	July	August	September	October	November	December
1990	0.4300	0.3650	0.1900	0.2900	0.3200	0.1900	0.3900	0.3700	0.3225	0.4320	0.4500	0.5500
1991	0.4550	0.5900	0.4333	0.2300	0.2100	0.3500	0.3500	0.3600	0.3467	0.2667	0.4400	0.4300
1992	0.3250	0.3050	0.0750	0.0967	0.1200	0.3800	0.5150	0.5567	0.4900	0.4650	0.5000	0.5100
1993	0.1500	0.1300	0.2367	0.1133	0.1700	0.1500	0.0467	0.3100	0.0867	0.0900	0.3800	0.2000
1994	0.2700	0.1800	0.3100	0.3600	0.2200	0.2000	0.3000	0.2400	0.4300	0.2800	0.3600	0.2200
1995	0.1800	0.1200	0.0500	0.1200	0.0600	0.0900	0.0600	0.2000	0.1200	0.0500	0.1800	0.1000
1996	0.0800	0.0900	0.0800	0.1200	0.1150	0.2000	0.1800	0.2400	0.2250	0.1300	0.1400	0.0600
1997	0.0300	0.0700	0.1000	0.1000	0.1350	0.1400	0.1600	0.0800	0.0800			

SUMMARY OF TREND ANALYSIS RESULTS													
	Bromide												
	January	February	March	April	May	June	July	August	September	October	November	December	All Months
Number of Observations:	8	8	8	8	8	8	8	8	8	7	7	7	93
Significance													
Alpha													
0.01	down	down	no	no	no	no	no	down	no	no	no	no	down
0.05	down	down	no	no	no	no	no	down	no	no	down	down	down
0.1	down	down	no	no	no	no	no	down	no	no	down	down	down
0.2	down	down	no	no	down	no	down	down	no	no	down	down	down

Figure 8. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at DMC



ALL DATA



SEN'S SLOPE ESTIMATOR
DMC

n = 105

Slope = -0.093
units per year.

Mann Kendall
normal approx. =
-3.41

Alpha	Critical	Signif.
0.01	-2.575	Down
0.05	-1.96	Down
0.1	-1.645	Down
0.2	-1.282	Down

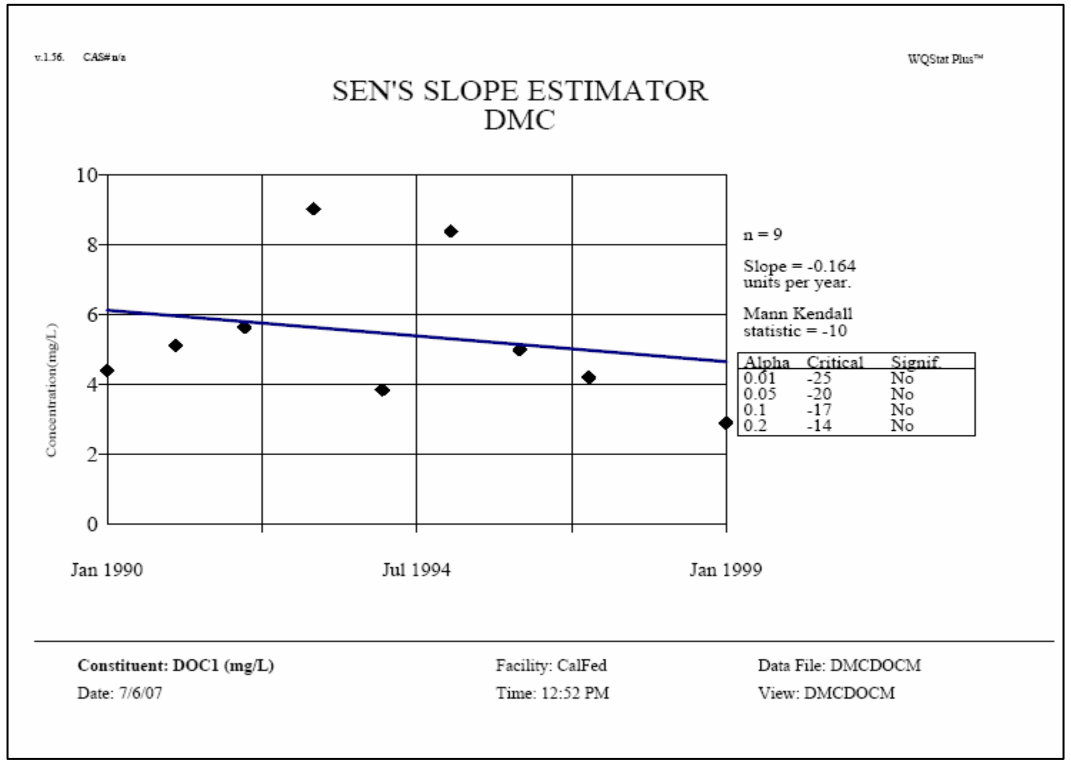
Constituent: DOC (mg/L)
Date: 7/6/07

Facility: CalFed
Time: 12:46 PM

Data File: DMCDOCA
View: DMCDOCA

Figure 8. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at DMC

JANUARY



SEN'S SLOPE ESTIMATOR
DMC

n = 9

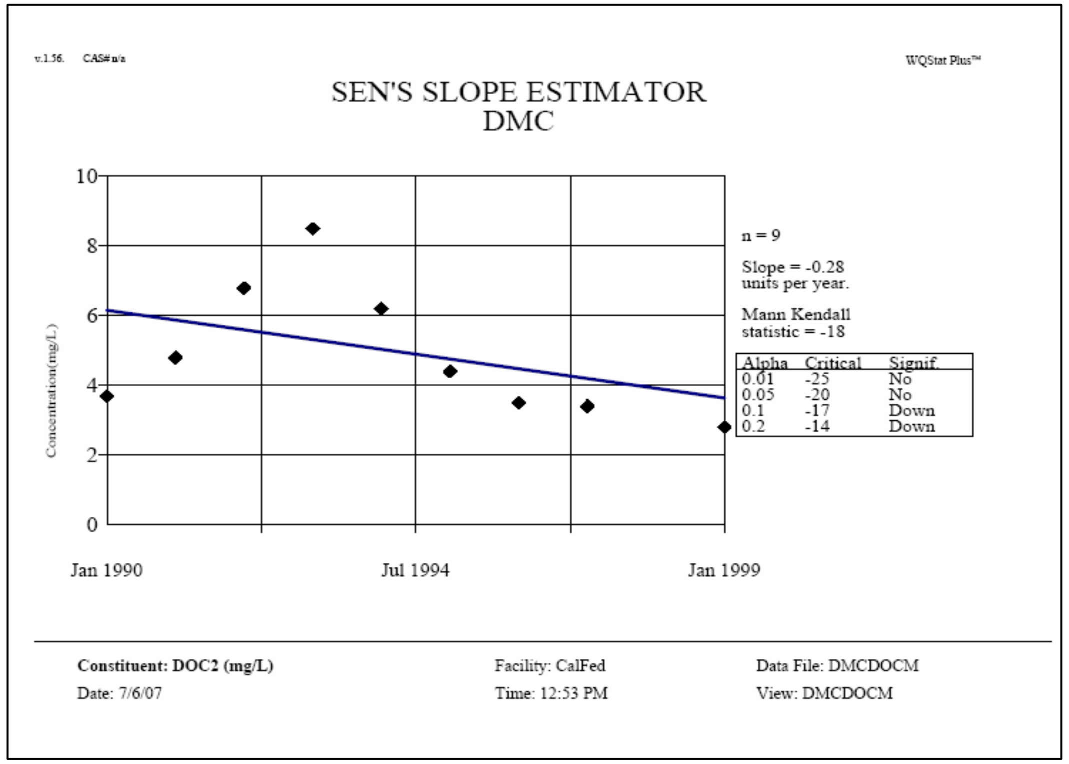
Slope = -0.164
units per year.

Mann Kendall
statistic = -10

Alpha	Critical	Signif.
0.01	-25	No
0.05	-20	No
0.1	-17	No
0.2	-14	No

Constituent: DOC1 (mg/L) Facility: CalFed Data File: DMCDOCM
Date: 7/6/07 Time: 12:52 PM View: DMCDOCM

FEBRUARY



SEN'S SLOPE ESTIMATOR
DMC

n = 9

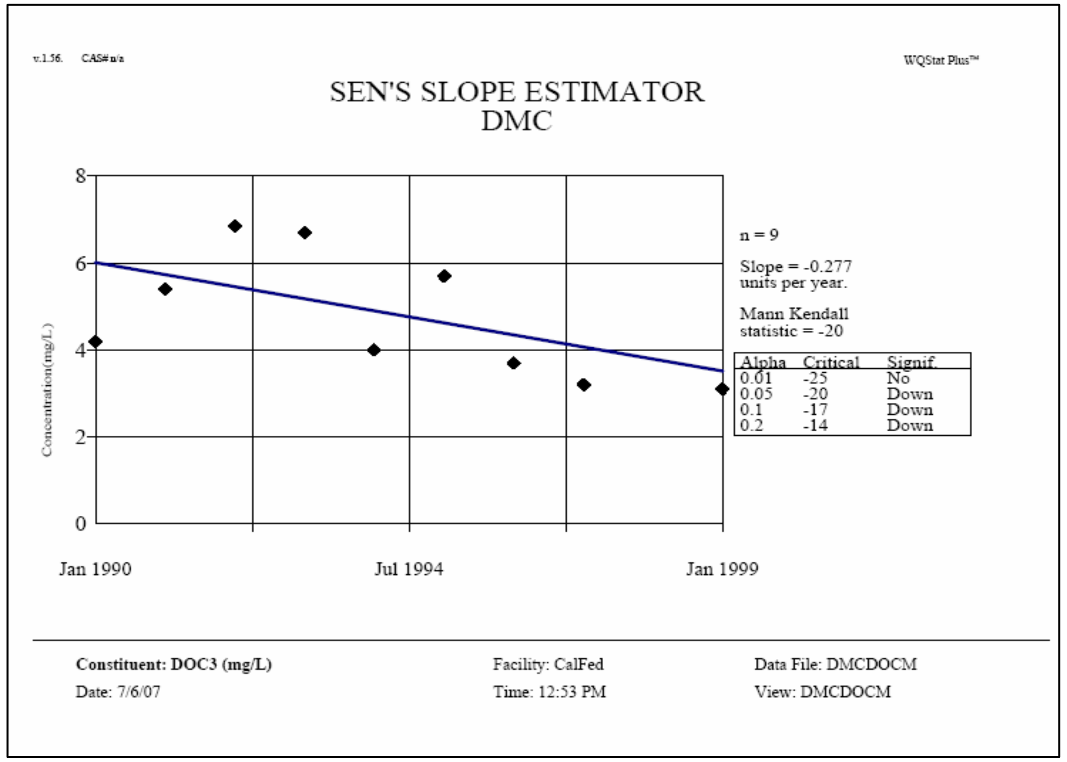
Slope = -0.28
units per year.

Mann Kendall
statistic = -18

Alpha	Critical	Signif.
0.01	-25	No
0.05	-20	No
0.1	-17	Down
0.2	-14	Down

Constituent: DOC2 (mg/L) Facility: CalFed Data File: DMCDOCM
Date: 7/6/07 Time: 12:53 PM View: DMCDOCM

MARCH



SEN'S SLOPE ESTIMATOR
DMC

n = 9

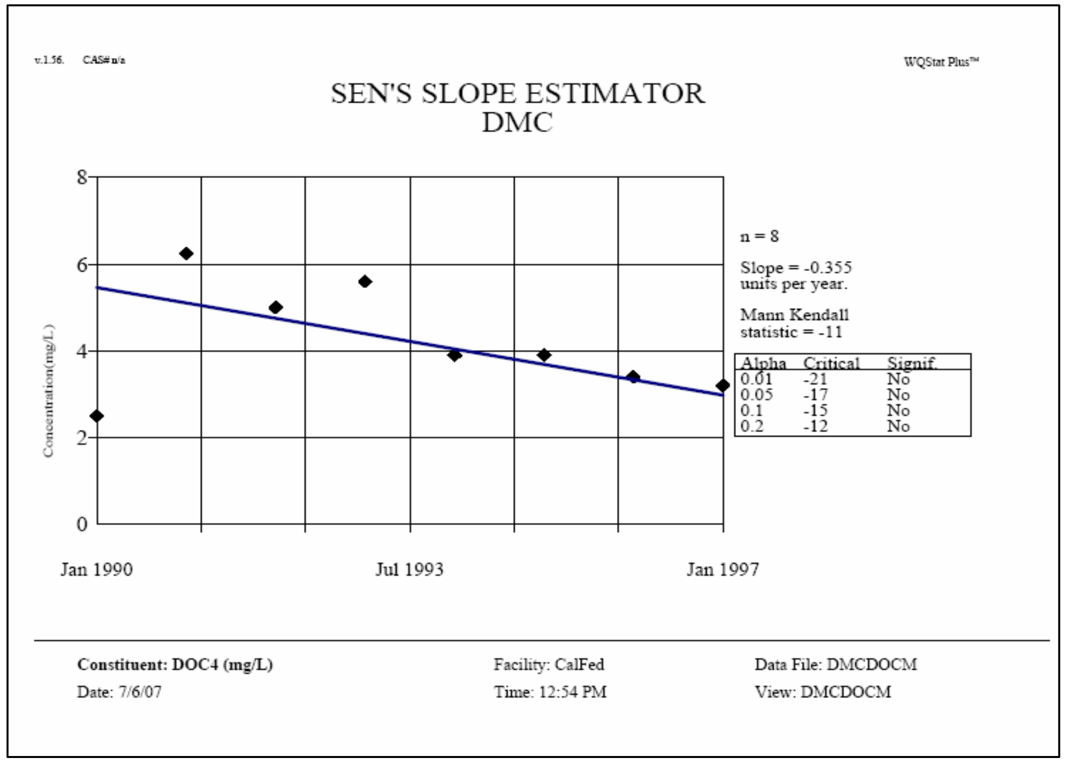
Slope = -0.277
units per year.

Mann Kendall
statistic = -20

Alpha	Critical	Signif.
0.01	-25	No
0.05	-20	Down
0.1	-17	Down
0.2	-14	Down

Constituent: DOC3 (mg/L) Facility: CalFed Data File: DMCDOCM
Date: 7/6/07 Time: 12:53 PM View: DMCDOCM

APRIL



SEN'S SLOPE ESTIMATOR
DMC

n = 8

Slope = -0.355
units per year.

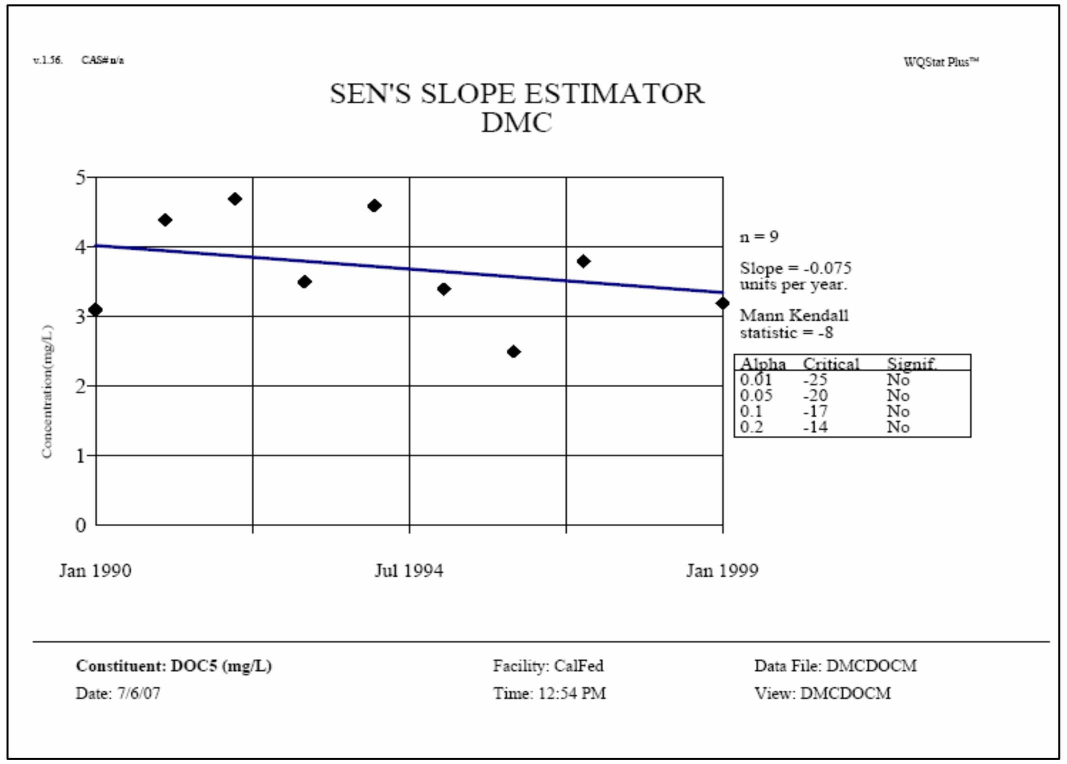
Mann Kendall
statistic = -11

Alpha	Critical	Signif.
0.01	-21	No
0.05	-17	No
0.1	-15	No
0.2	-12	No

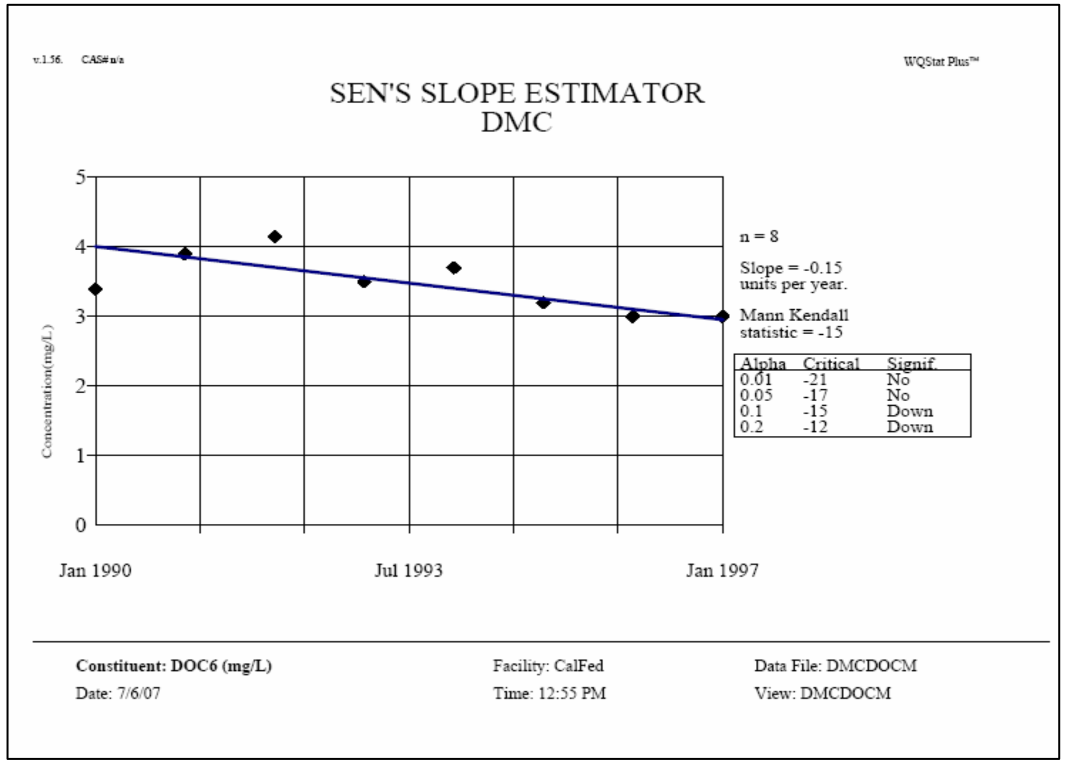
Constituent: DOC4 (mg/L) Facility: CalFed Data File: DMCDOCM
Date: 7/6/07 Time: 12:54 PM View: DMCDOCM

Figure 8. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at DMC

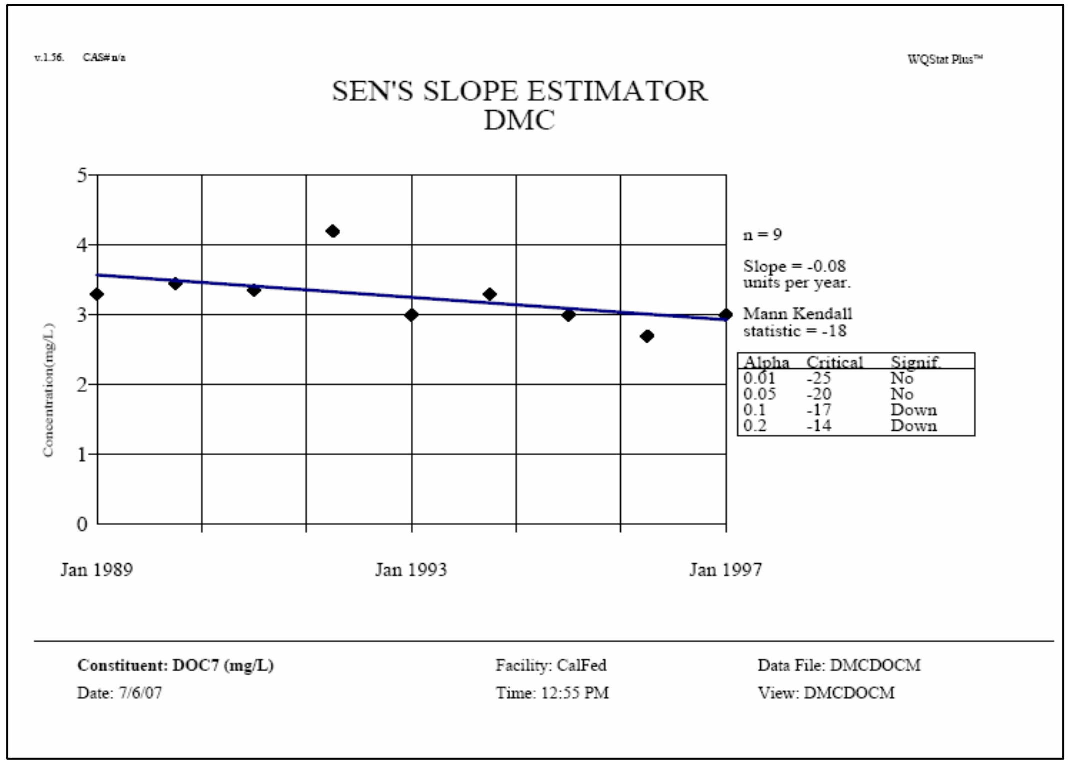
MAY



JUNE



JULY



AUGUST

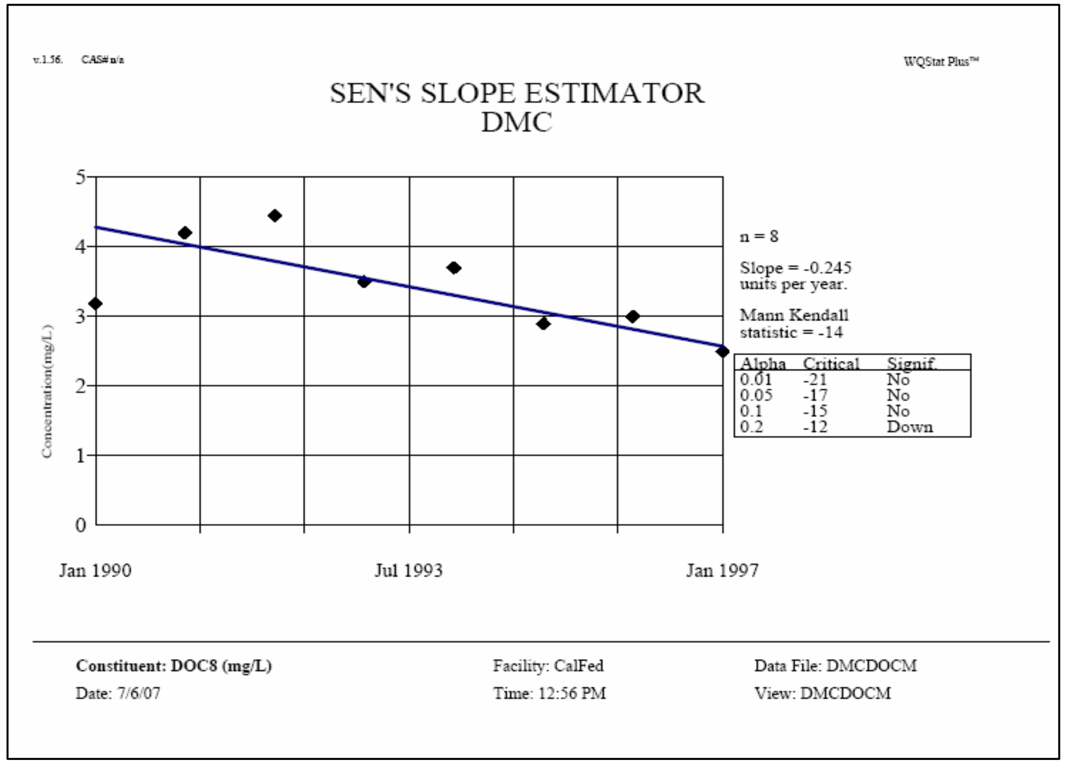
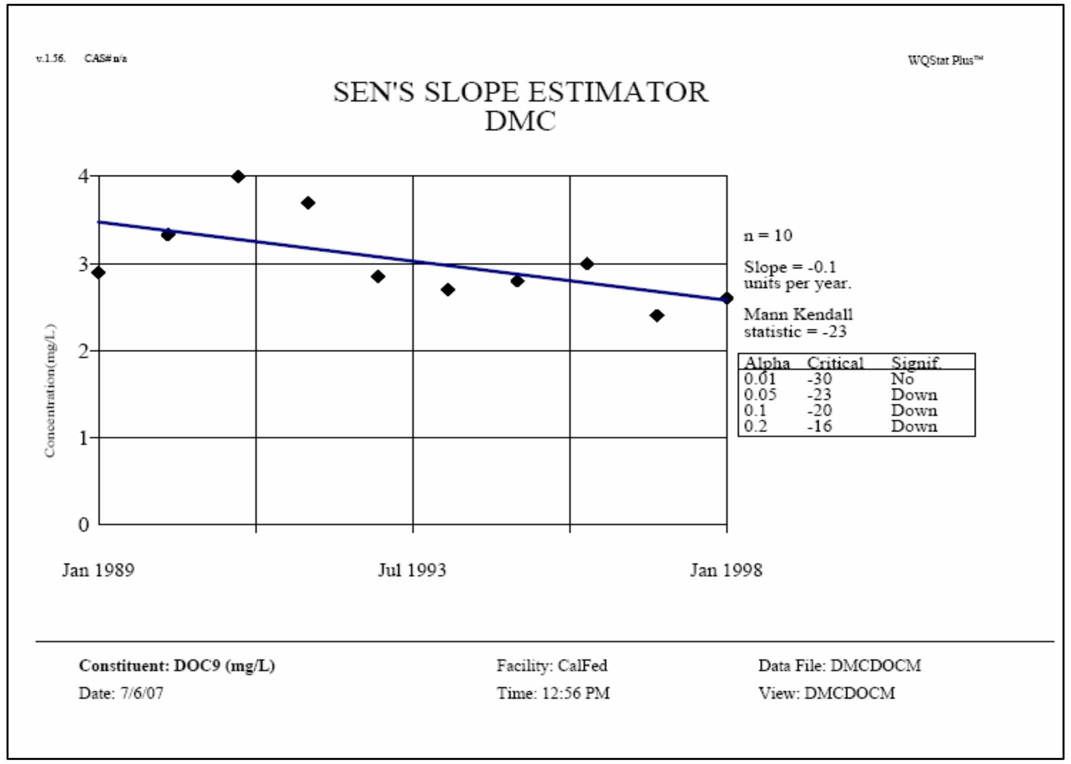


Figure 8. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at DMC

SEPTEMBER



SEN'S SLOPE ESTIMATOR
DMC

n = 10

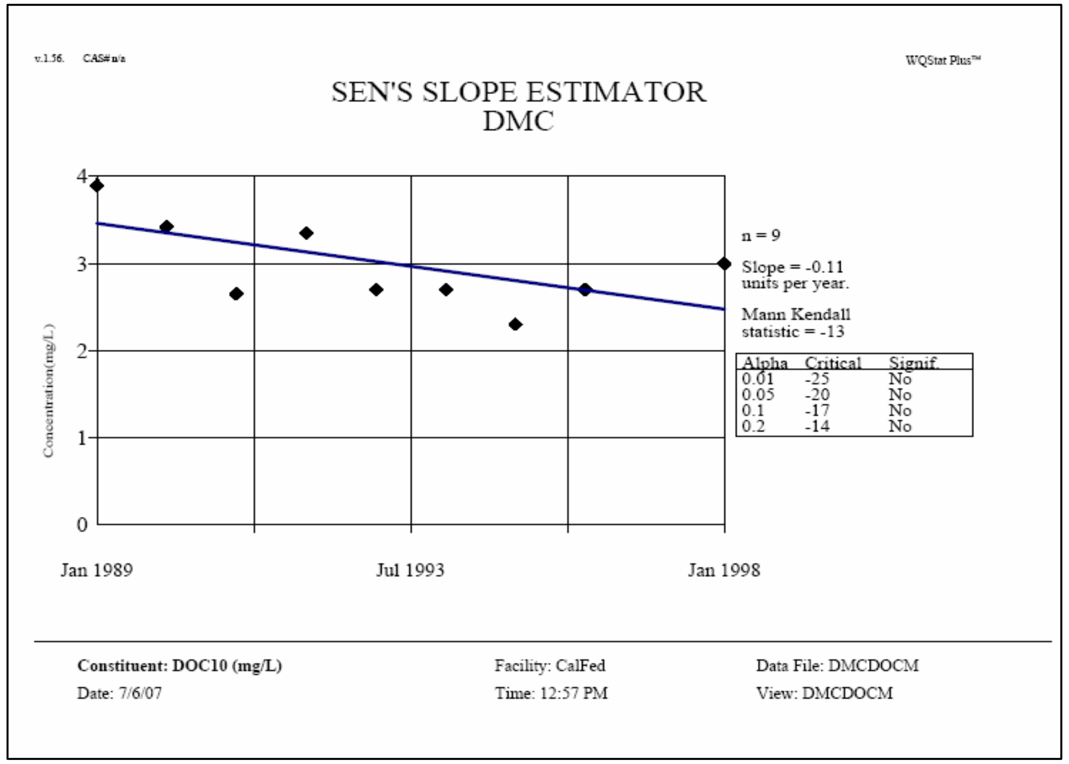
Slope = -0.1
units per year.

Mann Kendall
statistic = -23

Alpha	Critical	Signif.
0.01	-30	No
0.05	-23	Down
0.1	-20	Down
0.2	-16	Down

Constituent: DOC9 (mg/L)
Date: 7/6/07
Facility: CalFed
Time: 12:56 PM
Data File: DMCDOCM
View: DMCDOCM

OCTOBER



SEN'S SLOPE ESTIMATOR
DMC

n = 9

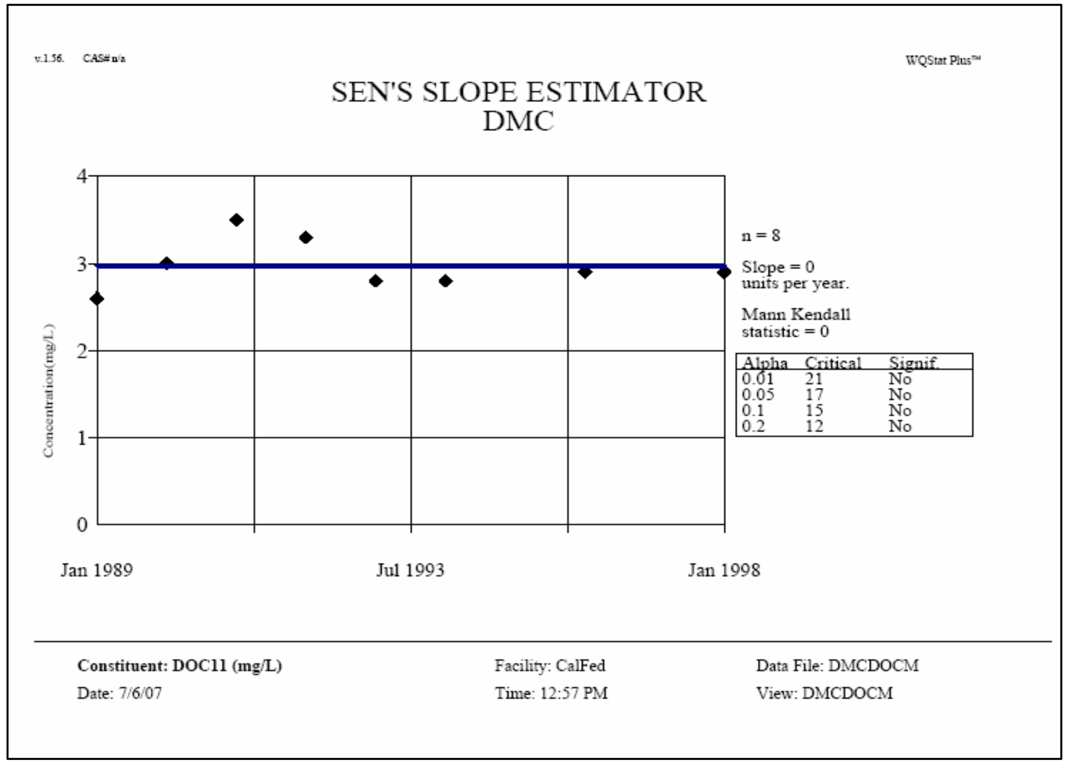
Slope = -0.11
units per year.

Mann Kendall
statistic = -13

Alpha	Critical	Signif.
0.01	-25	No
0.05	-20	No
0.1	-17	No
0.2	-14	No

Constituent: DOC10 (mg/L)
Date: 7/6/07
Facility: CalFed
Time: 12:57 PM
Data File: DMCDOCM
View: DMCDOCM

NOVEMBER



SEN'S SLOPE ESTIMATOR
DMC

n = 8

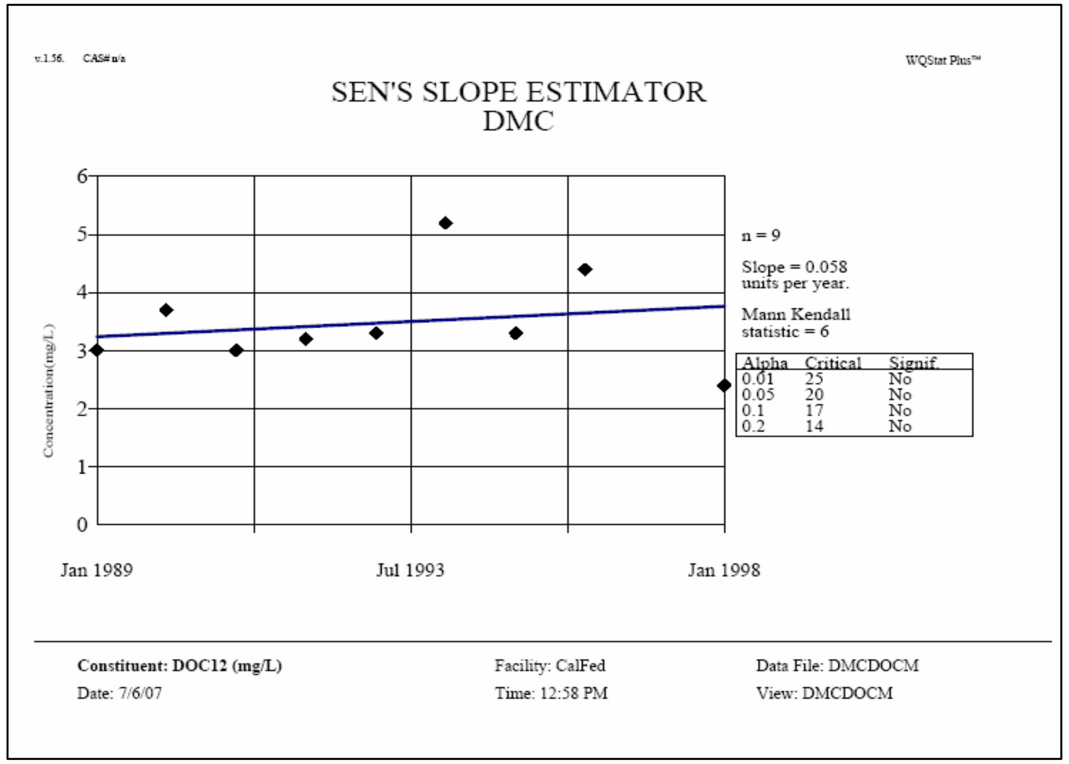
Slope = 0
units per year.

Mann Kendall
statistic = 0

Alpha	Critical	Signif.
0.01	21	No
0.05	17	No
0.1	15	No
0.2	12	No

Constituent: DOC11 (mg/L)
Date: 7/6/07
Facility: CalFed
Time: 12:57 PM
Data File: DMCDOCM
View: DMCDOCM

DECEMBER



SEN'S SLOPE ESTIMATOR
DMC

n = 9

Slope = 0.058
units per year.

Mann Kendall
statistic = 6

Alpha	Critical	Signif.
0.01	25	No
0.05	20	No
0.1	17	No
0.2	14	No

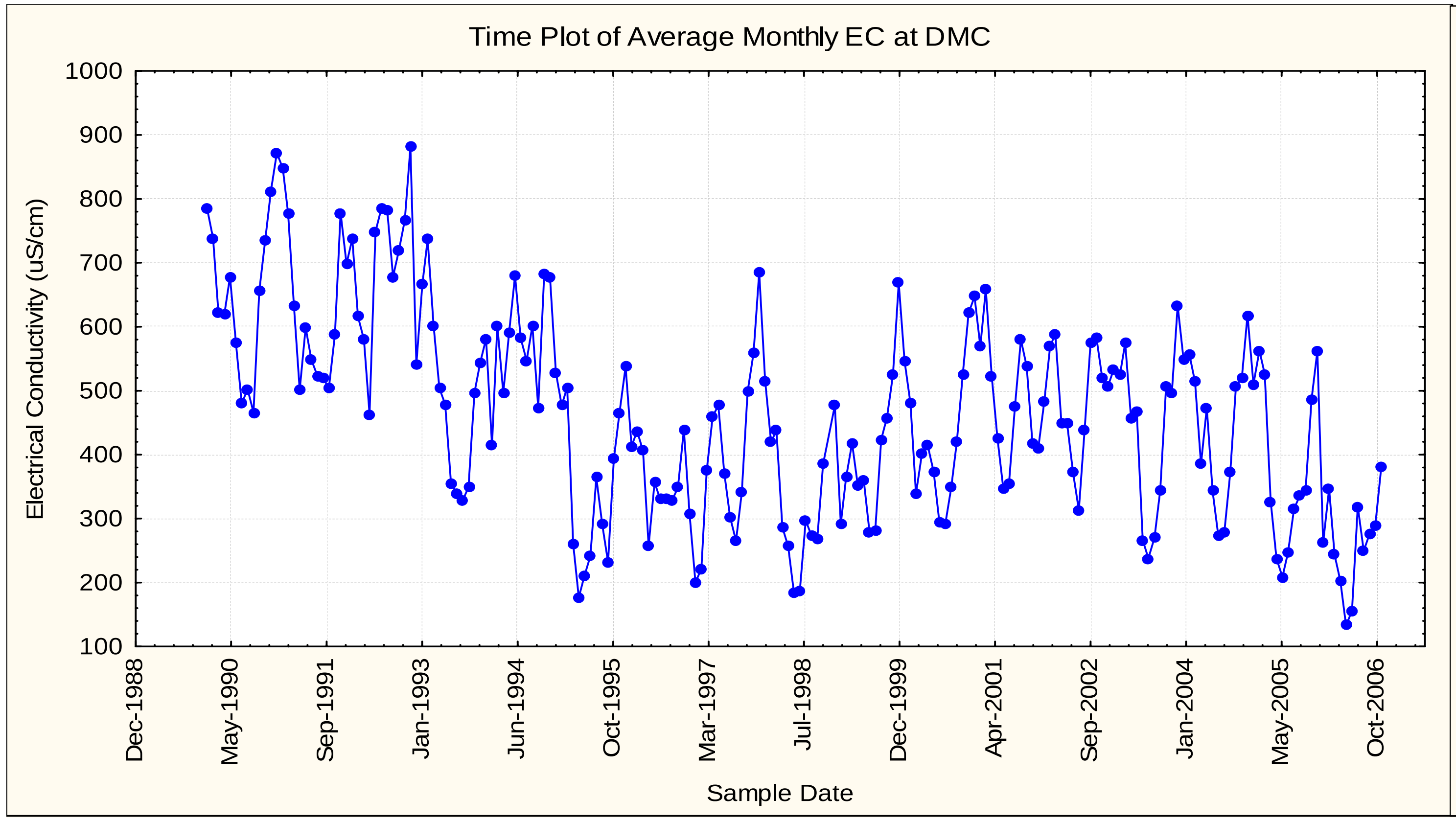
Constituent: DOC12 (mg/L)
Date: 7/6/07
Facility: CalFed
Time: 12:58 PM
Data File: DMCDOCM
View: DMCDOCM

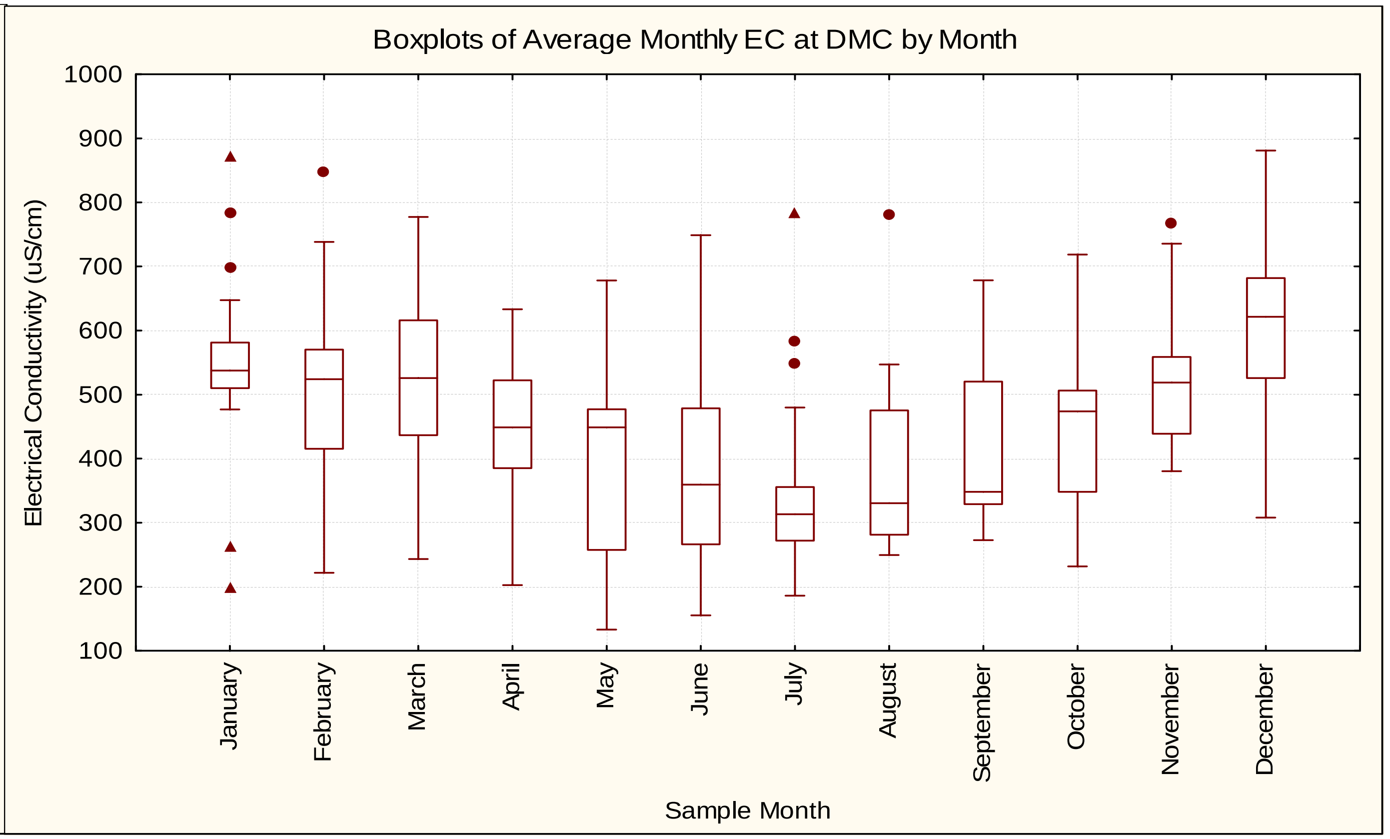
Figure 8. Trend Analysis Using Average Monthly Concentrations of Dissolved Organic Carbon at DMC

DATA USED IN TREND ANALYSIS - AVERAGE MONTHLY CONCENTRATIONS OF DISSOLVED ORGANIC CARBON (MG/L)												
Sample Year	January	February	March	April	May	June	July	August	September	October	November	December
1989							3.30		2.90	3.90	2.60	3.00
1990	4.40	3.70	4.20	2.50	3.10	3.40	3.45	3.18	3.33	3.42	3.00	3.70
1991	5.13	4.80	5.40	6.25	4.40	3.90	3.35	4.20	4.00	2.65	3.50	3.00
1992	5.65	6.80	6.85	5.00	4.70	4.15	4.20	4.45	3.70	3.35	3.30	3.20
1993	9.05	8.50	6.70	5.60	3.50	3.50	3.00	3.50	2.85	2.70	2.80	3.30
1994	3.85	6.20	4.00	3.90	4.60	3.70	3.30	3.70	2.70	2.70	2.80	5.20
1995	8.40	4.40	5.70	3.90	3.40	3.20	3.00	2.90	2.80	2.30		3.30
1996	5.00	3.50	3.70	3.40	2.50	3.00	2.70	3.00	3.00	2.70	2.90	4.40
1997	4.20	3.40	3.20	3.20	3.80	3.00	3.00	2.50	2.40			
1998									2.60	3.00	2.90	2.40
1999	2.90	2.80	3.10		3.20							

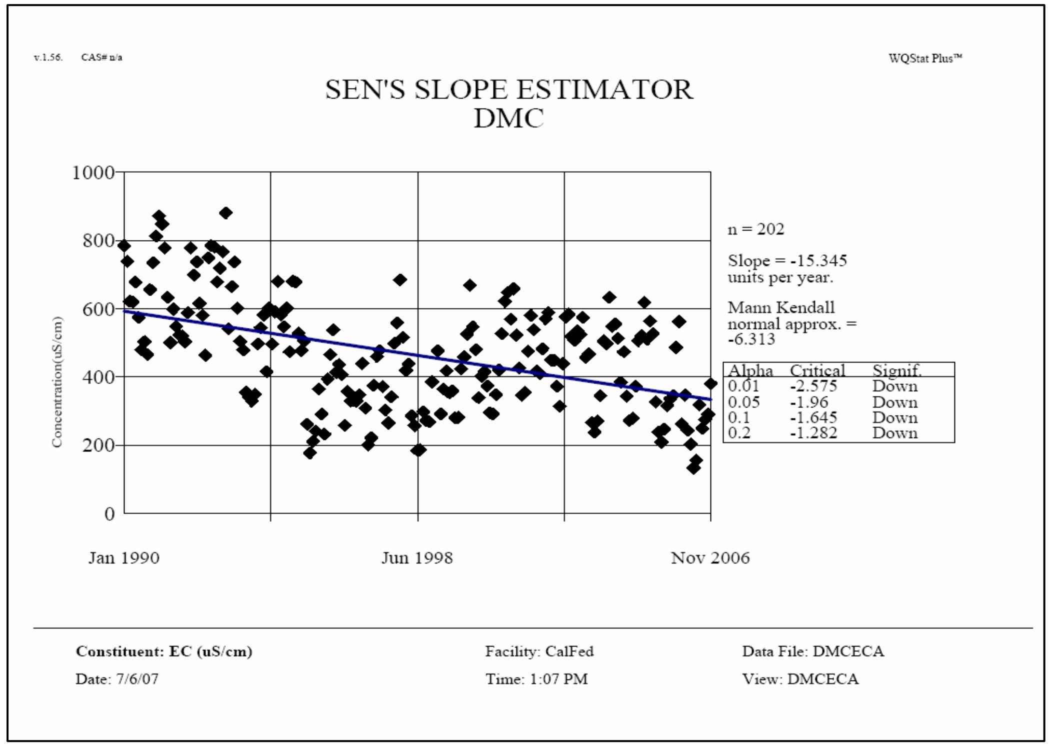
SUMMARY OF TREND ANALYSIS RESULTS													
	Dissolved Organic Carbon												
	January	February	March	April	May	June	July	August	September	October	November	December	All Months
Number of Observations:	9	9	9	8	9	8	9	8	10	9	8	9	105
Significance													
Alpha													
0.01	no	no	no	no	no	no	no	no	no	no	no	no	down
0.05	no	no	down	no	no	no	no	no	down	no	no	no	down
0.1	no	down	down	no	no	down	down	no	down	no	no	no	down
0.2	no	down	down	no	no	down	down	down	down	no	no	no	down

Figure 9. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at DMC


Time Plot of Average Monthly EC at DMC


Boxplots of Average Monthly EC at DMC by Month

ALL DATA



SEN'S SLOPE ESTIMATOR
DMC

n = 202

Slope = -15.345
units per year.

Mann Kendall
normal approx. =
-6.313

Alpha	Critical	Signif.
0.01	-2.575	Down
0.05	-1.96	Down
0.1	-1.645	Down
0.2	-1.282	Down

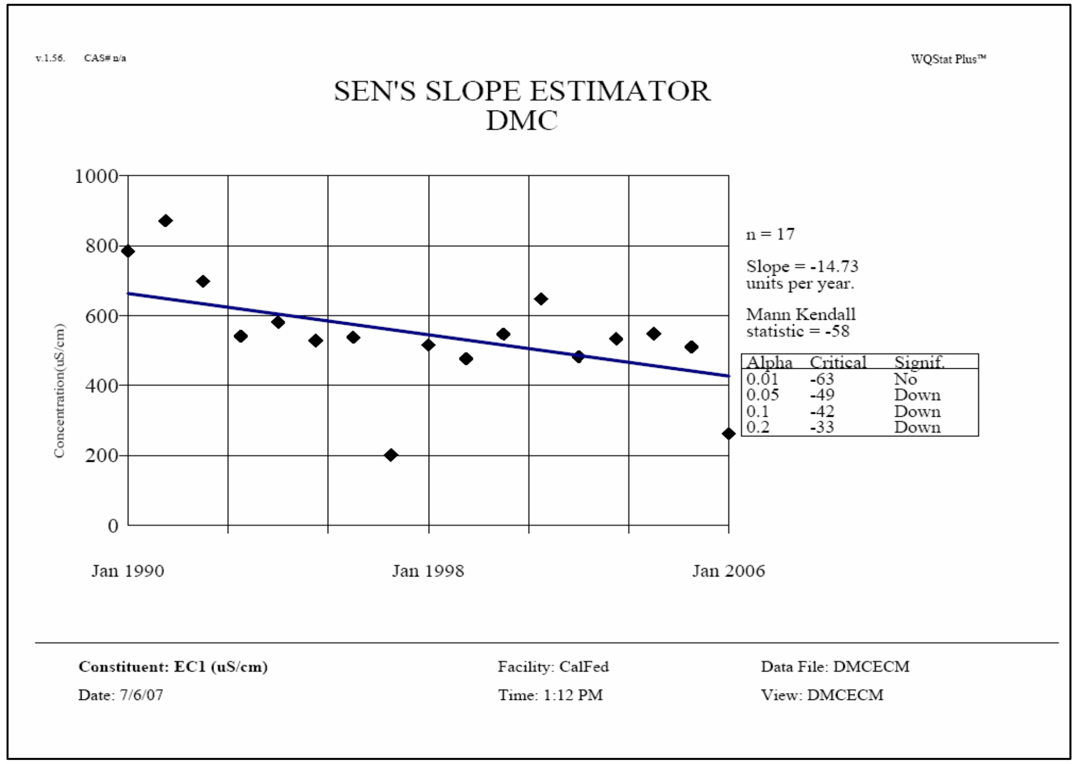
Constituent: EC (uS/cm)
Date: 7/6/07

Facility: CalFed
Time: 1:07 PM

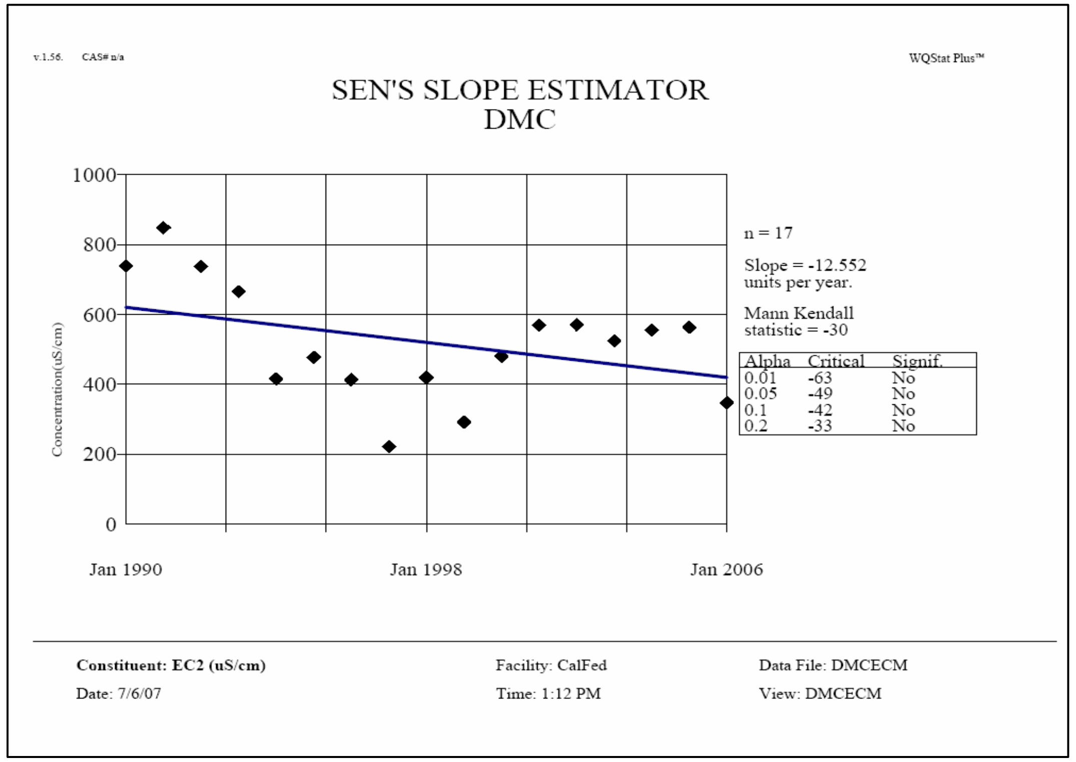
Data File: DMCECA
View: DMCECA

Figure 9. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at DMC

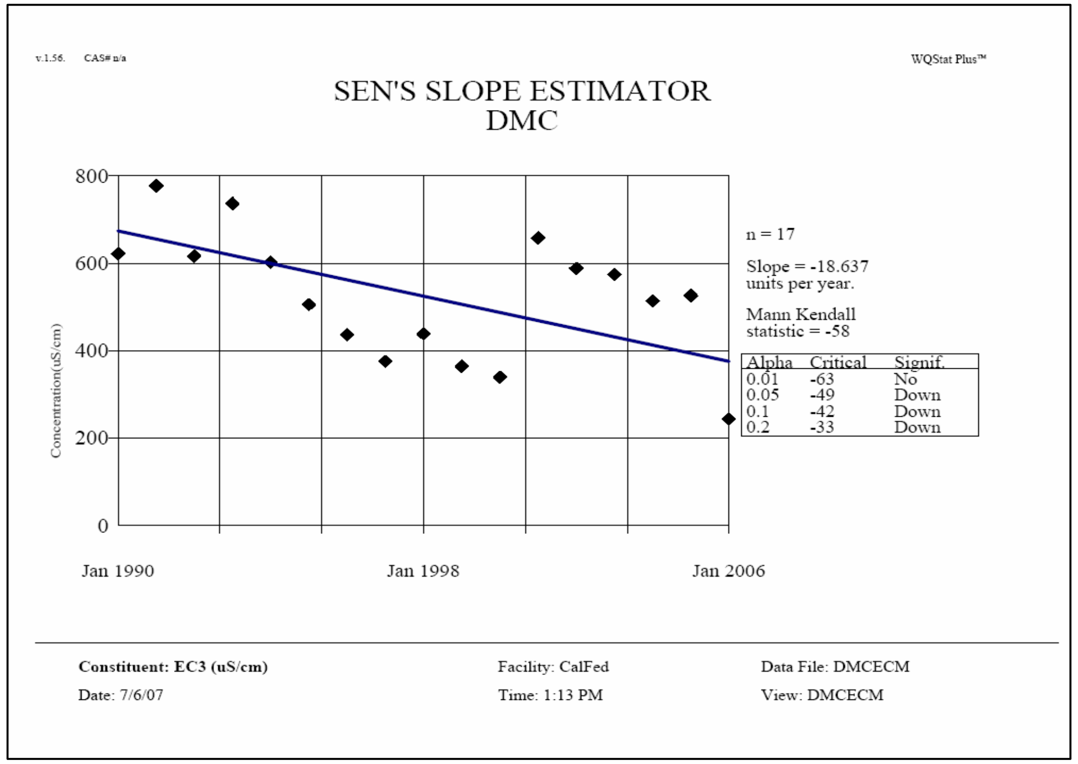
JANUARY



FEBRUARY



MARCH



APRIL

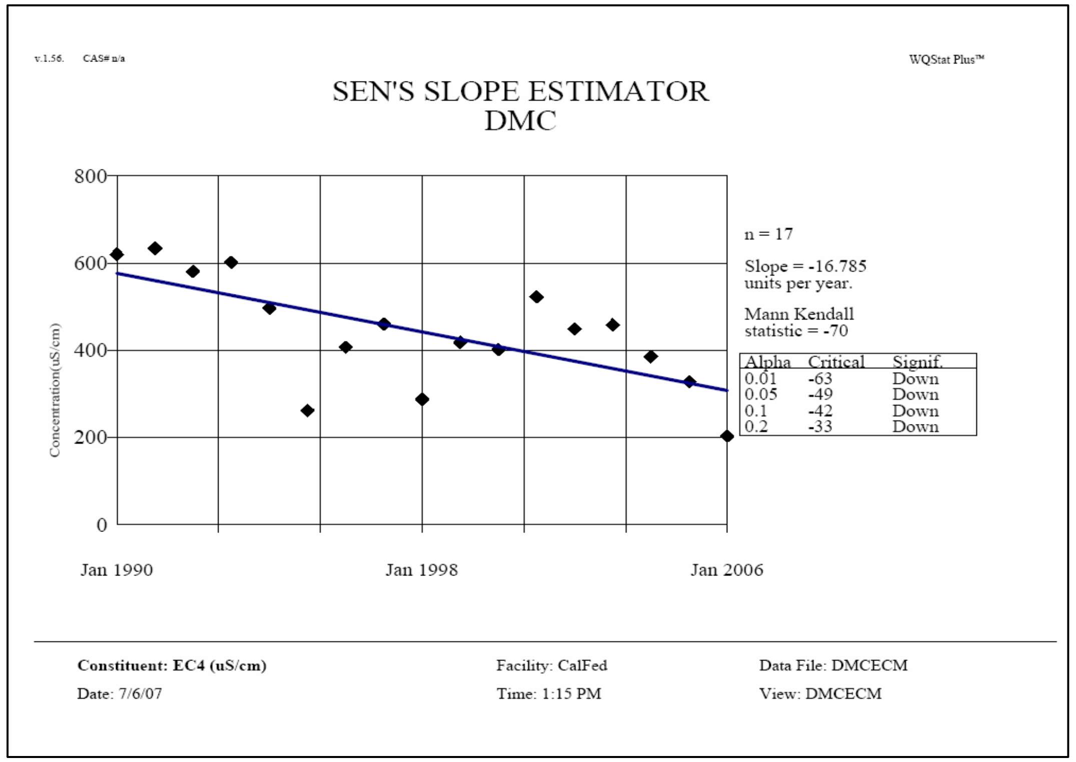
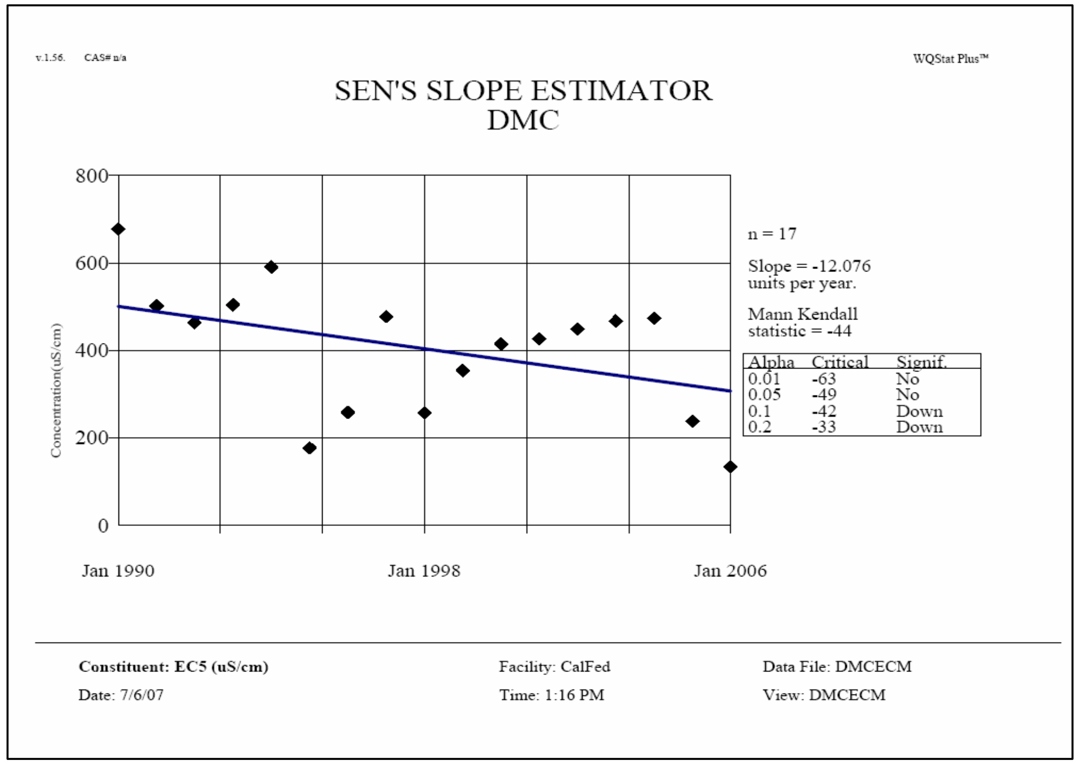


Figure 9. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at DMC

MAY



n = 17

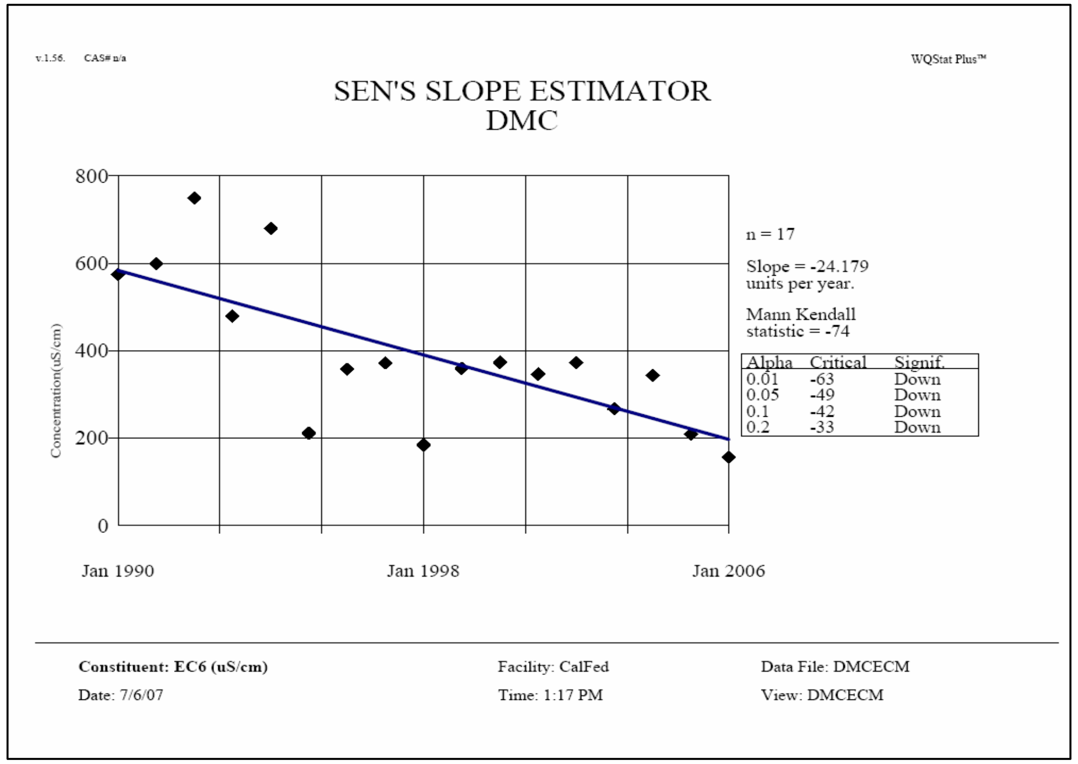
Slope = -12.076 units per year.

Mann Kendall statistic = -44

Alpha	Critical	Signif.
0.01	-63	No
0.05	-49	No
0.1	-42	Down
0.2	-33	Down

Constituent: EC5 (uS/cm) Facility: CalFed Data File: DMCECM
Date: 7/6/07 Time: 1:16 PM View: DMCECM

JUNE



n = 17

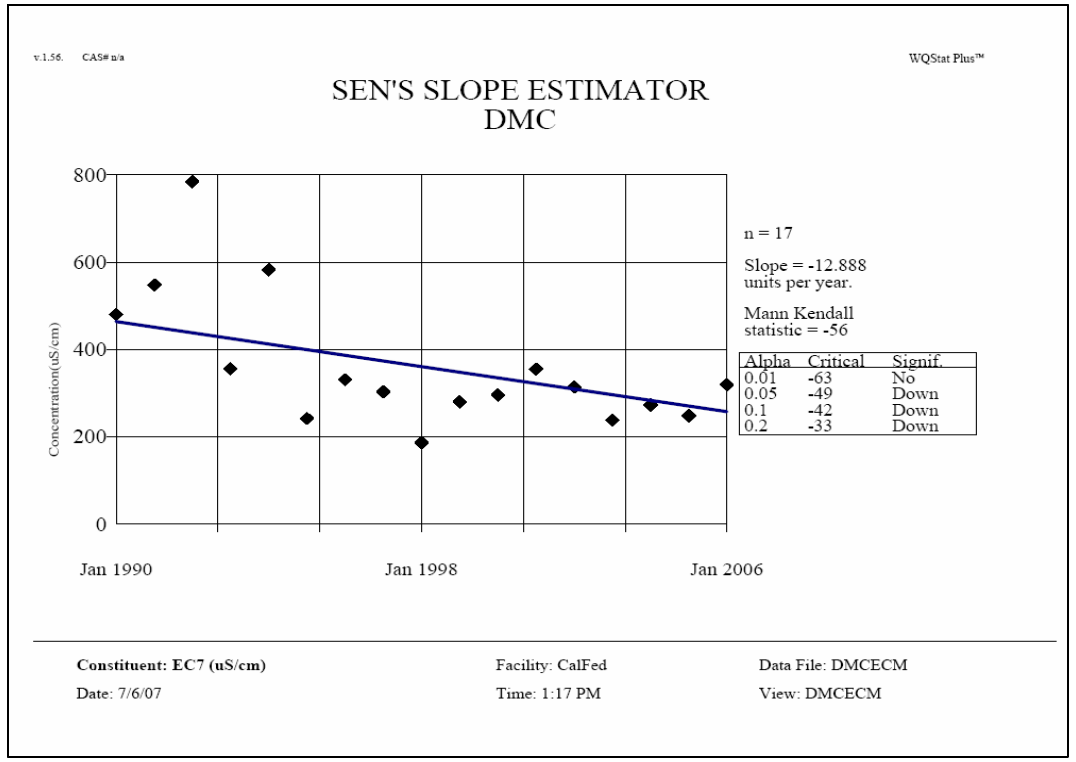
Slope = -24.179 units per year.

Mann Kendall statistic = -74

Alpha	Critical	Signif.
0.01	-63	Down
0.05	-49	Down
0.1	-42	Down
0.2	-33	Down

Constituent: EC6 (uS/cm) Facility: CalFed Data File: DMCECM
Date: 7/6/07 Time: 1:17 PM View: DMCECM

JULY



n = 17

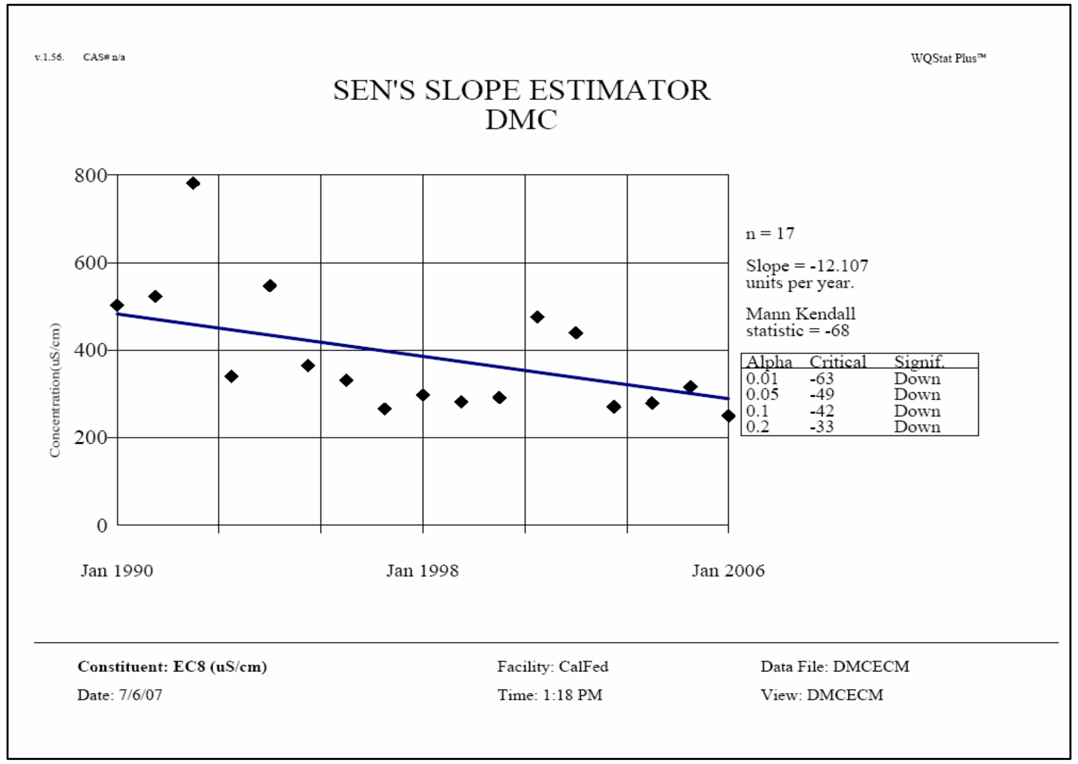
Slope = -12.888 units per year.

Mann Kendall statistic = -56

Alpha	Critical	Signif.
0.01	-63	No
0.05	-49	Down
0.1	-42	Down
0.2	-33	Down

Constituent: EC7 (uS/cm) Facility: CalFed Data File: DMCECM
Date: 7/6/07 Time: 1:17 PM View: DMCECM

AUGUST



n = 17

Slope = -12.107 units per year.

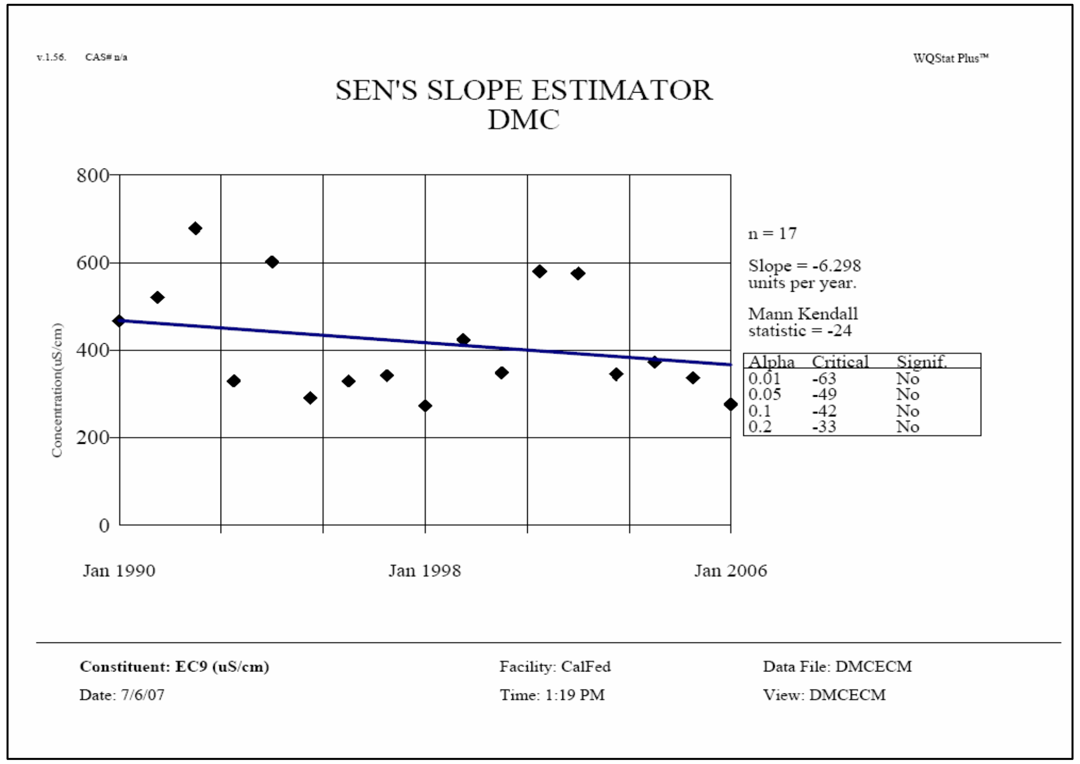
Mann Kendall statistic = -68

Alpha	Critical	Signif.
0.01	-63	Down
0.05	-49	Down
0.1	-42	Down
0.2	-33	Down

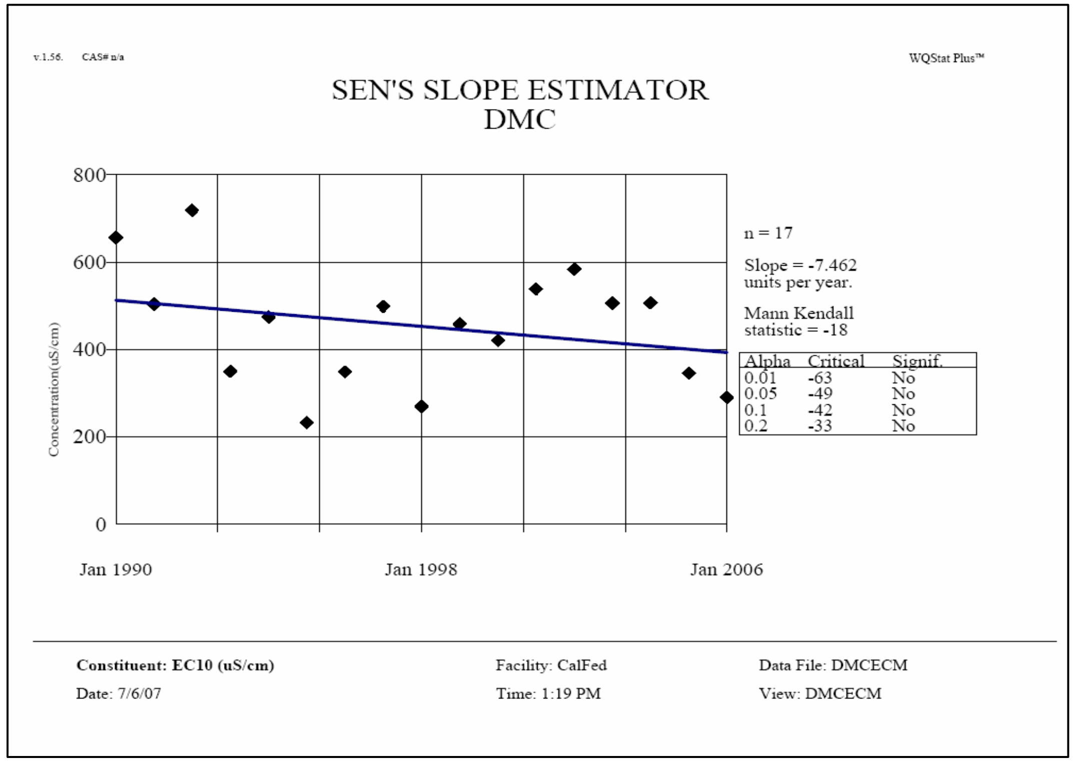
Constituent: EC8 (uS/cm) Facility: CalFed Data File: DMCECM
Date: 7/6/07 Time: 1:18 PM View: DMCECM

Figure 9. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at DMC

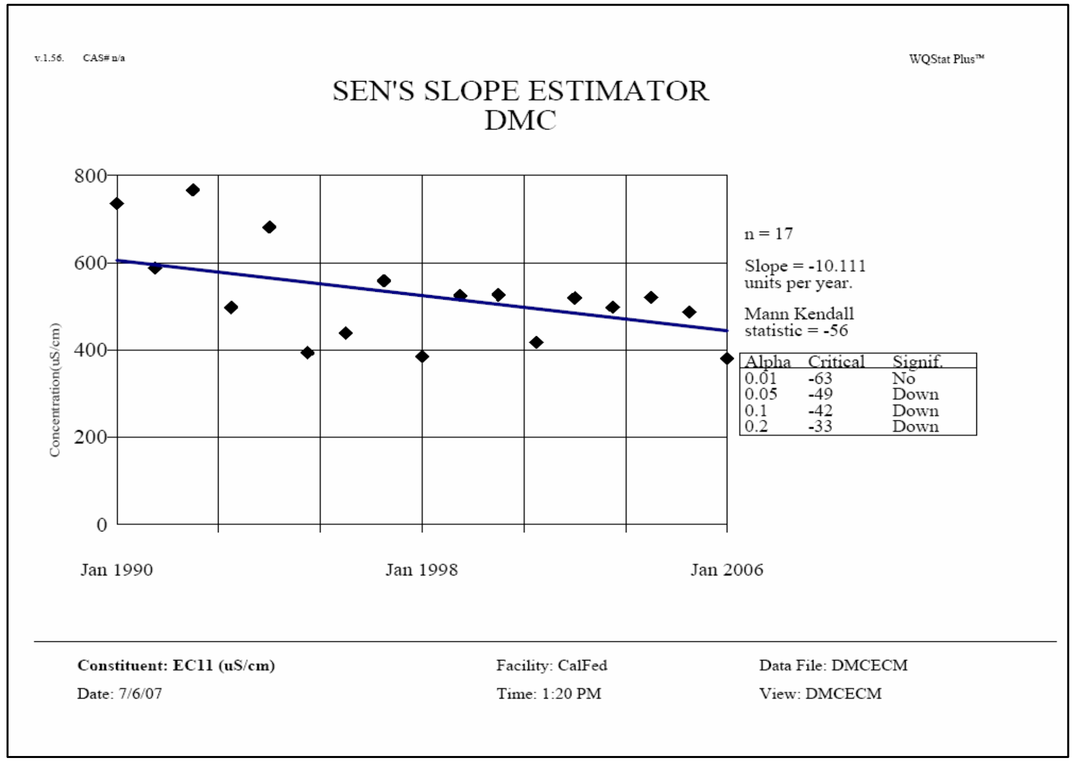
SEPTEMBER



OCTOBER



NOVEMBER



DECEMBER

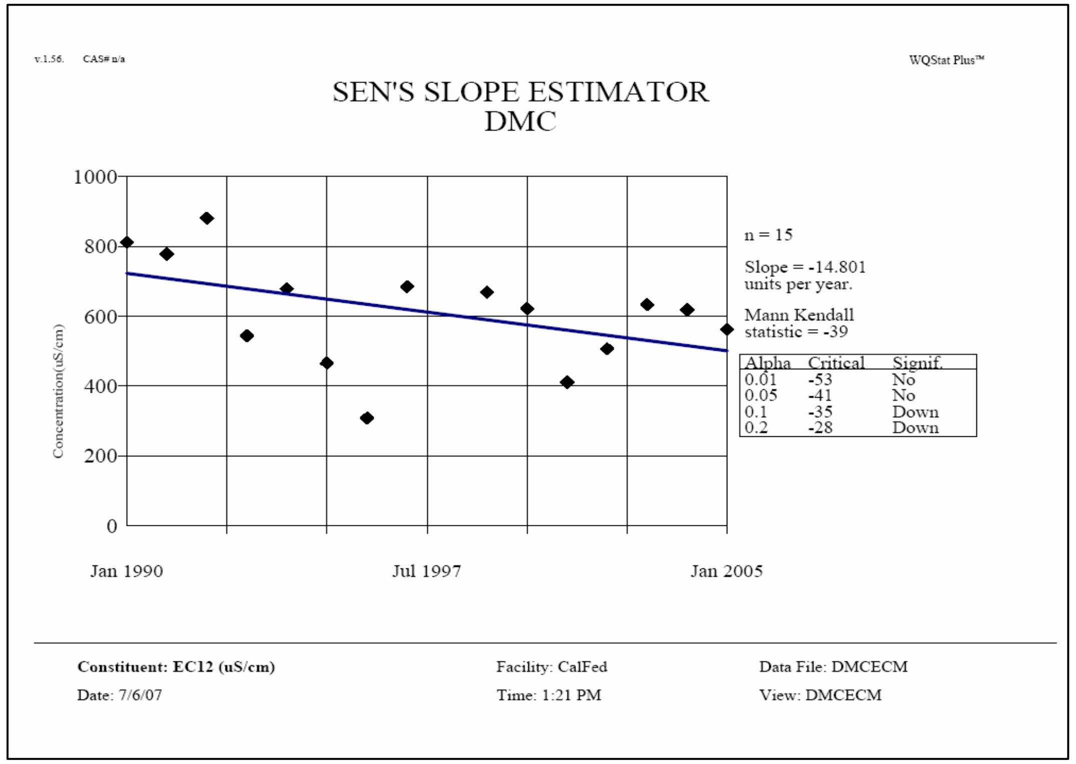
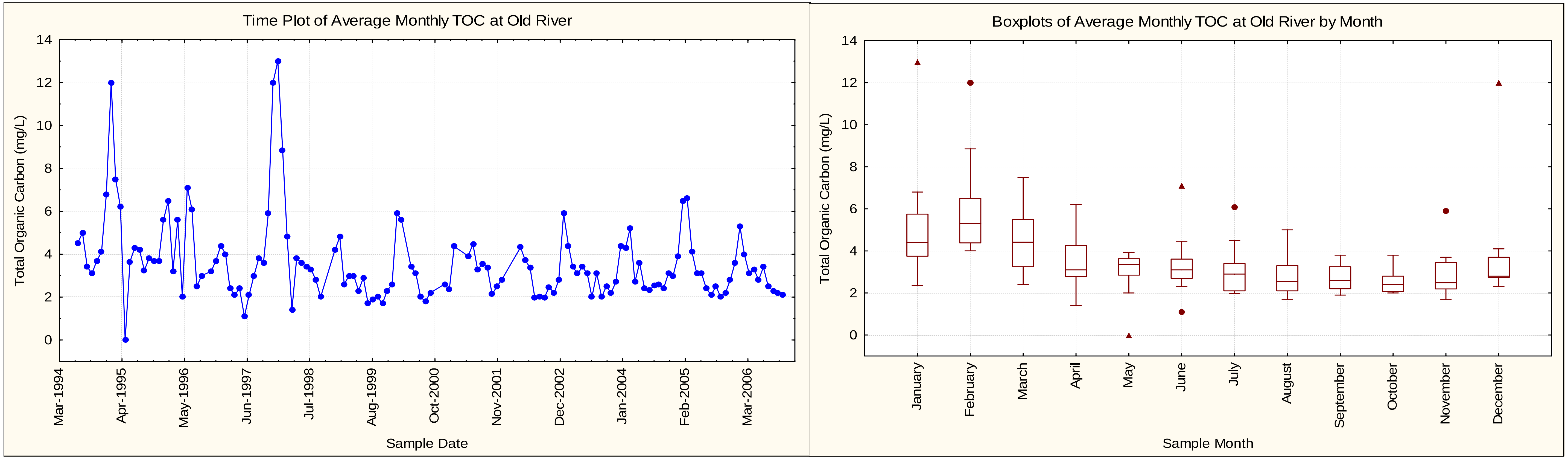


Figure 9. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at DMC

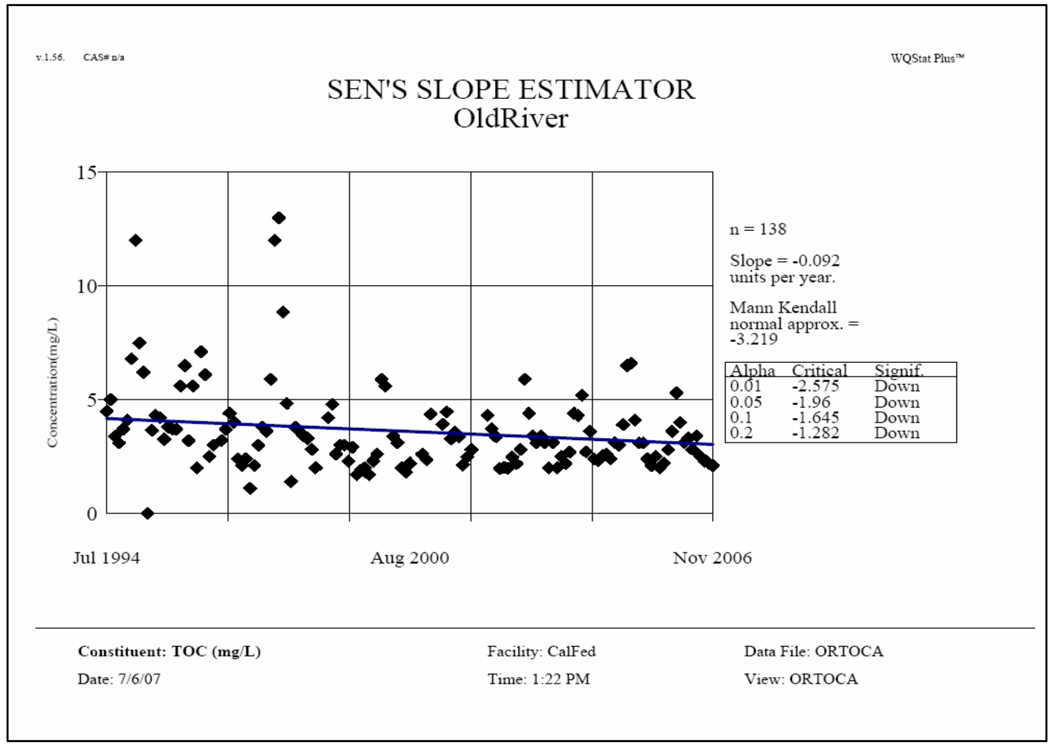
DATA USED IN TREND ANALYSIS - AVERAGE MONTHLY MEASUREMENTS OF ELECTRICAL CONDUCTIVITY (µS/CM)												
Sample Year	January	February	March	April	May	June	July	August	September	October	November	December
1990	784.7	738.4	621.8	619.9	678.2	574.5	479.7	502.7	466.0	655.8	735.7	812.2
1991	871.9	848.2	777.5	633.3	501.0	598.9	548.1	523.4	520.2	503.4	587.9	778.2
1992	698.5	737.6	615.9	580.5	463.4	748.9	784.3	781.6	678.4	718.7	766.6	881.1
1993	541.6	665.7	736.7	601.7	503.8	478.7	355.6	339.6	328.8	349.6	497.2	544.5
1994	581.2	415.4	602.0	496.5	590.6	680.0	582.3	547.1	601.8	473.9	681.5	678.4
1995	528.1	477.2	505.4	261.3	176.8	211.2	241.5	364.2	290.6	231.9	393.5	465.7
1996	537.6	413.0	436.7	406.6	257.7	357.0	329.9	330.5	329.1	348.2	438.8	308.1
1997	200.2	221.8	375.4	459.7	477.2	371.6	302.5	265.1	341.4	498.4	558.8	685.3
1998	515.6	419.6	437.9	286.5	256.7	183.8	186.1	297.4	272.9	268.7	385.2	
1999	476.9	291.8	364.5	418.2	353.4	359.5	279.7	281.3	423.6	458.3	524.7	668.6
2000	546.9	480.1	339.2	401.4	414.6	373.2	295.5	291.2	348.2	420.3	526.1	621.5
2001	647.4	569.2	658.4	522.3	426.4	346.5	355.0	475.4	580.0	538.1	417.2	410.1
2002	482.3	570.3	588.5	448.7	448.9	372.2	313.3	439.1	575.3	583.8	518.9	507.0
2003	533.6	524.1	574.7	458.0	467.0	266.3	237.9	270.2	344.9	505.8	497.4	633.1
2004	548.1	555.6	513.6	385.1	473.5	343.2	272.1	278.6	372.1	506.4	520.6	618.3
2005	510.1	562.9	526.0	327.0	237.6	208.8	247.4	315.5	336.2	345.4	486.7	562.2
2006	262.1	346.9	243.3	202.5	133.1	155.5	318.9	249.6	275.7	289.7	380.3	

SUMMARY OF TREND ANALYSIS RESULTS													
	Electrical Conductivity												
	January	February	March	April	May	June	July	August	September	October	November	December	All Months
Number of Observations:	17	17	17	17	17	17	17	17	17	17	17	15	202
Significance													
Alpha													
0.01	no	no	no	down	no	down	no	down	no	no	no	no	down
0.05	down	no	down	down	no	down	down	down	no	no	down	no	down
0.1	down	no	down	down	down	down	down	down	no	no	down	down	down
0.2	down	no	down	down	down	down	down	down	no	no	down	down	down

Figure 10. Trend Analysis Using Average Monthly Concentrations of Total Organic Carbon at Old River



ALL DATA



SEN'S SLOPE ESTIMATOR
OldRiver

n = 138

Slope = -0.092
units per year.

Mann Kendall
normal approx. =
-3.219

Alpha	Critical	Signif.
0.01	-2.575	Down
0.05	-1.96	Down
0.1	-1.645	Down
0.2	-1.282	Down

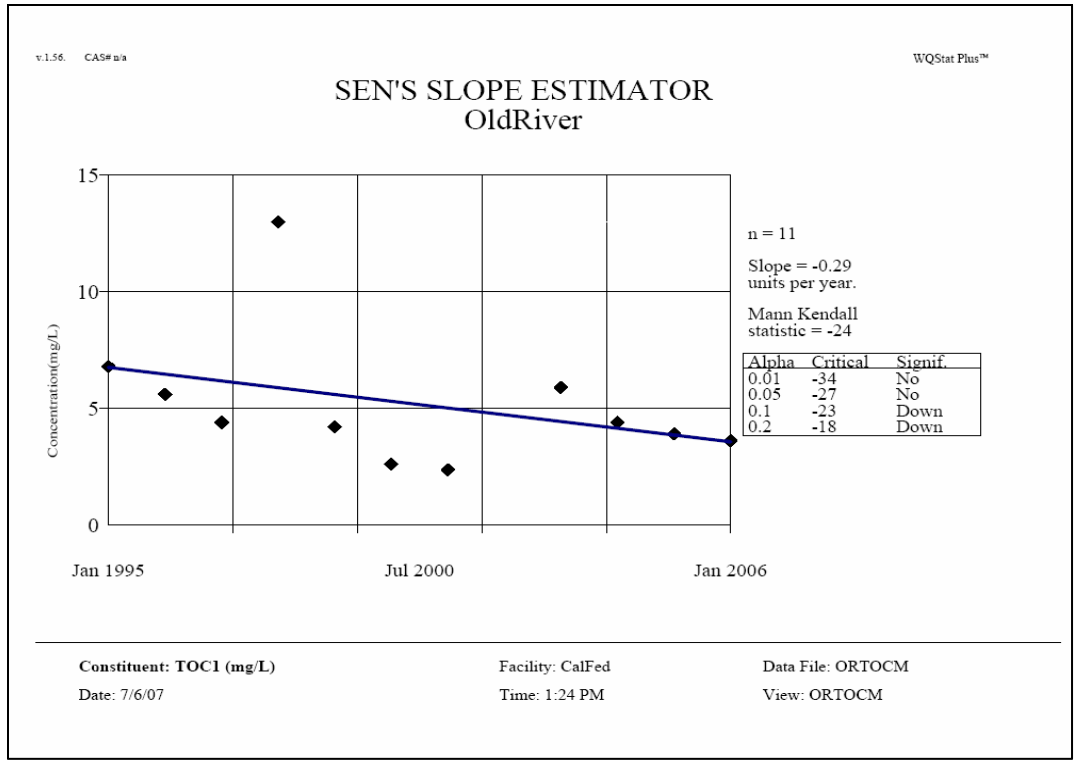
Constituent: TOC (mg/L)
Date: 7/6/07

Facility: CalFed
Time: 1:22 PM

Data File: ORTOCA
View: ORTOCA

Figure 10. Trend Analysis Using Average Monthly Concentrations of Total Organic Carbon at Old River

JANUARY



SEN'S SLOPE ESTIMATOR
OldRiver

n = 11

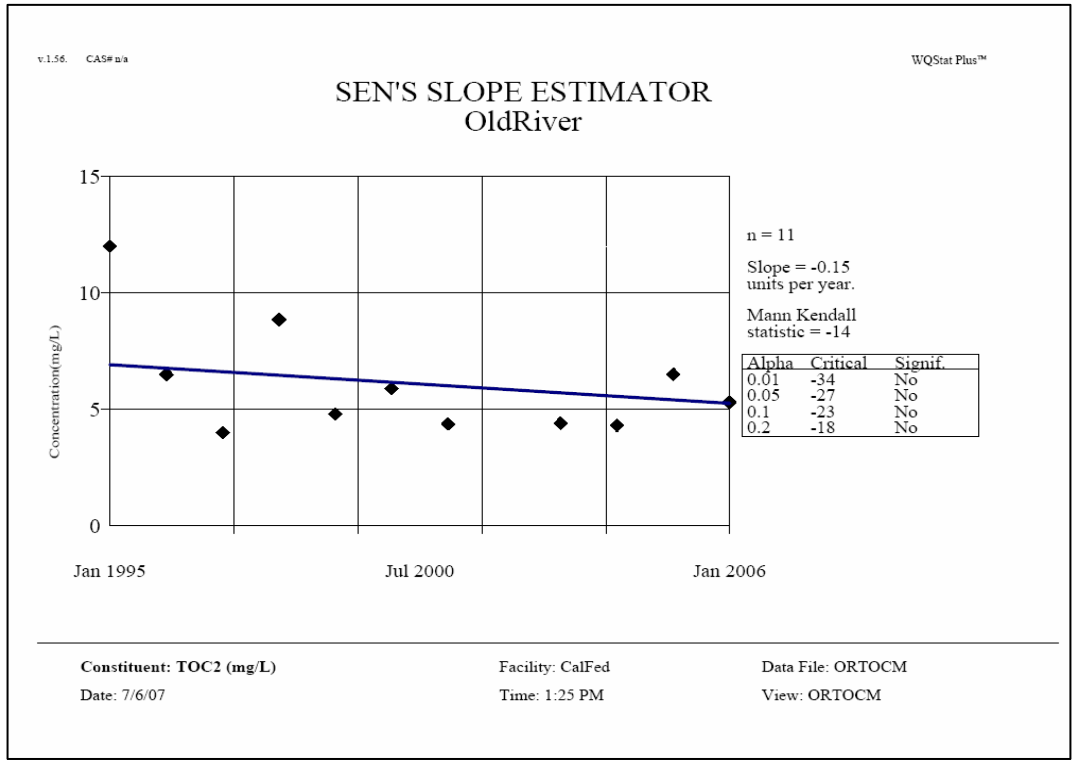
Slope = -0.29
units per year.

Mann Kendall
statistic = -24

Alpha	Critical	Signif.
0.01	-34	No
0.05	-27	No
0.1	-23	Down
0.2	-18	Down

Constituent: TOC1 (mg/L)   Facility: CalFed   Data File: ORTOCM
Date: 7/6/07   Time: 1:24 PM   View: ORTOCM

FEBRUARY



SEN'S SLOPE ESTIMATOR
OldRiver

n = 11

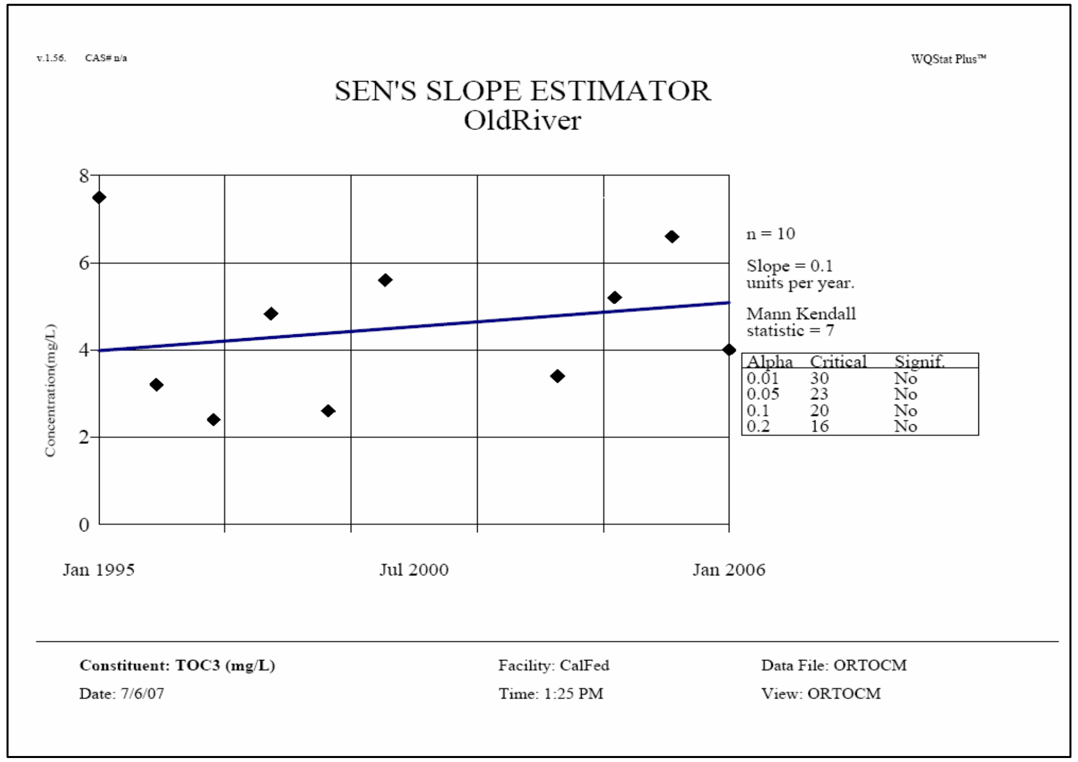
Slope = -0.15
units per year.

Mann Kendall
statistic = -14

Alpha	Critical	Signif.
0.01	-34	No
0.05	-27	No
0.1	-23	No
0.2	-18	No

Constituent: TOC2 (mg/L)   Facility: CalFed   Data File: ORTOCM
Date: 7/6/07   Time: 1:25 PM   View: ORTOCM

MARCH



SEN'S SLOPE ESTIMATOR
OldRiver

n = 10

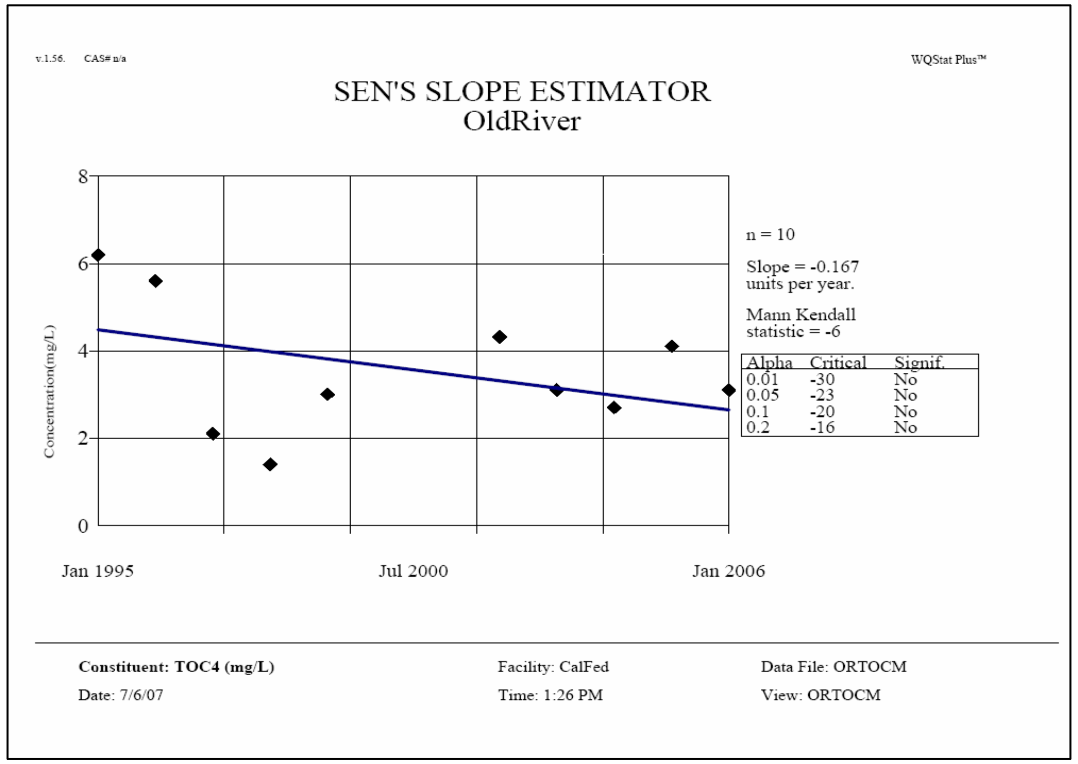
Slope = 0.1
units per year.

Mann Kendall
statistic = 7

Alpha	Critical	Signif.
0.01	30	No
0.05	23	No
0.1	20	No
0.2	16	No

Constituent: TOC3 (mg/L)   Facility: CalFed   Data File: ORTOCM
Date: 7/6/07   Time: 1:25 PM   View: ORTOCM

APRIL



SEN'S SLOPE ESTIMATOR
OldRiver

n = 10

Slope = -0.167
units per year.

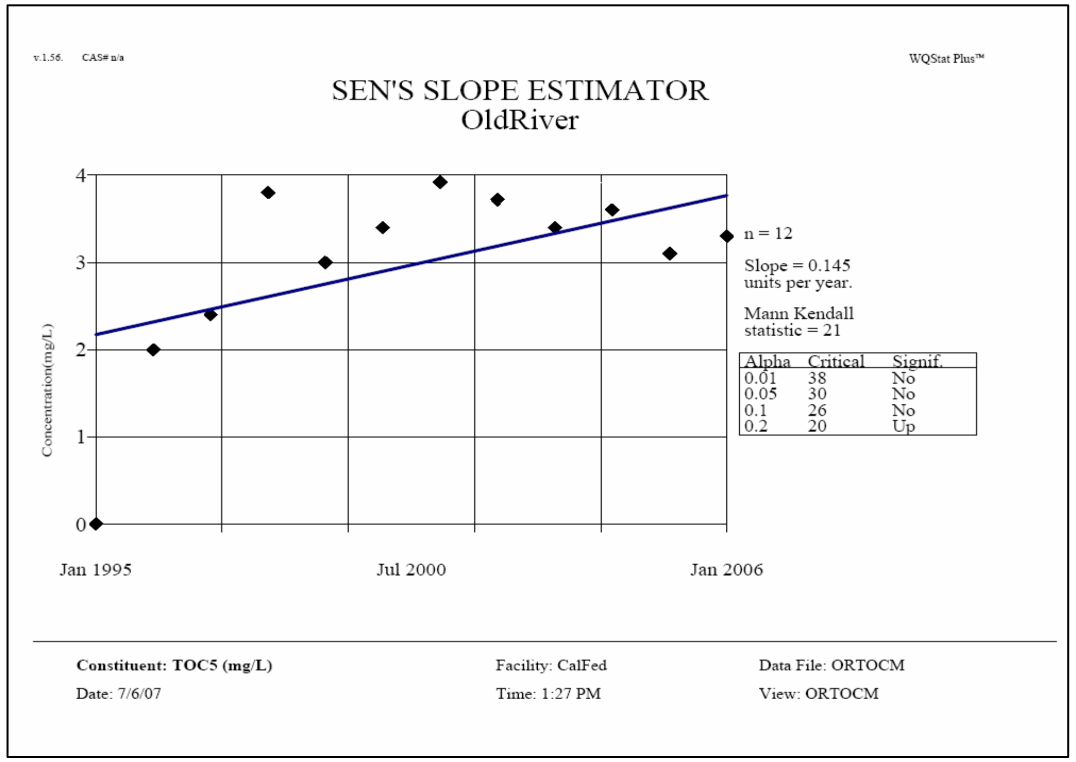
Mann Kendall
statistic = -6

Alpha	Critical	Signif.
0.01	-30	No
0.05	-23	No
0.1	-20	No
0.2	-16	No

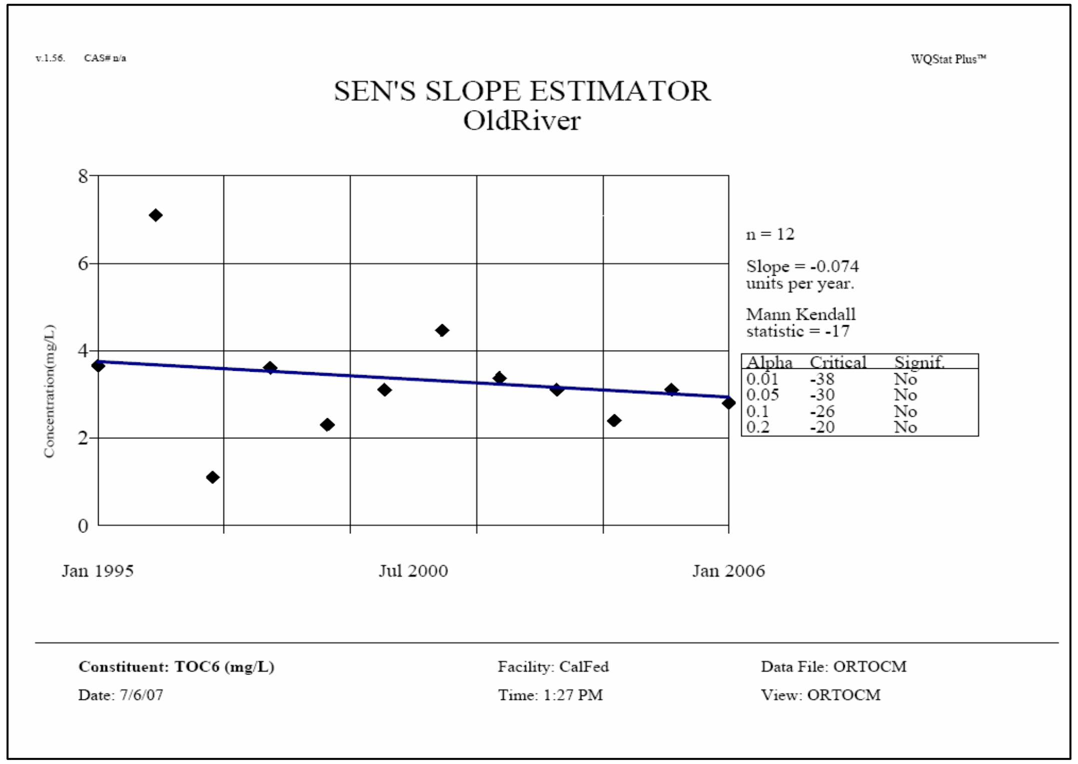
Constituent: TOC4 (mg/L)   Facility: CalFed   Data File: ORTOCM
Date: 7/6/07   Time: 1:26 PM   View: ORTOCM

Figure 10. Trend Analysis Using Average Monthly Concentrations of Total Organic Carbon at Old River

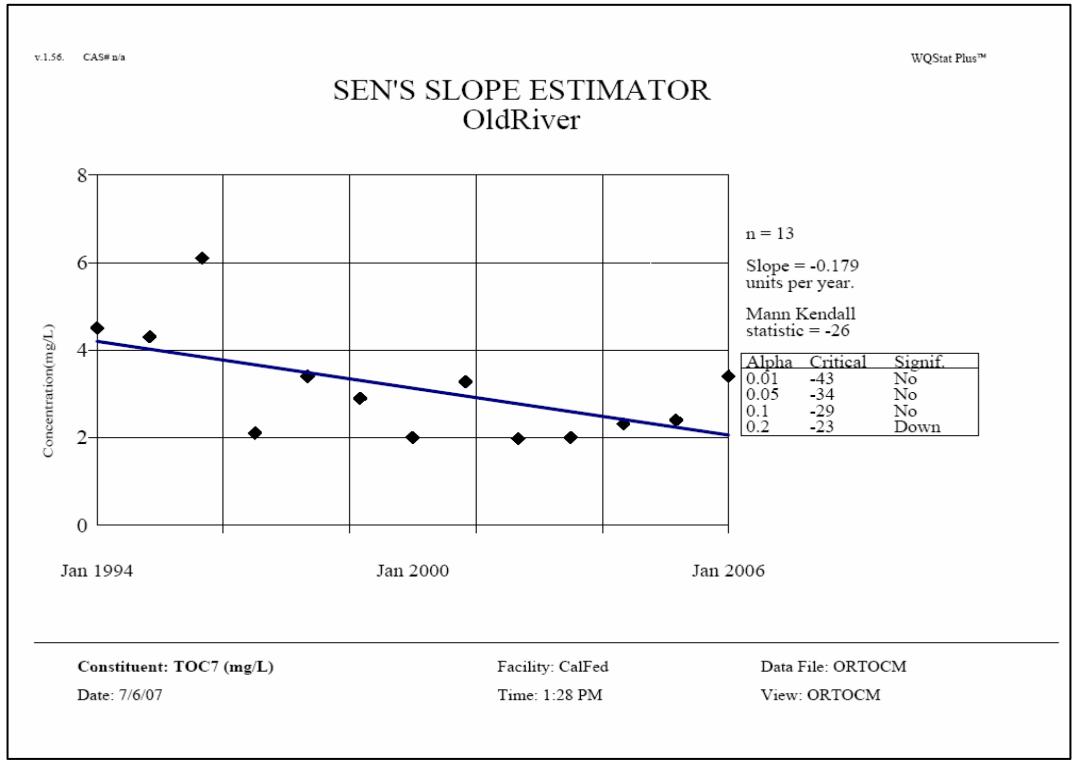
MAY



JUNE



JULY



AUGUST

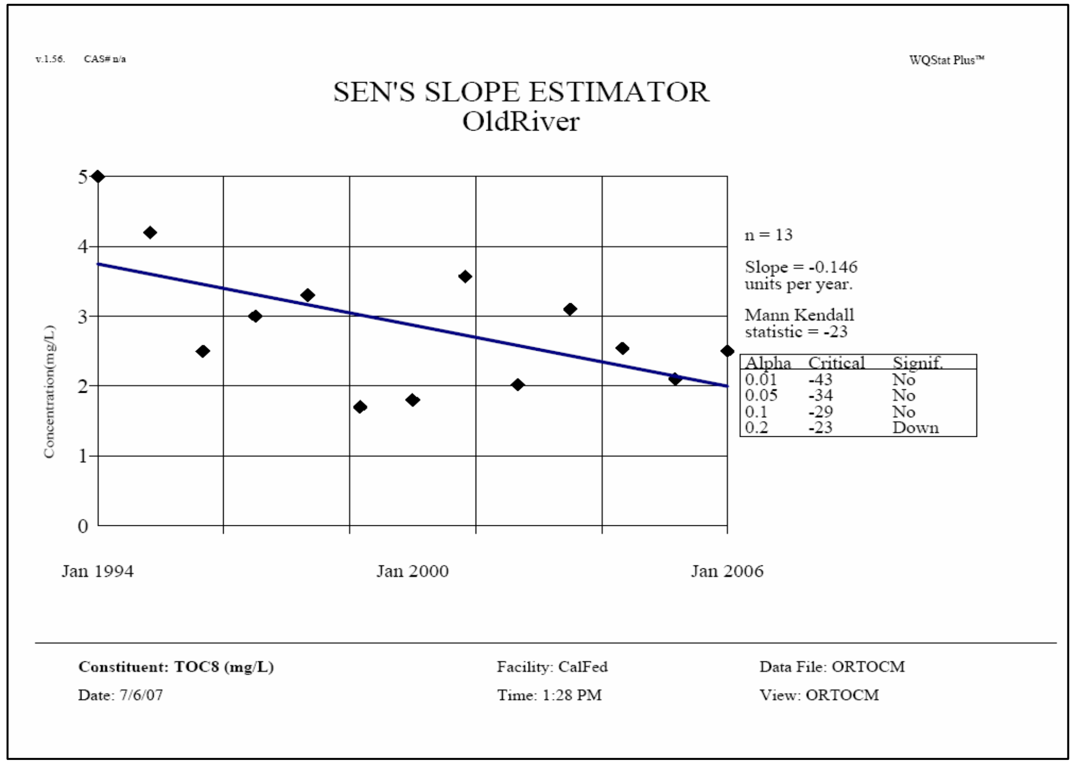
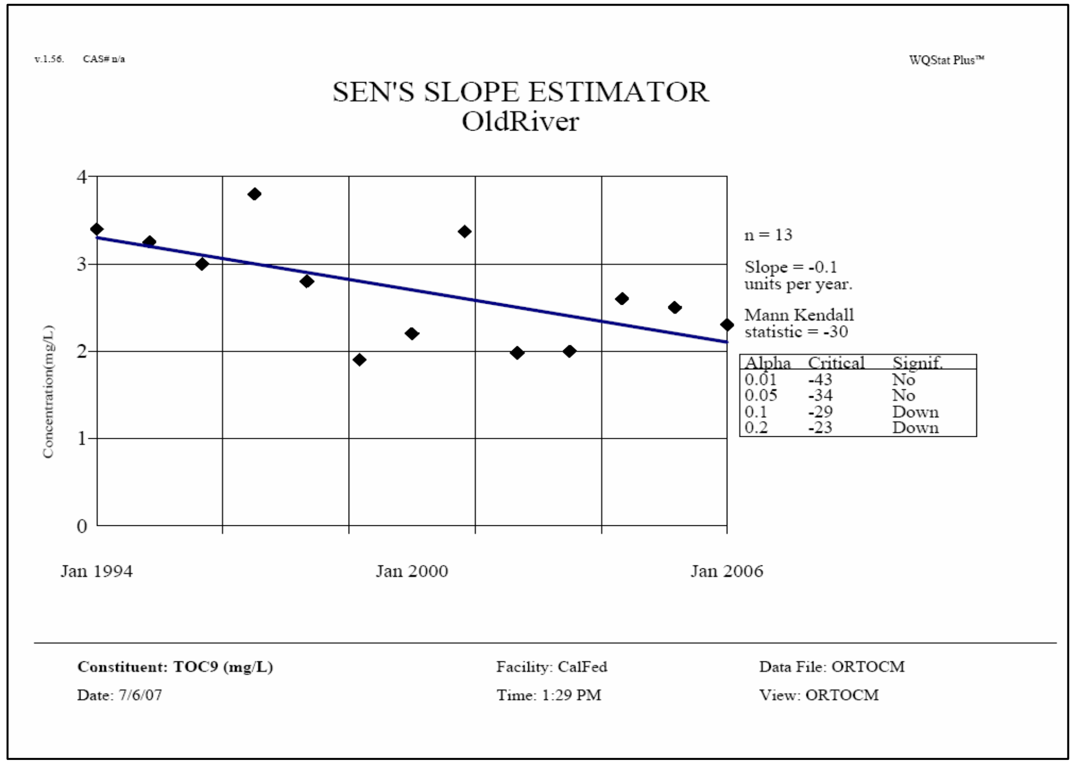
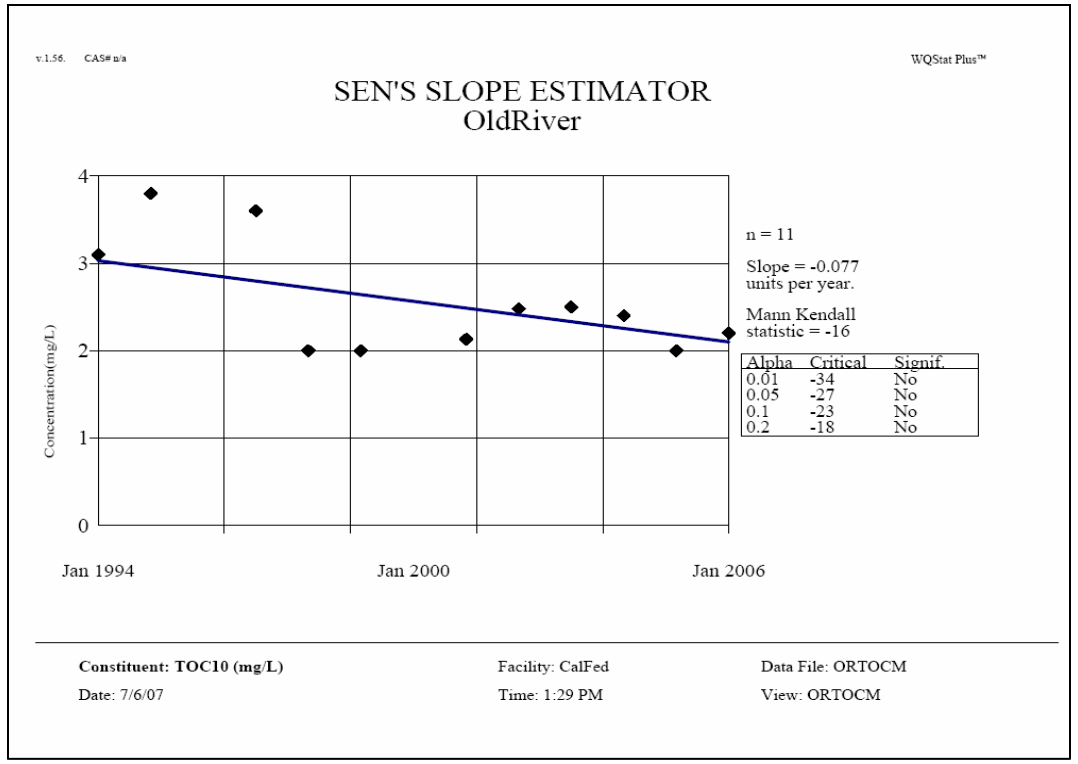


Figure 10. Trend Analysis Using Average Monthly Concentrations of Total Organic Carbon at Old River

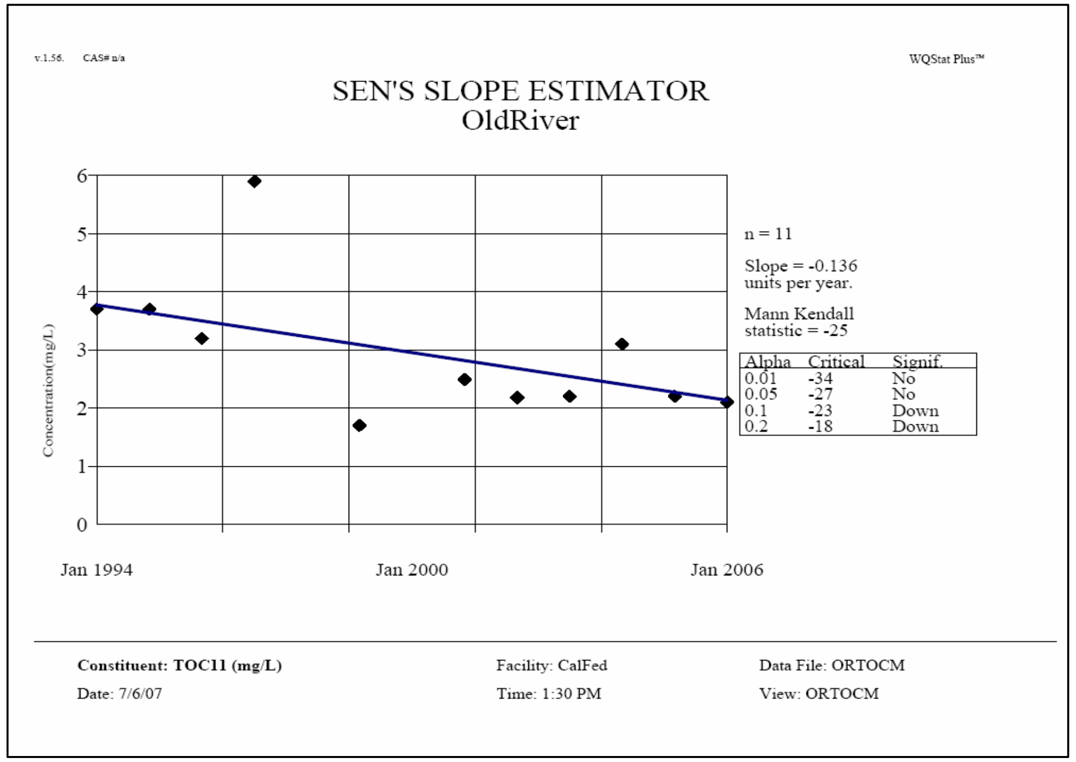
SEPTEMBER



OCTOBER



NOVEMBER



DECEMBER

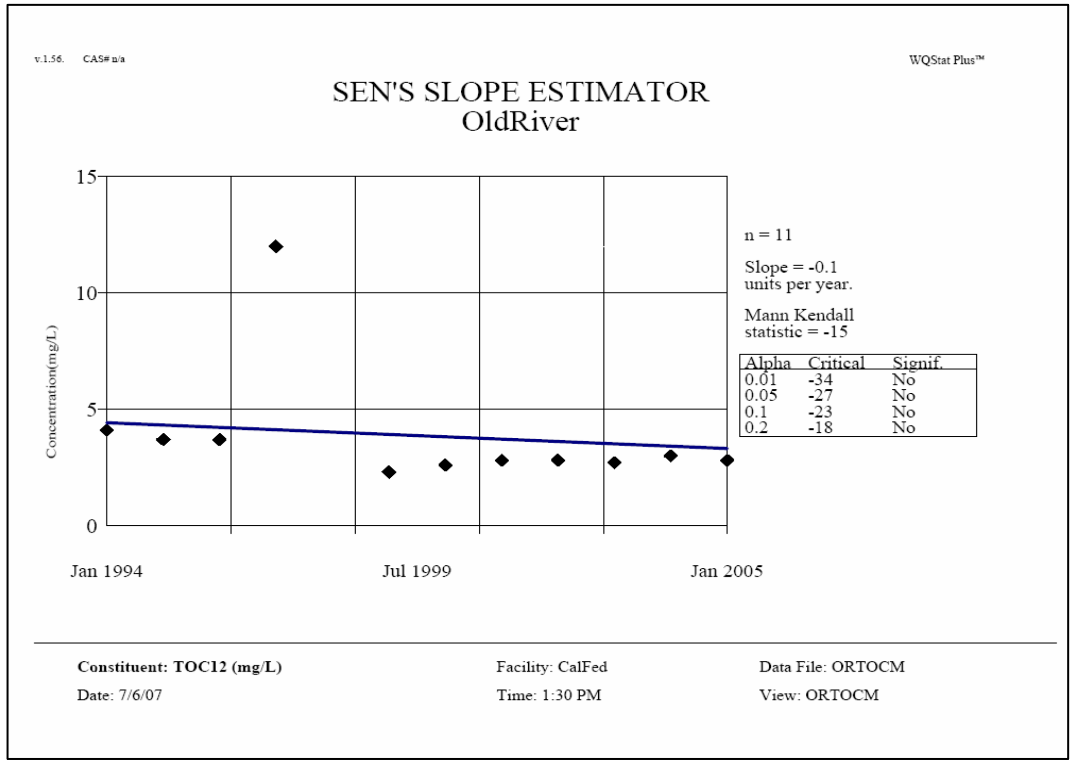


Figure 10. Trend Analysis Using Average Monthly Concentrations of Total Organic Carbon at Old River

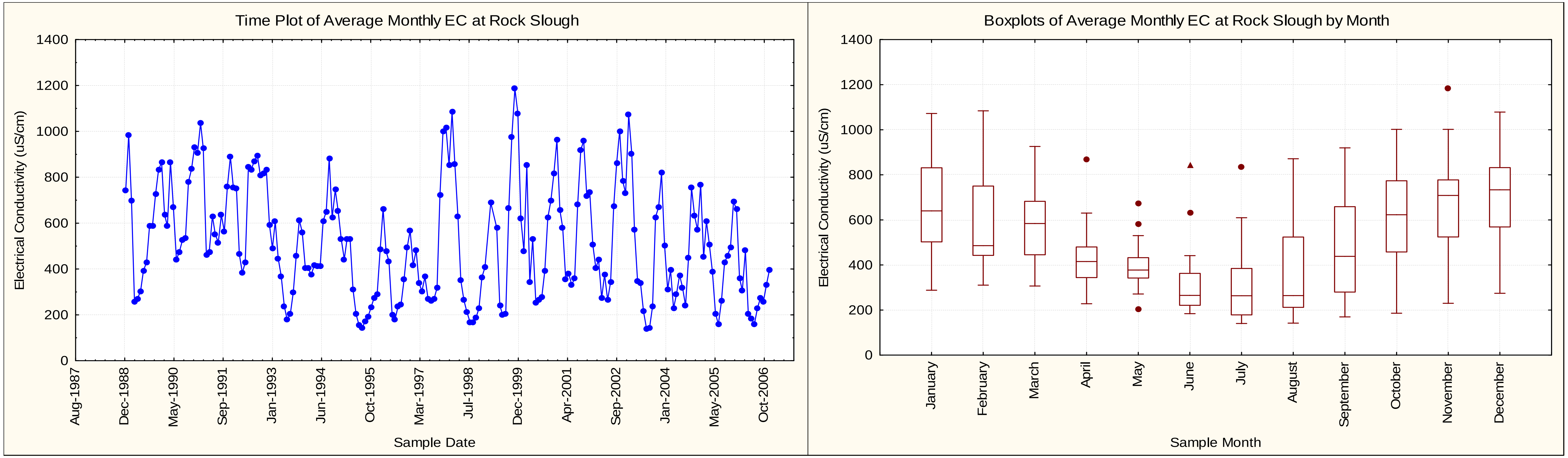
DATA USED IN TREND ANALYSIS - AVERAGE MONTHLY CONCENTRATIONS OF TOTAL ORGANIC CARBON (MG/L)

Sample Year	January	February	March	April	May	June	July	August	September	October	November	December
1994							4.50	5.00	3.40	3.10	3.70	4.10
1995	6.80	12.00	7.50	6.20	0.00	3.65	4.30	4.20	3.25	3.80	3.70	3.70
1996	5.60	6.50	3.20	5.60	2.00	7.10	6.10	2.50	3.00		3.20	3.70
1997	4.40	4.00	2.40	2.10	2.40	1.10	2.10	3.00	3.80	3.60	5.90	12.00
1998	13.00	8.85	4.83	1.40	3.80	3.60	3.40	3.30	2.80	2.00		
1999	4.20	4.80	2.60	3.00	3.00	2.30	2.90	1.70	1.90	2.00	1.70	2.30
2000	2.60	5.90	5.60		3.40	3.10	2.00	1.80	2.20			2.60
2001	2.36	4.36			3.92	4.46	3.27	3.57	3.37	2.13	2.49	2.80
2002				4.32	3.72	3.37	1.97	2.02	1.98	2.48	2.18	2.80
2003	5.90	4.40	3.40	3.10	3.40	3.10	2.00	3.10	2.00	2.50	2.20	2.70
2004	4.40	4.30	5.20	2.70	3.60	2.40	2.31	2.54	2.60	2.40	3.10	3.00
2005	3.90	6.50	6.60	4.10	3.10	3.10	2.40	2.10	2.50	2.00	2.20	2.80
2006	3.60	5.30	4.00	3.10	3.30	2.80	3.40	2.50	2.30	2.20	2.10	

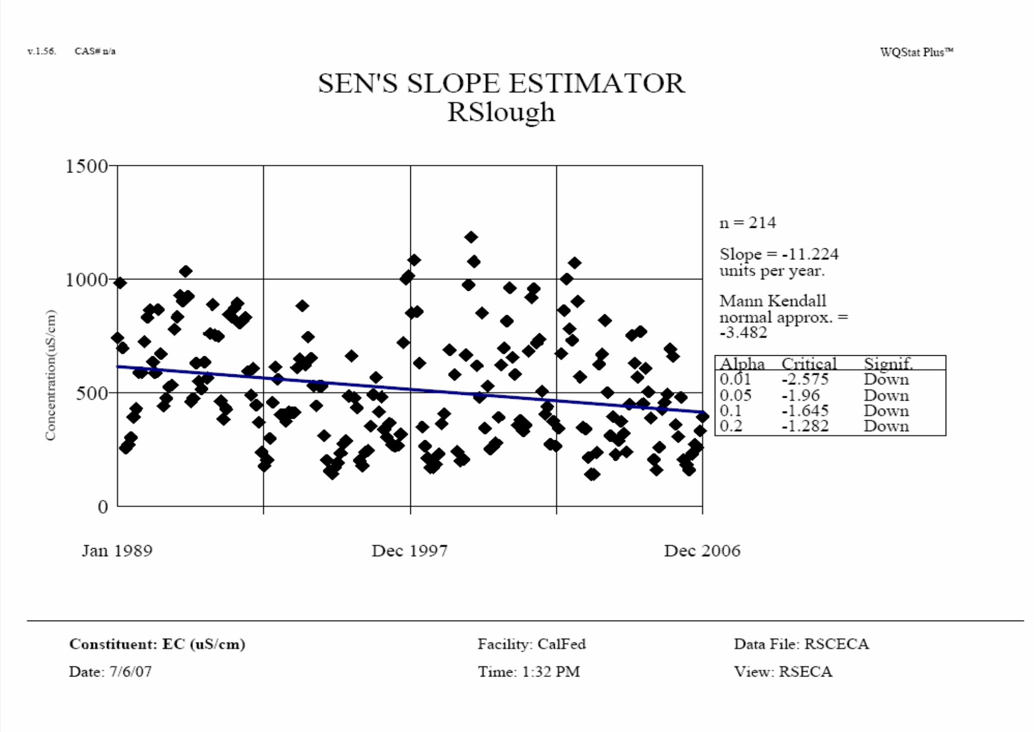
SUMMARY OF TREND ANALYSIS RESULTS

	Total Organic Carbon												
	January	February	March	April	May	June	July	August	September	October	November	December	All Months
Number of Observations:	11	11	10	10	12	12	13	13	13	11	11	11	138
Significance													
Alpha													
0.01	no	no	no	no	no	no	no	no	no	no	no	no	down
0.05	no	no	no	no	no	no	no	no	no	no	no	no	down
0.1	down	no	no	no	no	no	no	no	down	no	down	no	down
0.2	down	no	no	no	up	no	down	down	down	no	down	no	down

Figure 11. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Rock Slough



ALL DATA



SEN'S SLOPE ESTIMATOR
RSlough

n = 214

Slope = -11.224
units per year.

Mann Kendall
normal approx. =
-3.482

Alpha	Critical	Signif.
0.01	-2.575	Down
0.05	-1.96	Down
0.1	-1.645	Down
0.2	-1.282	Down

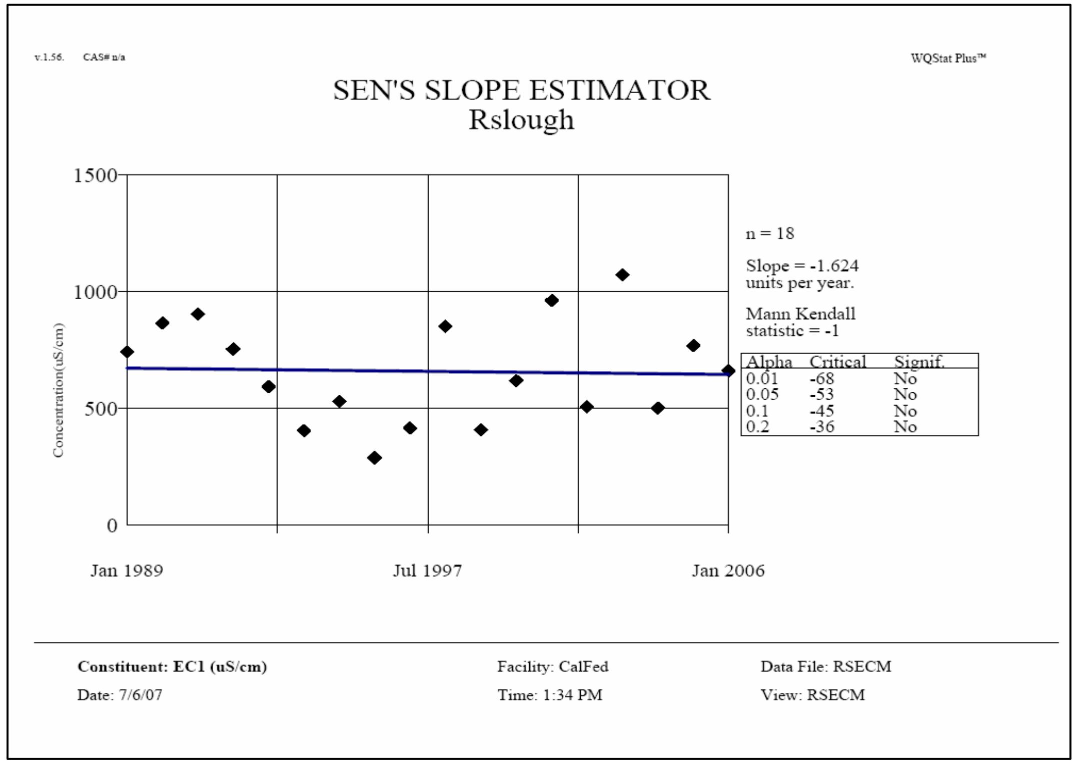
Constituent: EC (uS/cm)
Date: 7/6/07

Facility: CalFed
Time: 1:32 PM

Data File: RSCECA
View: RSECA

Figure 11. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Rock Slough

JANUARY



n = 18

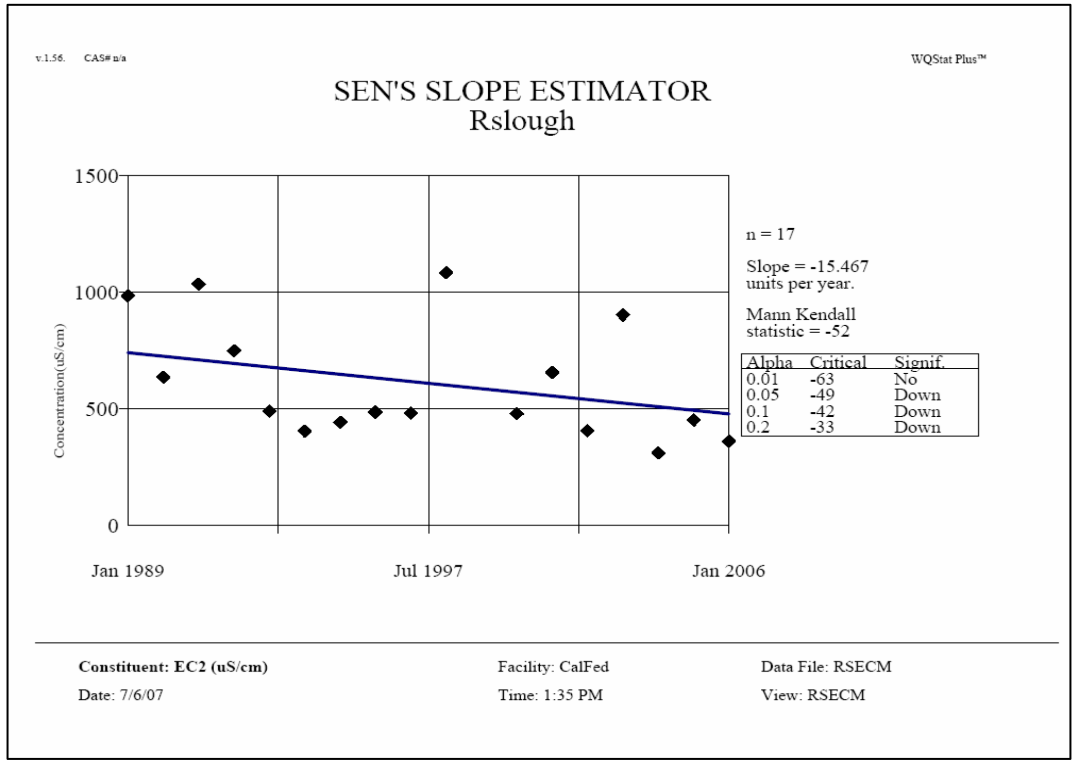
Slope = -1.624
units per year.

Mann Kendall
statistic = -1

Alpha	Critical	Signif.
0.01	-68	No
0.05	-53	No
0.1	-45	No
0.2	-36	No

Constituent: EC1 (uS/cm) Facility: CalFed Data File: RSECM
Date: 7/6/07 Time: 1:34 PM View: RSECM

FEBRUARY



n = 17

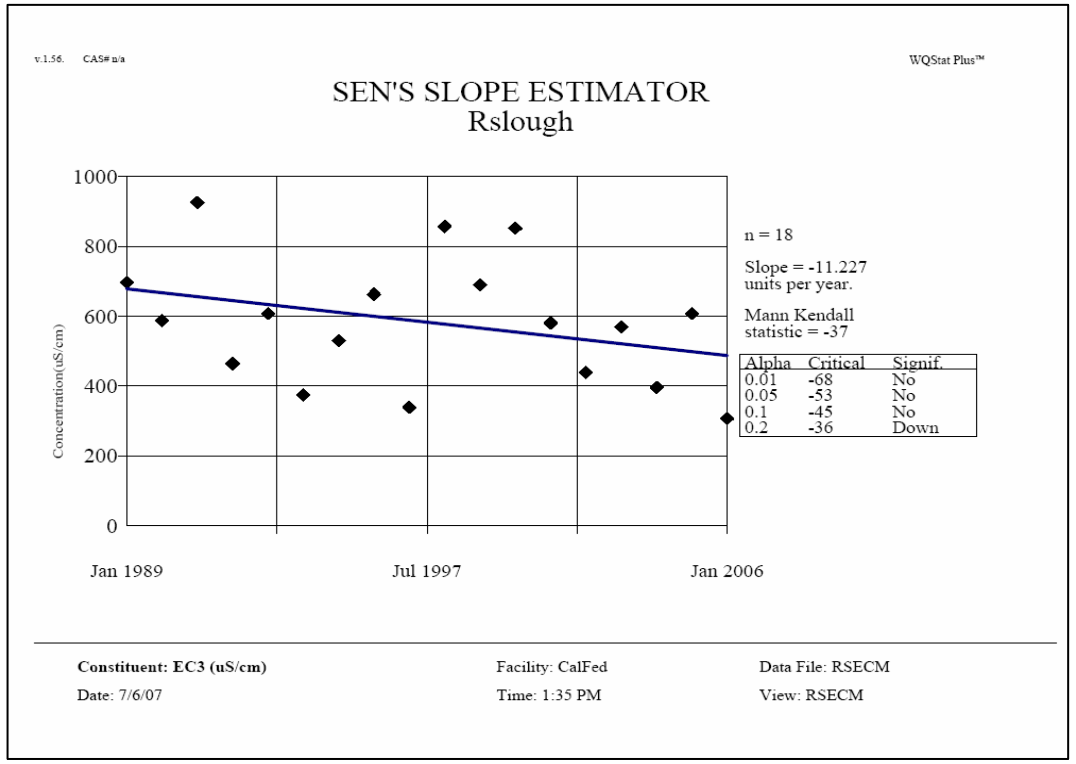
Slope = -15.467
units per year.

Mann Kendall
statistic = -52

Alpha	Critical	Signif.
0.01	-63	No
0.05	-49	Down
0.1	-42	Down
0.2	-33	Down

Constituent: EC2 (uS/cm) Facility: CalFed Data File: RSECM
Date: 7/6/07 Time: 1:35 PM View: RSECM

MARCH



n = 18

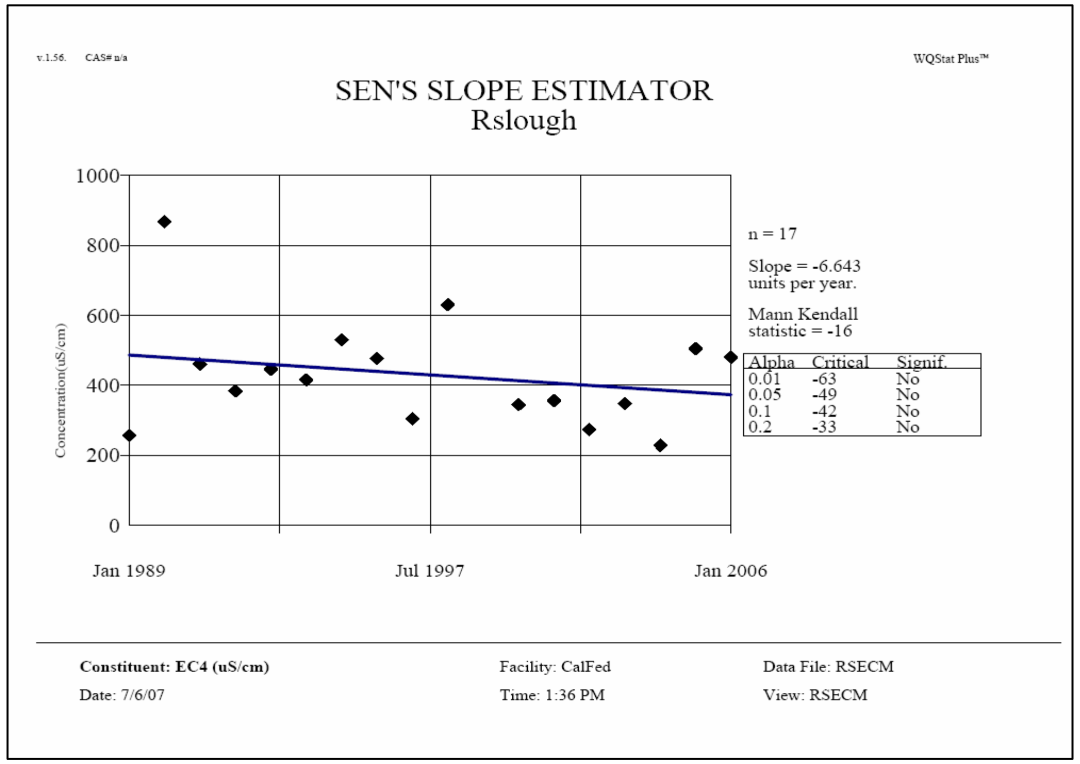
Slope = -11.227
units per year.

Mann Kendall
statistic = -37

Alpha	Critical	Signif.
0.01	-68	No
0.05	-53	No
0.1	-45	No
0.2	-36	Down

Constituent: EC3 (uS/cm) Facility: CalFed Data File: RSECM
Date: 7/6/07 Time: 1:35 PM View: RSECM

APRIL



n = 17

Slope = -6.643
units per year.

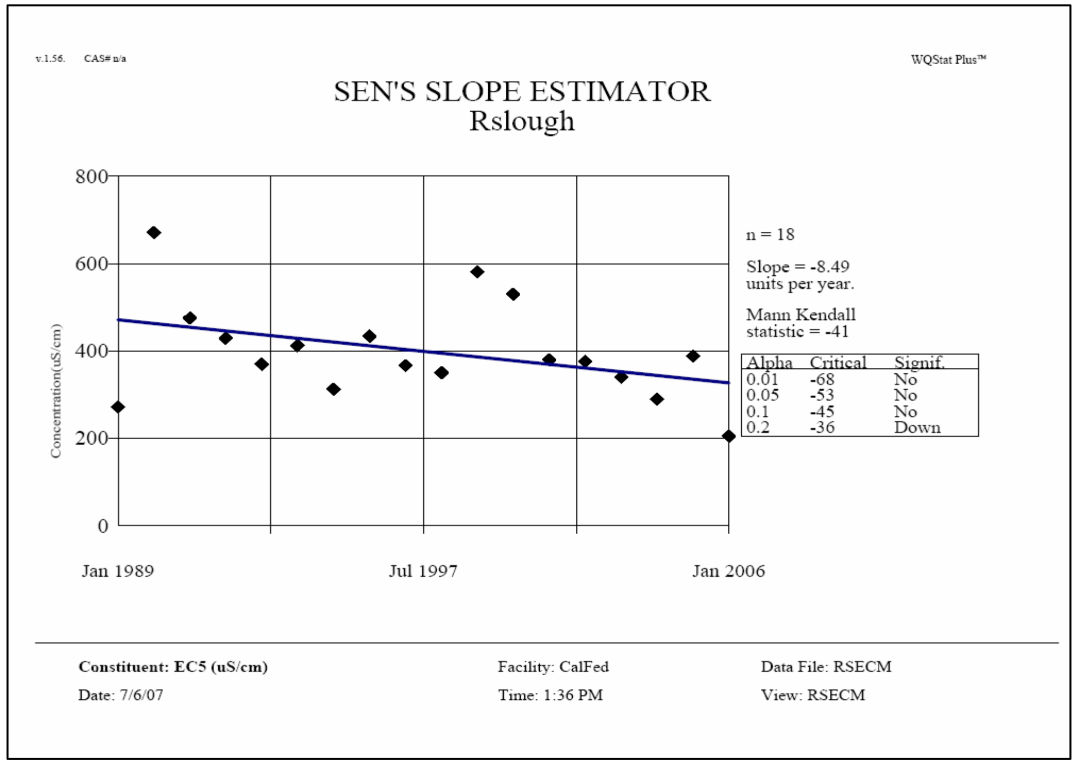
Mann Kendall
statistic = -16

Alpha	Critical	Signif.
0.01	-63	No
0.05	-49	No
0.1	-42	No
0.2	-33	No

Constituent: EC4 (uS/cm) Facility: CalFed Data File: RSECM
Date: 7/6/07 Time: 1:36 PM View: RSECM

Figure 11. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Rock Slough

MAY



n = 18

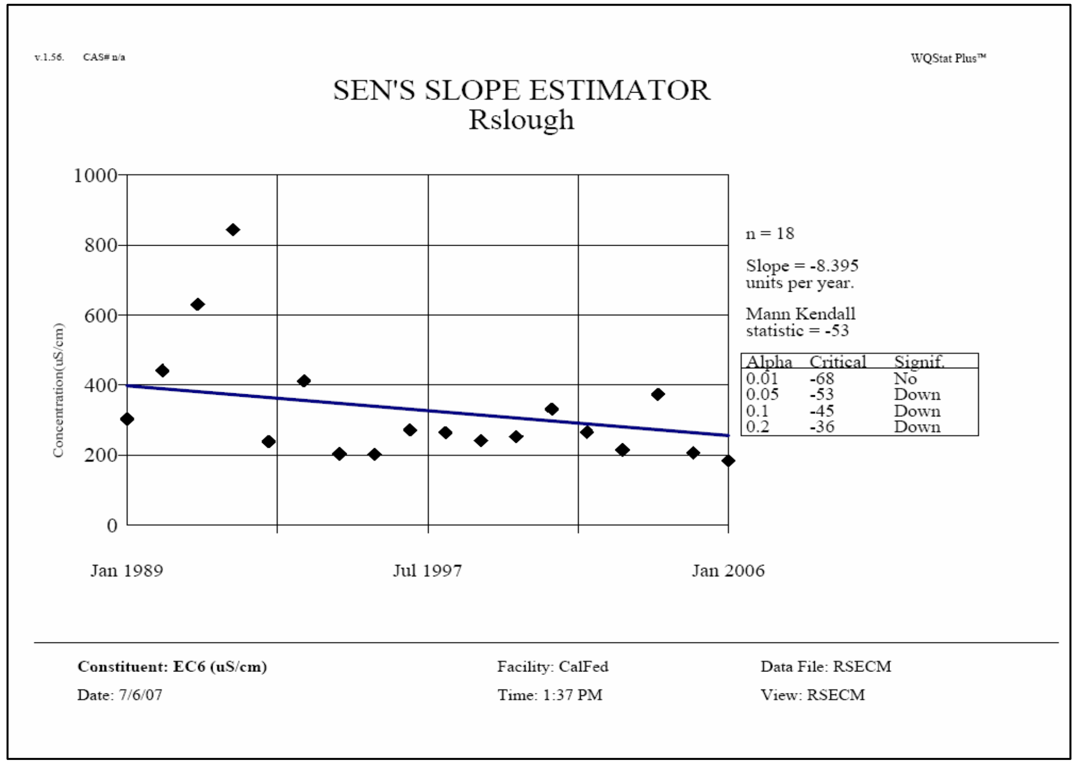
Slope = -8.49
units per year.

Mann Kendall
statistic = -41

Alpha	Critical	Signif.
0.01	-68	No
0.05	-53	No
0.1	-45	No
0.2	-36	Down

Constituent: EC5 (uS/cm) Facility: CalFed Data File: RSECM
Date: 7/6/07 Time: 1:36 PM View: RSECM

JUNE



n = 18

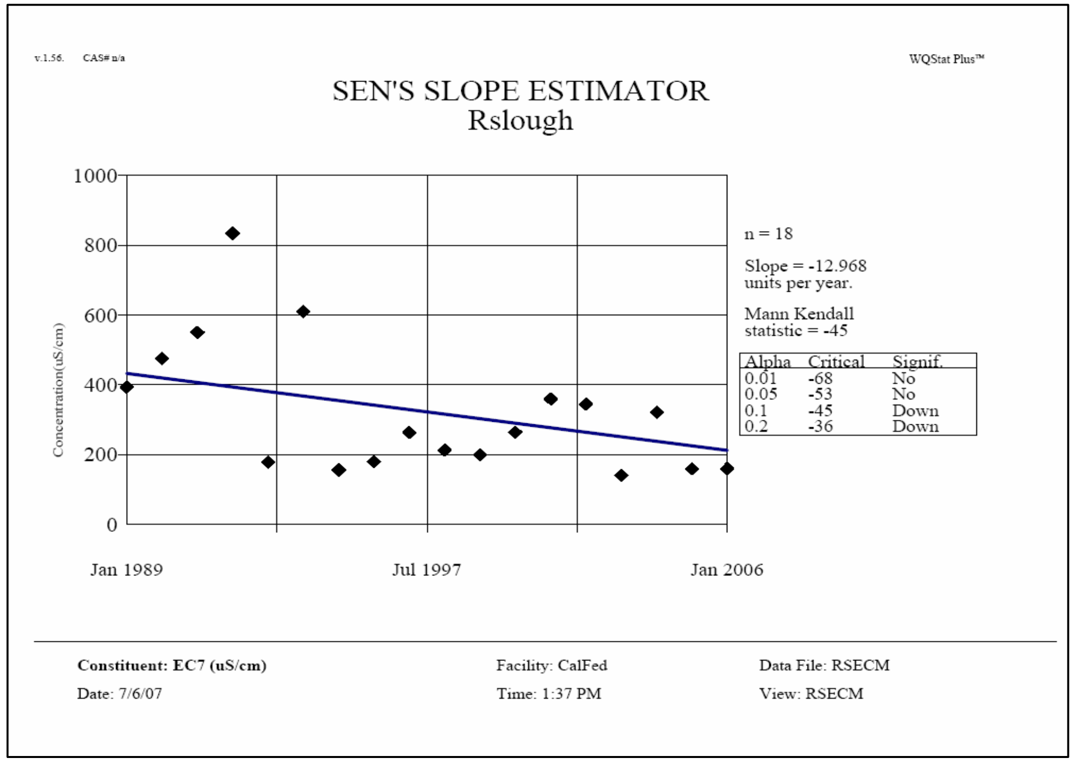
Slope = -8.395
units per year.

Mann Kendall
statistic = -53

Alpha	Critical	Signif.
0.01	-68	No
0.05	-53	Down
0.1	-45	Down
0.2	-36	Down

Constituent: EC6 (uS/cm) Facility: CalFed Data File: RSECM
Date: 7/6/07 Time: 1:37 PM View: RSECM

JULY



n = 18

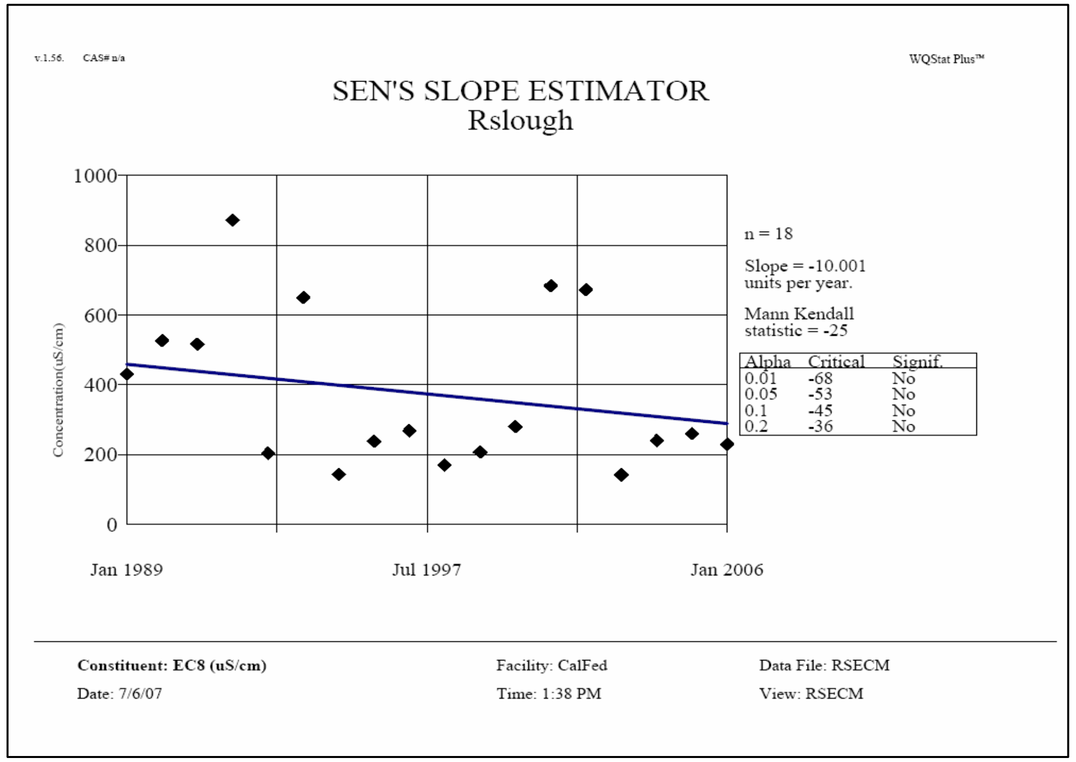
Slope = -12.968
units per year.

Mann Kendall
statistic = -45

Alpha	Critical	Signif.
0.01	-68	No
0.05	-53	No
0.1	-45	Down
0.2	-36	Down

Constituent: EC7 (uS/cm) Facility: CalFed Data File: RSECM
Date: 7/6/07 Time: 1:37 PM View: RSECM

AUGUST



n = 18

Slope = -10.001
units per year.

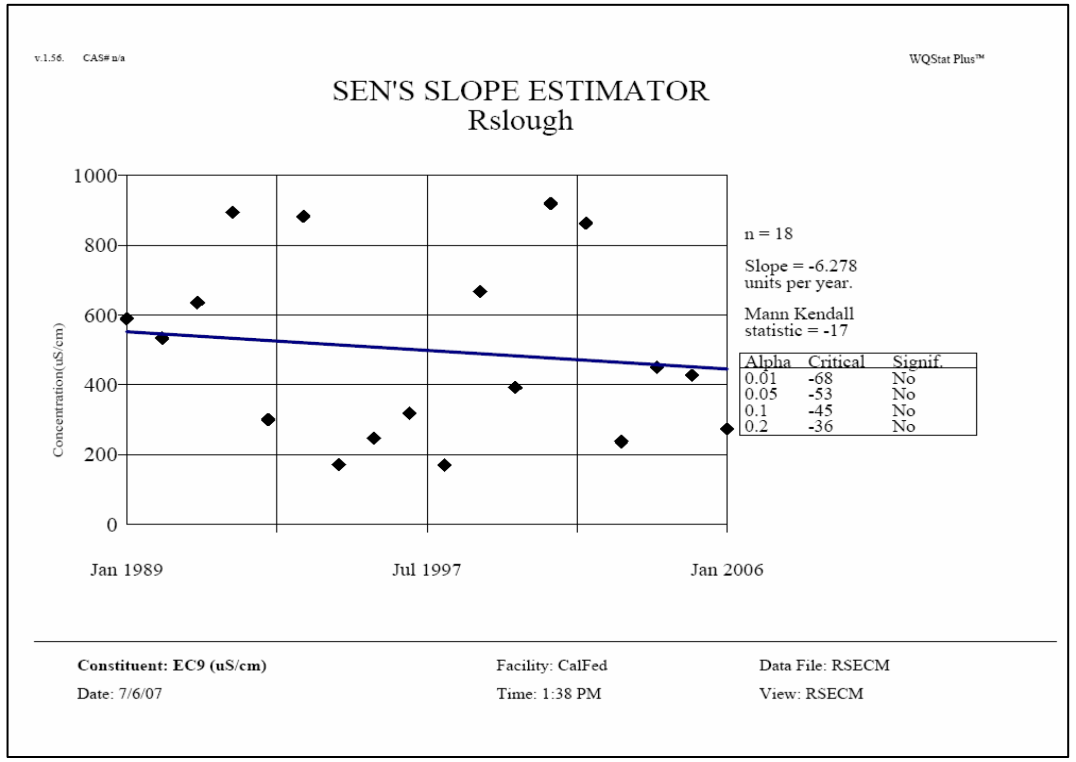
Mann Kendall
statistic = -25

Alpha	Critical	Signif.
0.01	-68	No
0.05	-53	No
0.1	-45	No
0.2	-36	No

Constituent: EC8 (uS/cm) Facility: CalFed Data File: RSECM
Date: 7/6/07 Time: 1:38 PM View: RSECM

Figure 11. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Rock Slough

SEPTEMBER



n = 18

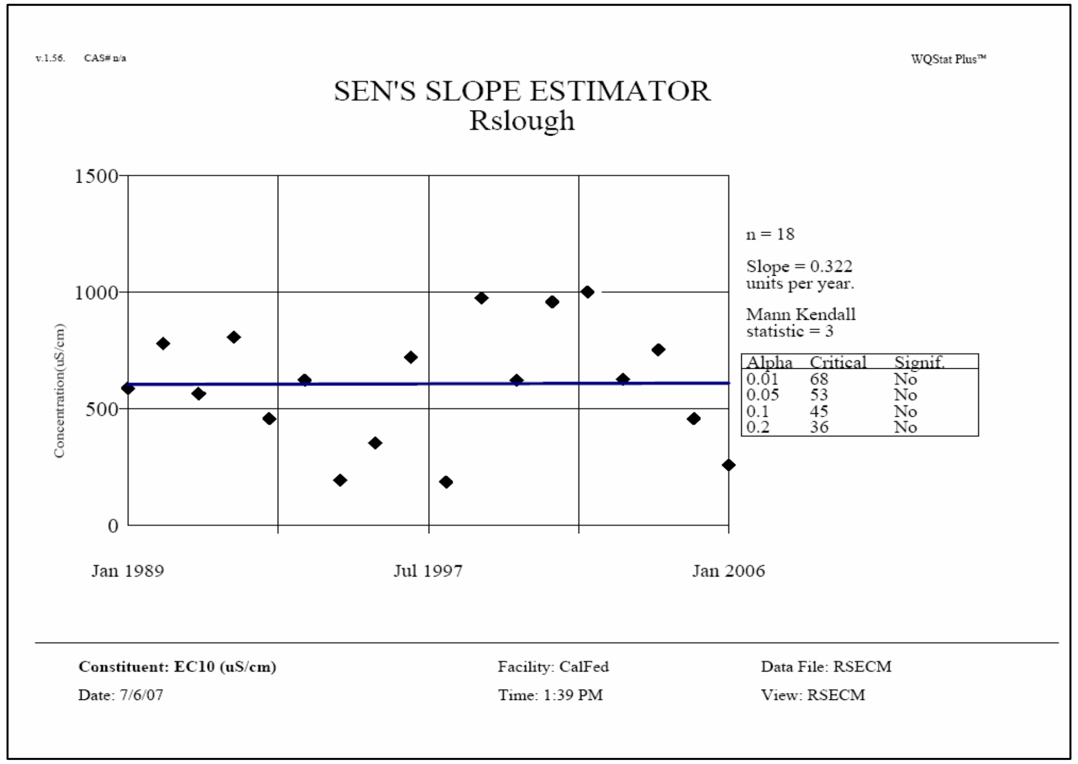
Slope = -6.278 units per year.

Mann Kendall statistic = -17

Alpha	Critical	Signif.
0.01	-68	No
0.05	-53	No
0.1	-45	No
0.2	-36	No

Constituent: EC9 (uS/cm) Facility: CalFed Data File: RSECM
Date: 7/6/07 Time: 1:38 PM View: RSECM

OCTOBER



n = 18

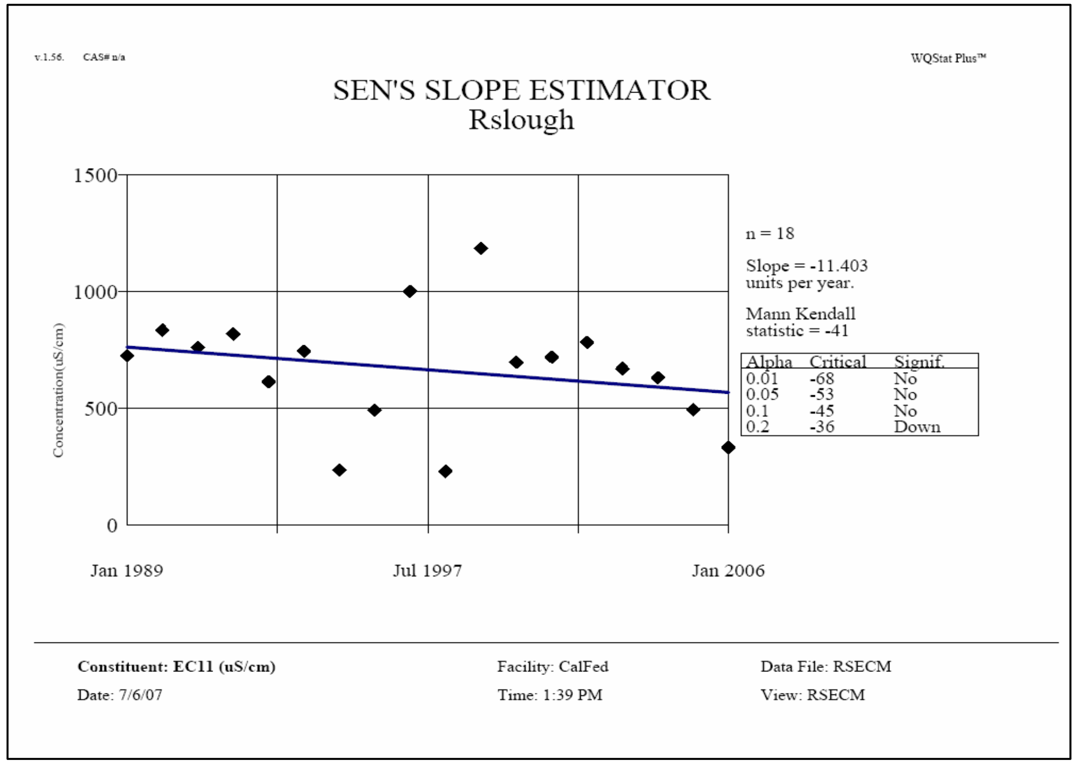
Slope = 0.322 units per year.

Mann Kendall statistic = 3

Alpha	Critical	Signif.
0.01	68	No
0.05	53	No
0.1	45	No
0.2	36	No

Constituent: EC10 (uS/cm) Facility: CalFed Data File: RSECM
Date: 7/6/07 Time: 1:39 PM View: RSECM

NOVEMBER



n = 18

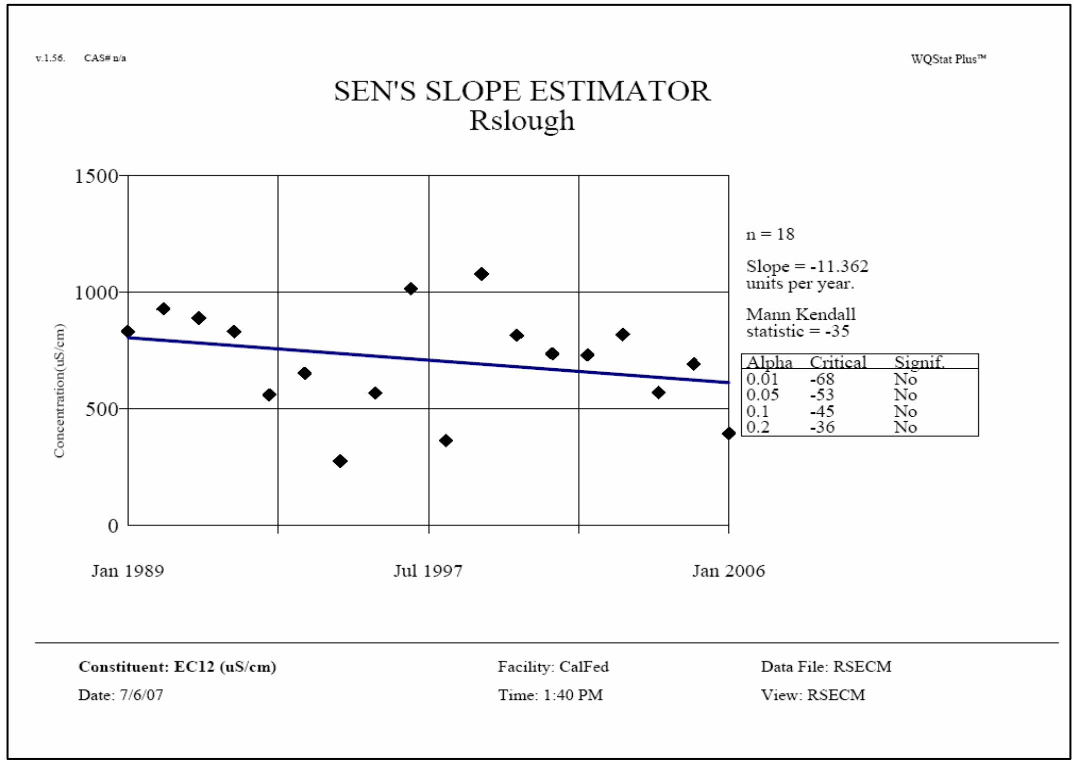
Slope = -11.403 units per year.

Mann Kendall statistic = -41

Alpha	Critical	Signif.
0.01	-68	No
0.05	-53	No
0.1	-45	No
0.2	-36	Down

Constituent: EC11 (uS/cm) Facility: CalFed Data File: RSECM
Date: 7/6/07 Time: 1:39 PM View: RSECM

DECEMBER



n = 18

Slope = -11.362 units per year.

Mann Kendall statistic = -35

Alpha	Critical	Signif.
0.01	-68	No
0.05	-53	No
0.1	-45	No
0.2	-36	No

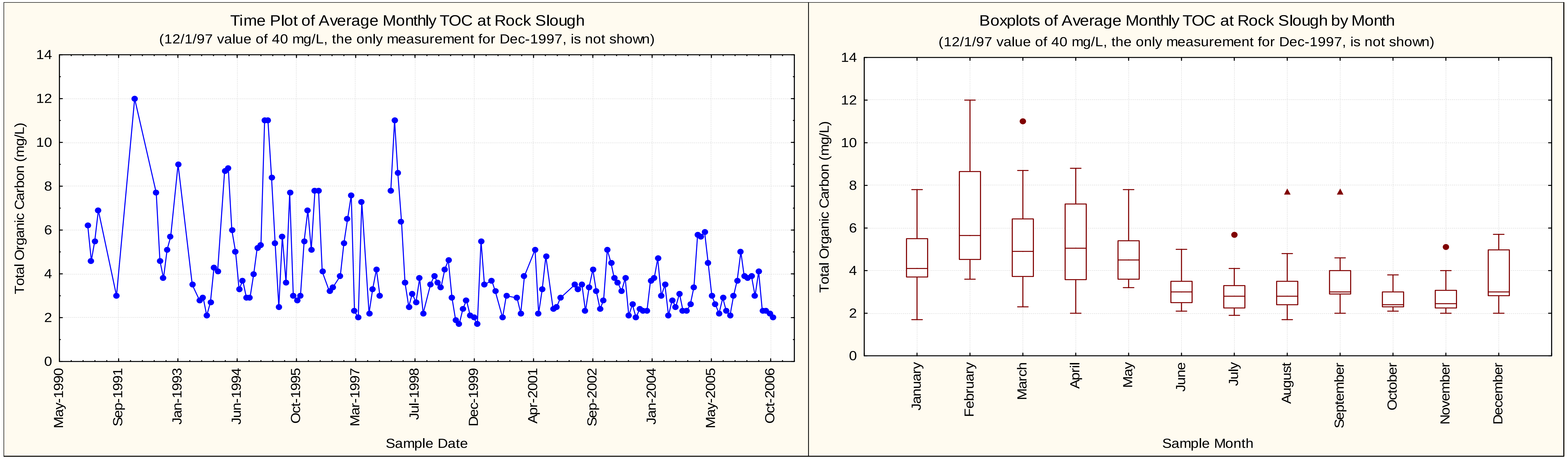
Constituent: EC12 (uS/cm) Facility: CalFed Data File: RSECM
Date: 7/6/07 Time: 1:40 PM View: RSECM

Figure 11. Trend Analysis Using Average Monthly Measurements of Electrical Conductivity at Rock Slough

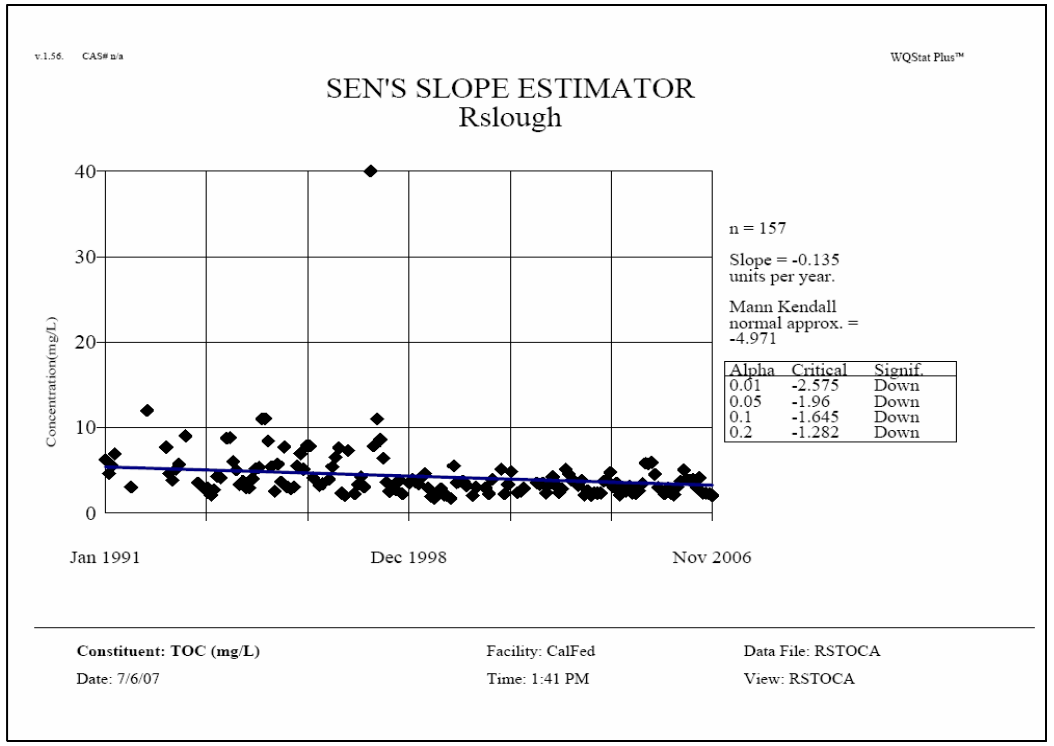
DATA USED IN TREND ANALYSIS - AVERAGE MONTHLY MEASUREMENTS OF ELECTRICAL CONDUCTIVITY (µS/CM)												
Sample Year	January	February	March	April	May	June	July	August	September	October	November	December
1989	742.6	984.9	697.3	256.0	271.1	302.9	393.0	430.0	589.4	588.2	725.3	832.1
1990	864.9	635.5	587.5	867.6	671.6	441.6	475.2	526.5	533.6	780.2	835.1	929.1
1991	904.6	1035.8	925.9	460.4	475.4	630.4	550.2	516.5	635.2	564.4	761.2	889.3
1992	754.4	750.3	463.8	383.6	428.8	843.7	834.3	871.4	895.1	807.4	818.5	831.7
1993	593.0	490.1	607.6	446.0	369.4	238.4	178.0	203.8	299.8	457.9	614.3	560.0
1994	404.2	404.1	374.1	415.5	411.8	412.1	609.9	649.8	882.8	623.3	745.2	652.5
1995	530.8	442.6	530.3	529.7	311.9	202.9	155.6	143.2	171.1	192.0	234.2	274.6
1996	287.9	485.8	662.8	477.5	433.7	201.2	179.3	237.5	246.6	354.2	492.1	568.4
1997	416.0	481.8	339.2	304.0	366.2	271.1	263.1	268.5	317.6	721.9	1001.8	1015.8
1998	851.9	1084.0	857.0	630.0	349.8	264.4	212.5	169.5	169.5	185.9	229.9	363.7
1999	408.0		689.3		580.5	240.6	199.4	206.3	666.7	975.9	1186.1	1078.8
2000	618.7	478.8	851.9	343.9	530.1	252.4	263.7	279.4	392.4	622.8	697.4	815.4
2001	961.9	656.0	580.2	356.1	379.6	331.2	359.5	683.6	919.7	958.5	719.8	736.7
2002	505.9	405.4	439.1	273.5	375.6	265.5	344.0	672.2	863.1	1001.9	782.9	730.4
2003	1072.4	902.9	570.0	347.7	339.8	214.9	140.3	141.8	237.0	626.2	670.3	818.8
2004	501.3	310.6	395.2	228.0	289.4	373.3	320.6	239.9	450.1	753.5	631.1	569.6
2005	769.5	451.4	607.7	504.3	388.6	205.6	159.3	259.7	426.7	458.0	494.1	692.9
2006	661.3	360.4	306.5	480.0	204.6	183.9	159.4	229.2	273.5	258.0	331.9	394.3

SUMMARY OF TREND ANALYSIS RESULTS													
	Electrical Conductivity												
	January	February	March	April	May	June	July	August	September	October	November	December	All Months
Number of Observations:	18	17	18	17	18	18	18	18	18	18	18	18	214
Significance													
Alpha													
0.01	no	no	no	no	no	no	no	no	no	no	no	no	down
0.05	no	down	no	no	no	down	no	no	no	no	no	no	down
0.1	no	down	no	no	no	down	down	no	no	no	no	no	down
0.2	no	down	down	no	down	down	down	no	no	no	down	no	down

Figure 12. Trend Analysis Using Average Monthly Concentrations of Total Organic Carbon at Rock Slough



ALL DATA



SEN'S SLOPE ESTIMATOR
Rslough

n = 157

Slope = -0.135
units per year.

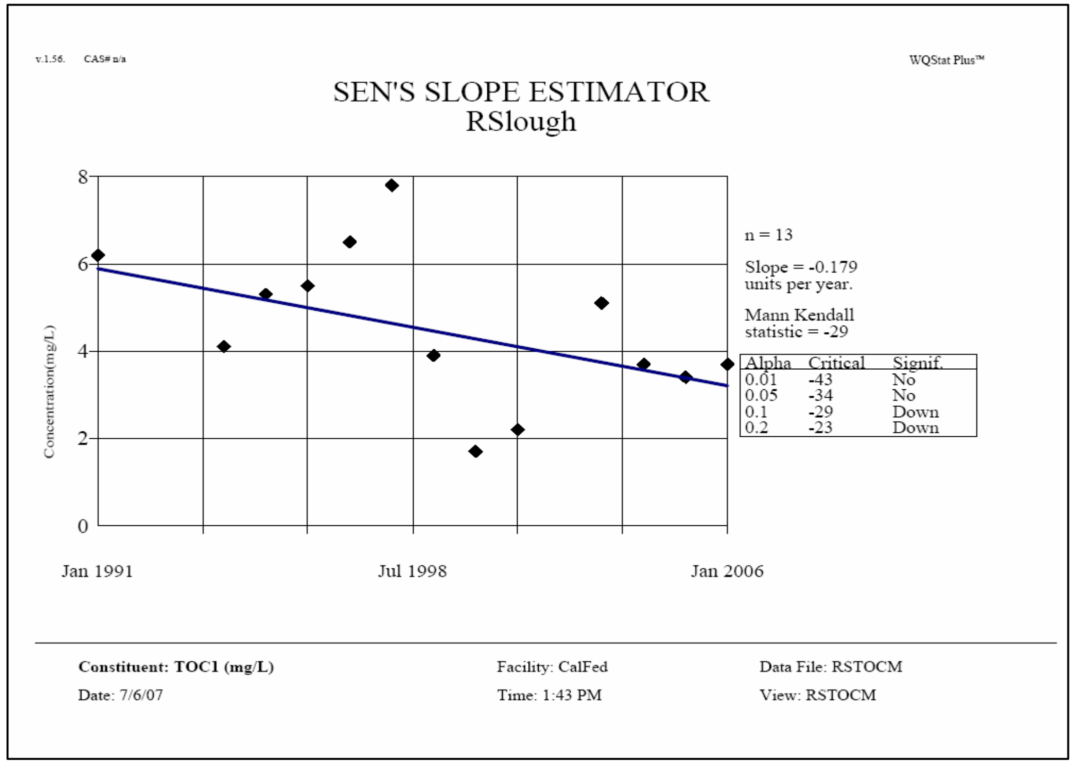
Mann Kendall
normal approx. =
-4.971

Alpha	Critical	Signif.
0.01	-2.575	Down
0.05	-1.96	Down
0.1	-1.645	Down
0.2	-1.282	Down

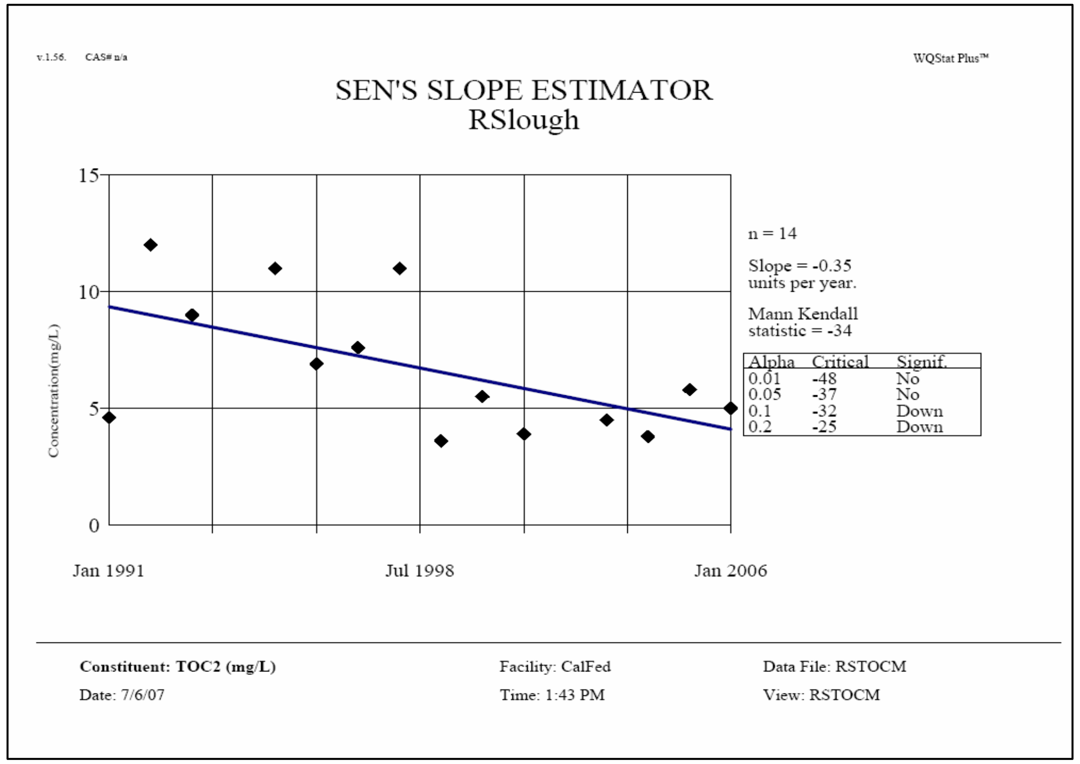
Constituent: TOC (mg/L)
Facility: CalFed
Data File: RSTOCA
Date: 7/6/07
Time: 1:41 PM
View: RSTOCA

Figure 12. Trend Analysis Using Average Monthly Concentrations of Total Organic Carbon at Rock Slough

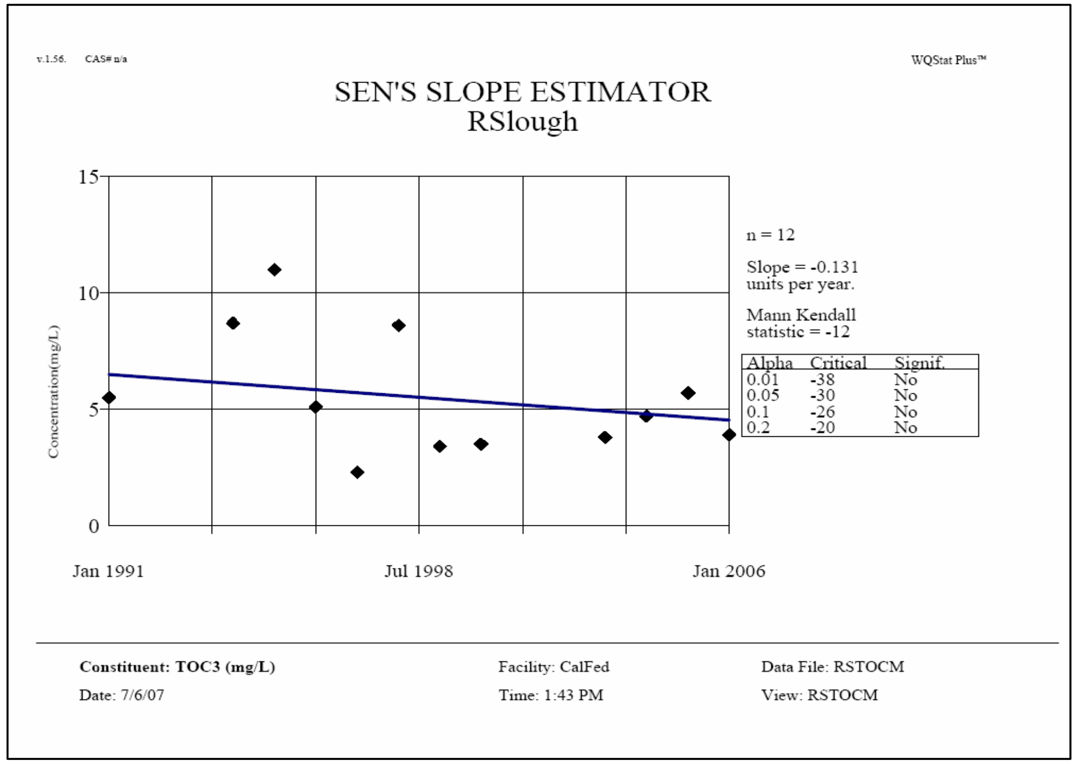
JANUARY



FEBRUARY



MARCH



APRIL

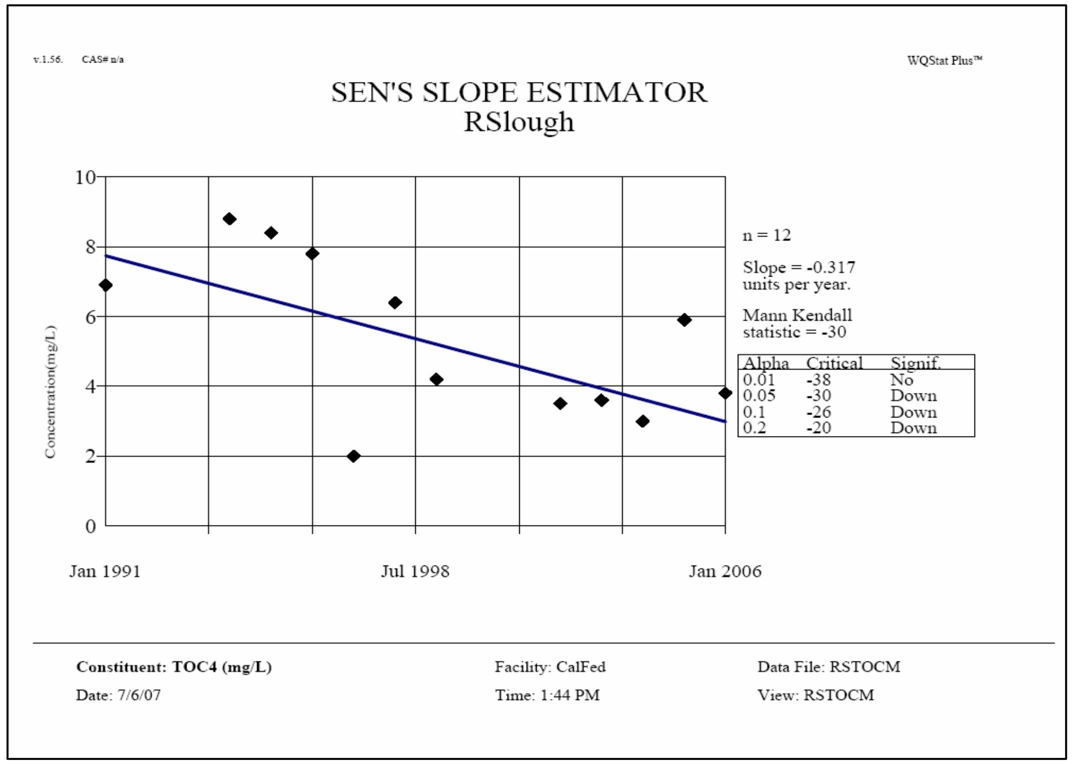
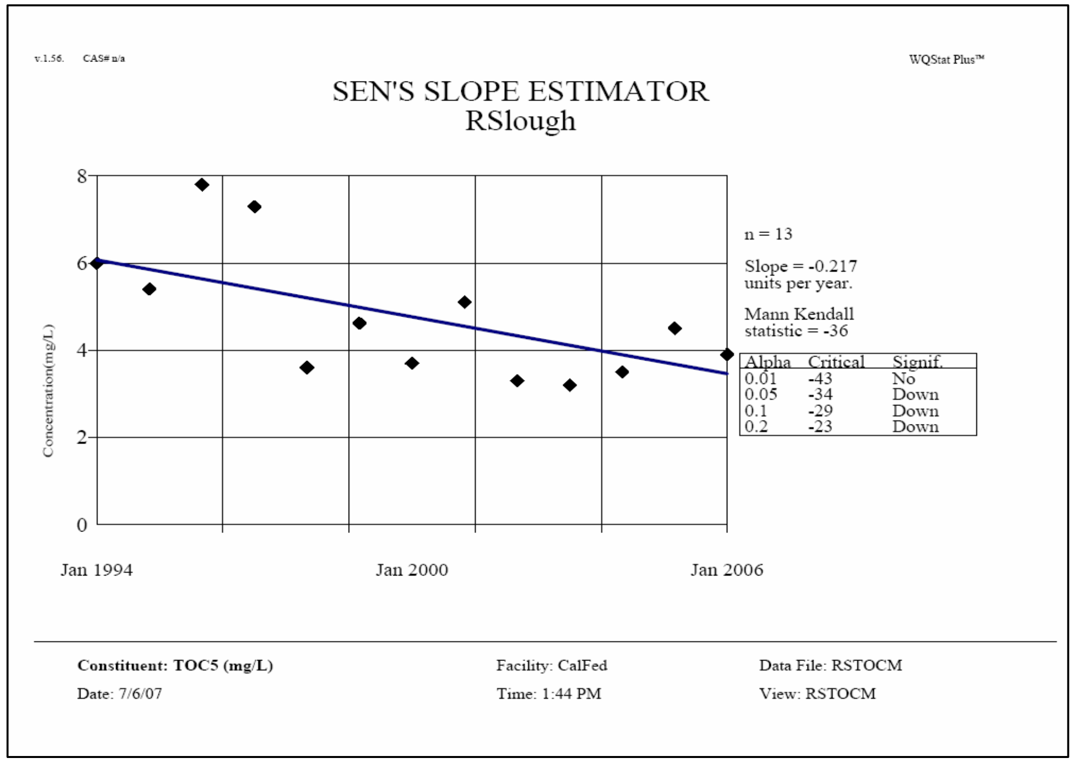
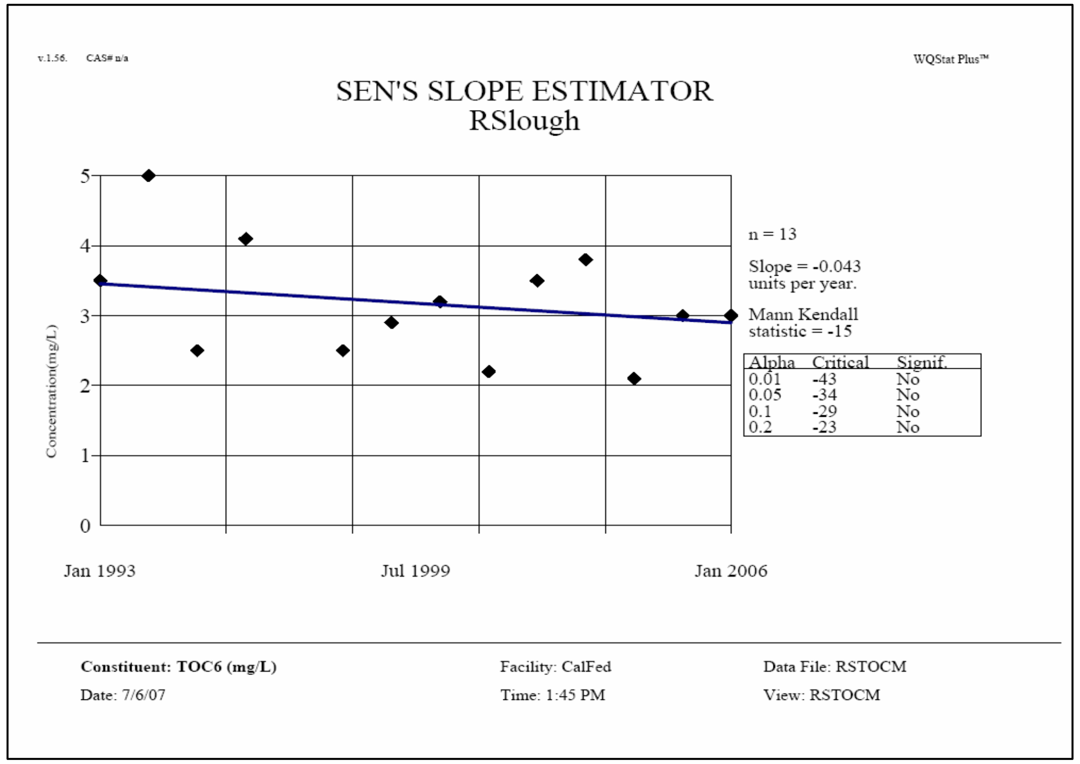


Figure 12. Trend Analysis Using Average Monthly Concentrations of Total Organic Carbon at Rock Slough

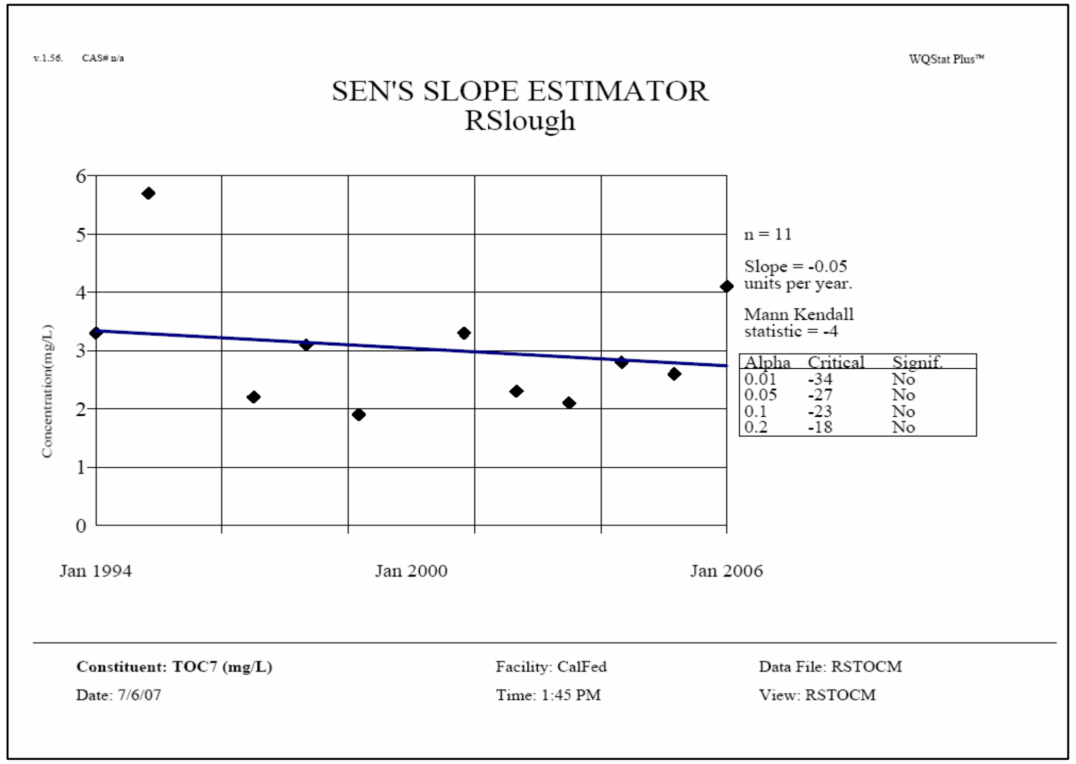
MAY



JUNE



JULY



AUGUST

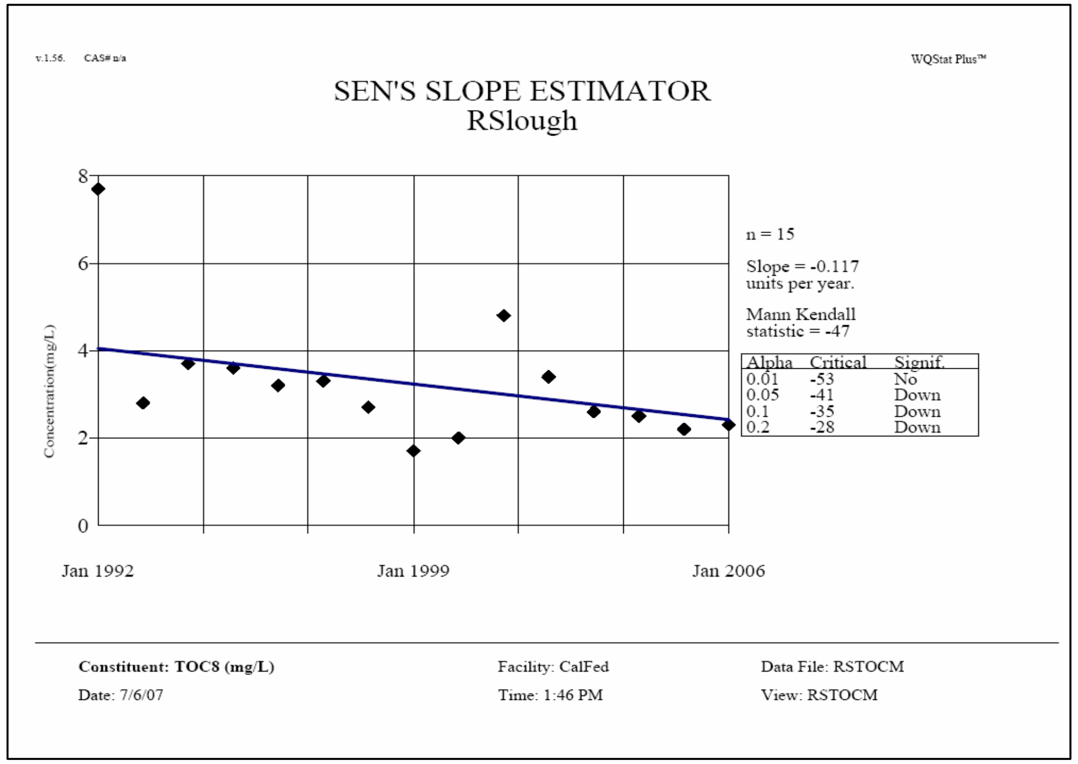
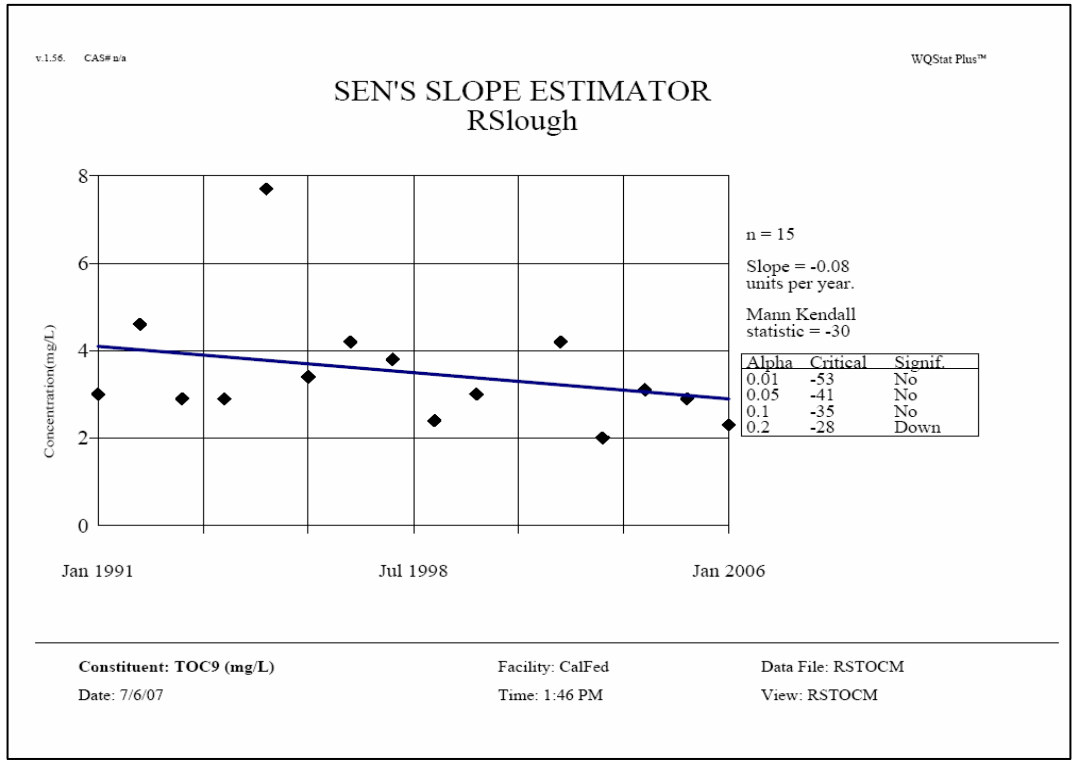
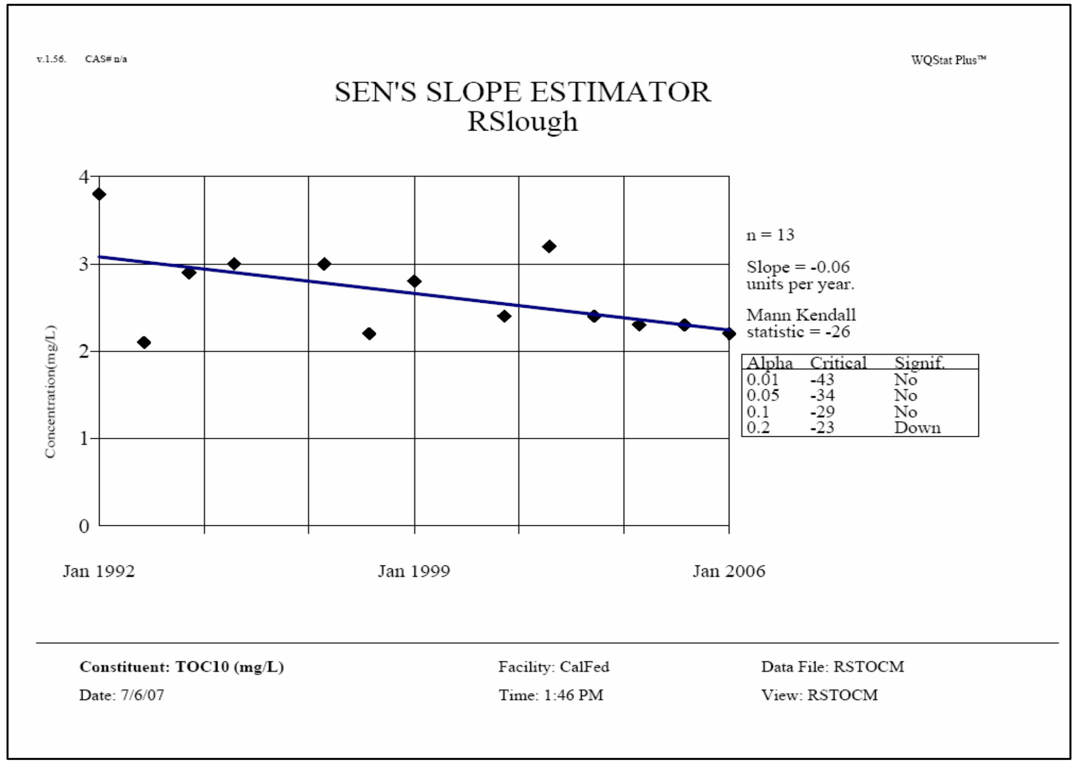


Figure 12. Trend Analysis Using Average Monthly Concentrations of Total Organic Carbon at Rock Slough

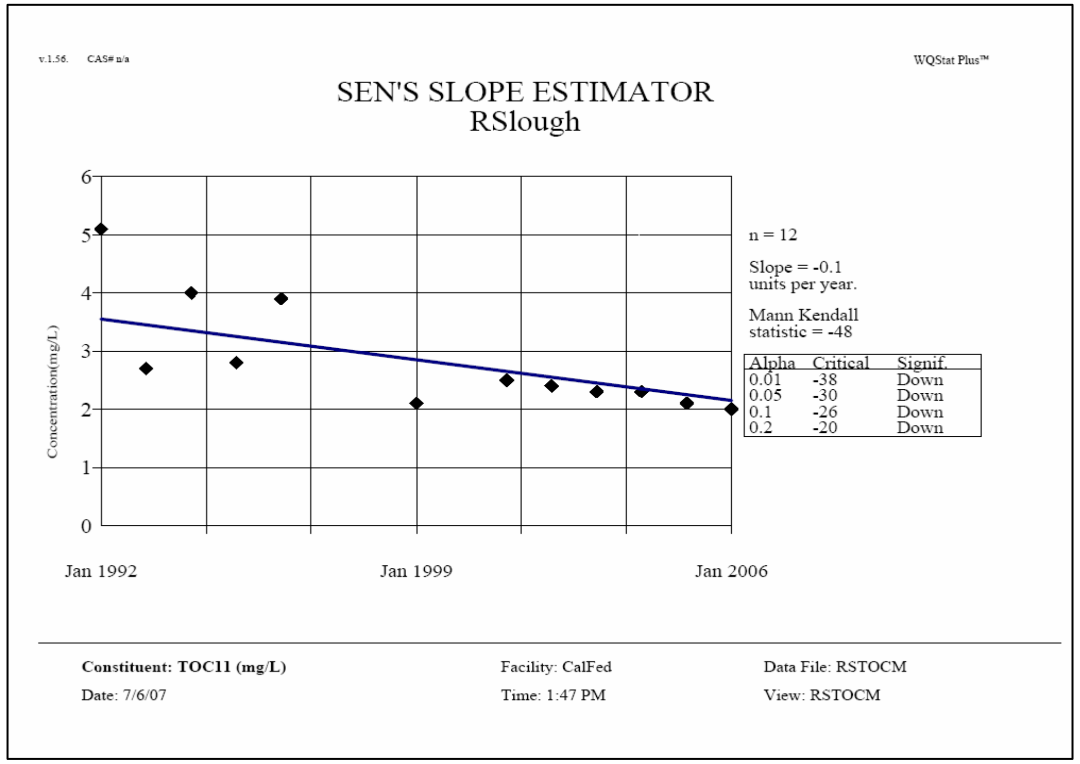
SEPTEMBER



OCTOBER



NOVEMBER



DECEMBER

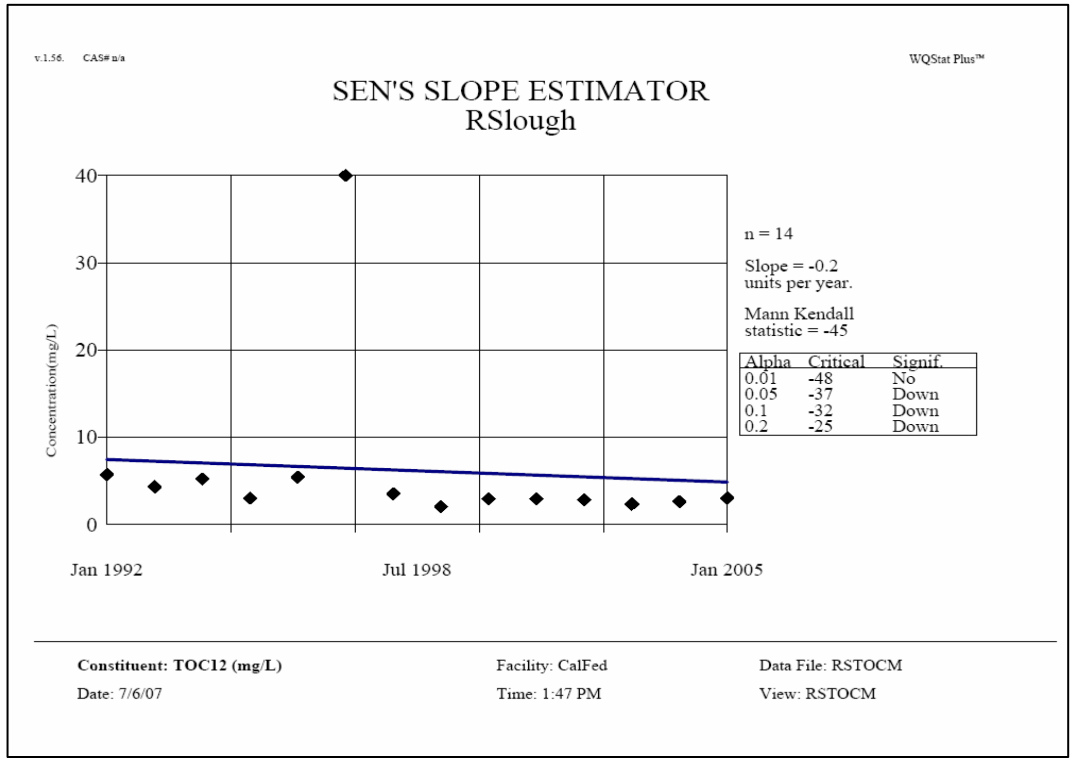


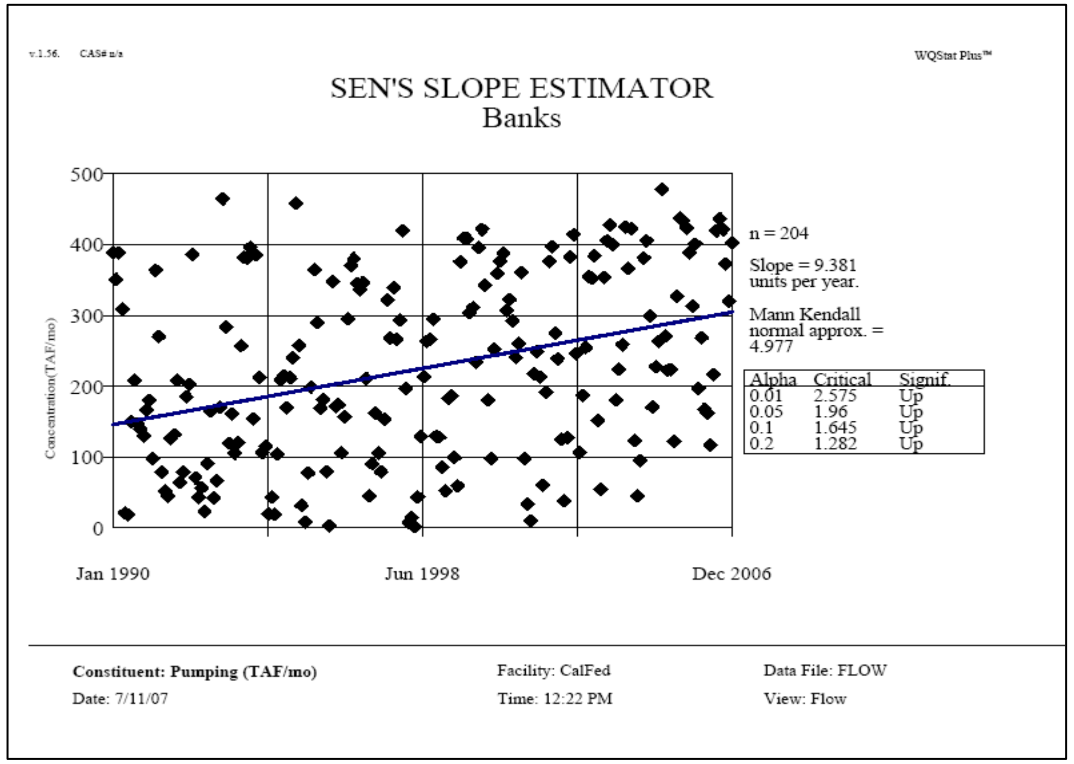
Figure 12. Trend Analysis Using Average Monthly Concentrations of Total Organic Carbon at Rock Slough

DATA USED IN TREND ANALYSIS - AVERAGE MONTHLY CONCENTRATIONS OF TOTAL ORGANIC CARBON (MG/L)												
Sample Year	January	February	March	April	May	June	July	August	September	October	November	December
1991	6.20	4.60	5.50	6.90					3.00			
1992		12.00						7.70	4.60	3.80	5.10	5.70
1993		9.00				3.50		2.80	2.90	2.10	2.70	4.30
1994	4.10		8.70	8.80	6.00	5.00	3.30	3.70	2.90	2.90	4.00	5.20
1995	5.30	11.00	11.00	8.40	5.40	2.50	5.70	3.60	7.70	3.00	2.80	3.00
1996	5.50	6.90	5.10	7.80	7.80	4.10		3.20	3.40		3.90	5.40
1997	6.50	7.60	2.30	2.00	7.30		2.20	3.30	4.20	3.00		40.00
1998	7.80	11.00	8.60	6.40	3.60	2.50	3.10	2.70	3.80	2.20		3.50
1999	3.90	3.60	3.40	4.20	4.62	2.90	1.90	1.70	2.40	2.80	2.10	2.00
2000	1.70	5.50	3.50		3.70	3.20		2.00	3.00			2.90
2001	2.20	3.90			5.10	2.20	3.30	4.80		2.40	2.50	2.90
2002				3.50	3.30	3.50	2.30	3.40	4.20	3.20	2.40	2.80
2003	5.10	4.50	3.80	3.60	3.20	3.80	2.10	2.60	2.00	2.40	2.30	2.30
2004	3.70	3.80	4.70	3.00	3.50	2.10	2.80	2.50	3.10	2.30	2.30	2.60
2005	3.40	5.80	5.70	5.90	4.50	3.00	2.60	2.20	2.90	2.30	2.10	3.00
2006	3.70	5.00	3.90	3.80	3.90	3.00	4.10	2.30	2.30	2.20	2.00	

SUMMARY OF TREND ANALYSIS RESULTS													
	Total Organic Carbon												
	January	February	March	April	May	June	July	August	September	October	November	December	All Months
Number of Observations:	13	14	12	12	13	13	11	15	15	13	12	14	157
Significance													
Alpha													
0.01	no	no	no	no	no	no	no	no	no	no	down	no	down
0.05	no	no	no	down	down	no	no	down	no	no	down	down	down
0.1	down	down	no	down	down	no	no	down	no	no	down	down	down
0.2	down	down	no	down	down	no	no	down	down	down	down	down	down

Figure 13. Trend Analysis of Flow Data

BANKS PUMPING



v.1.56. CAS# n/a

WQStat Plus™

SEN'S SLOPE ESTIMATOR
Banks

n = 204

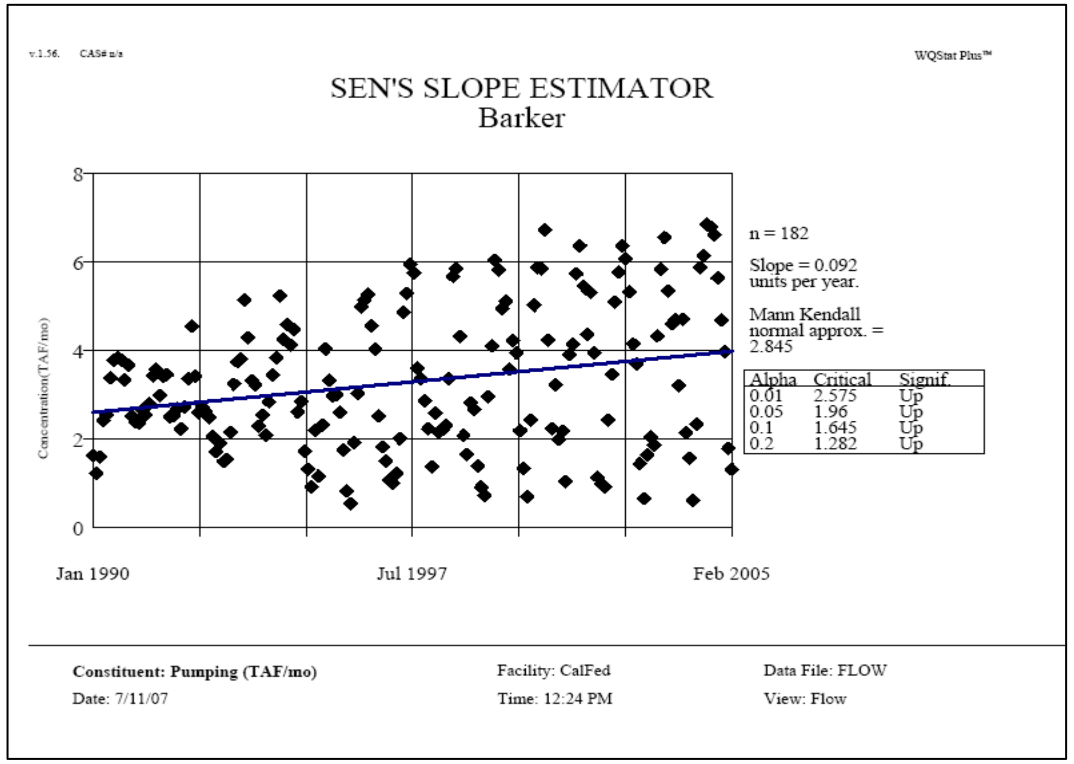
Slope = 9.381 units per year.

Mann Kendall normal approx. = 4.977

Alpha	Critical	Signif.
0.01	2.575	Up
0.05	1.96	Up
0.1	1.645	Up
0.2	1.282	Up

Constituent: Pumping (TAF/mo)
Facility: CalFed
Data File: FLOW
Date: 7/11/07
Time: 12:22 PM
View: Flow

BARKER PUMPING



v.1.56. CAS# n/a

WQStat Plus™

SEN'S SLOPE ESTIMATOR
Barker

n = 182

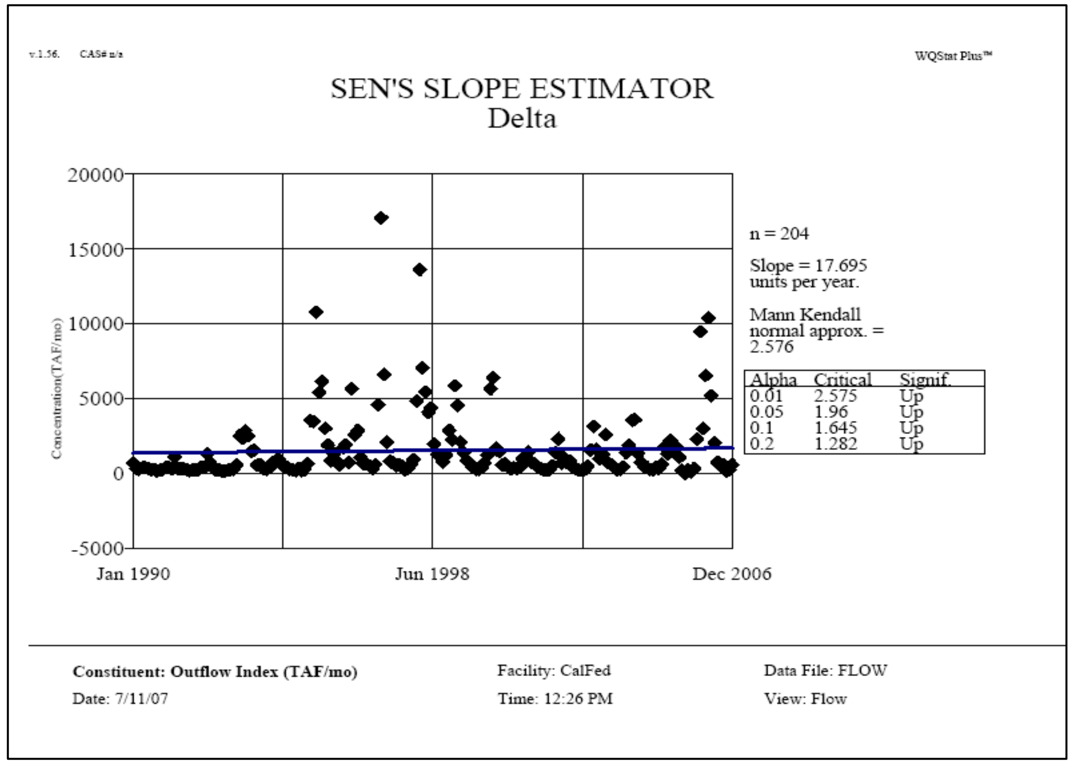
Slope = 0.092 units per year.

Mann Kendall normal approx. = 2.845

Alpha	Critical	Signif.
0.01	2.575	Up
0.05	1.96	Up
0.1	1.645	Up
0.2	1.282	Up

Constituent: Pumping (TAF/mo)
Facility: CalFed
Data File: FLOW
Date: 7/11/07
Time: 12:24 PM
View: Flow

DELTA OUTFLOW INDEX



v.1.56. CAS# n/a

WQStat Plus™

SEN'S SLOPE ESTIMATOR
Delta

n = 204

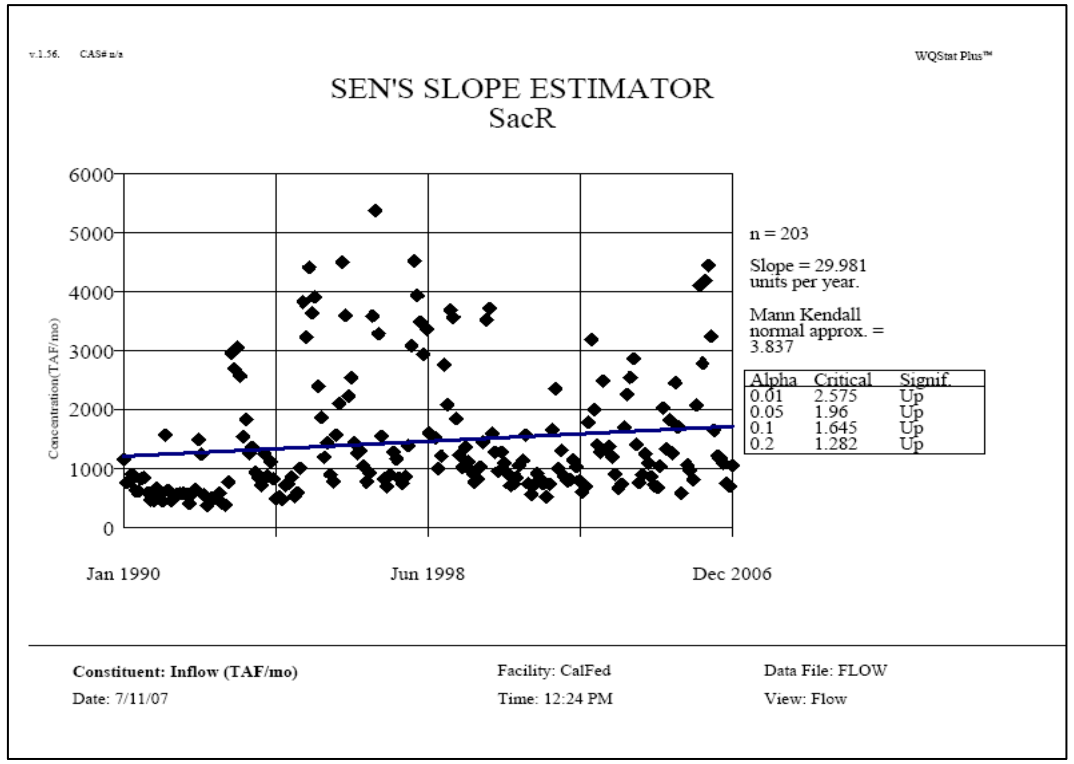
Slope = 17.695 units per year.

Mann Kendall normal approx. = 2.576

Alpha	Critical	Signif.
0.01	2.575	Up
0.05	1.96	Up
0.1	1.645	Up
0.2	1.282	Up

Constituent: Outflow Index (TAF/mo)
Facility: CalFed
Data File: FLOW
Date: 7/11/07
Time: 12:26 PM
View: Flow

SACRAMENTO RIVER INFLOW



v.1.56. CAS# n/a

WQStat Plus™

SEN'S SLOPE ESTIMATOR
SacR

n = 203

Slope = 29.981 units per year.

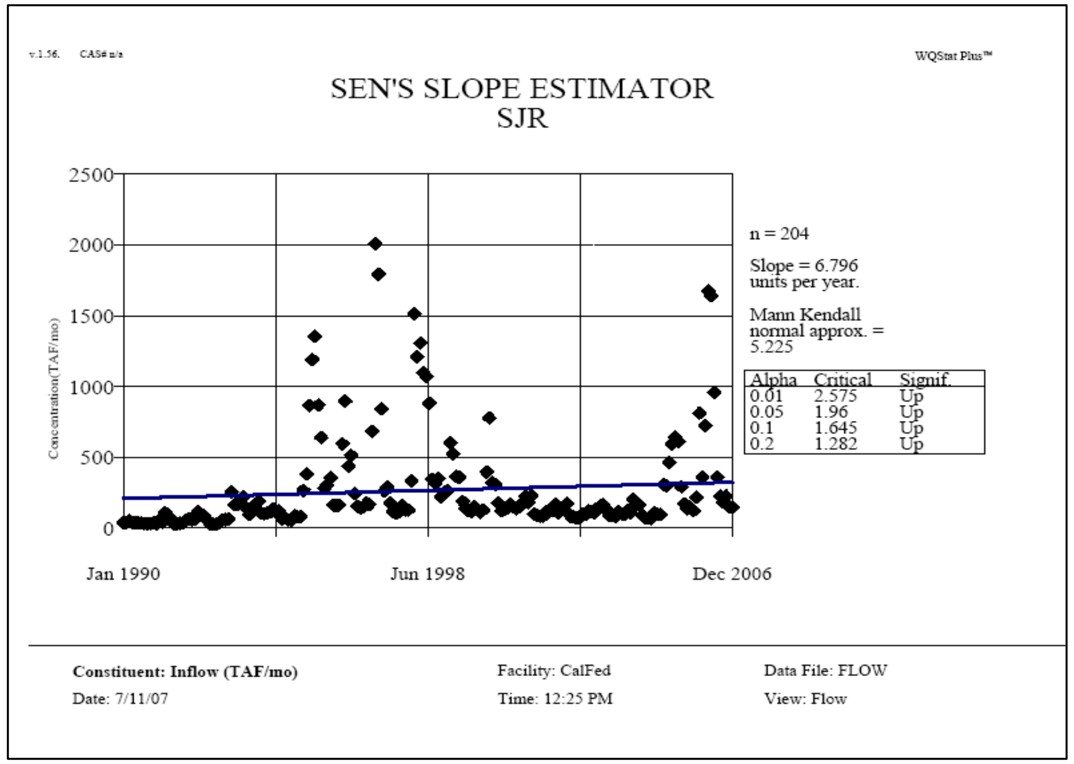
Mann Kendall normal approx. = 3.837

Alpha	Critical	Signif.
0.01	2.575	Up
0.05	1.96	Up
0.1	1.645	Up
0.2	1.282	Up

Constituent: Inflow (TAF/mo)
Facility: CalFed
Data File: FLOW
Date: 7/11/07
Time: 12:24 PM
View: Flow

Figure 13. Trend Analysis of Flow Data

SAN JOAQUIN RIVER INFLOW



SUMMARY OF TREND ANALYSIS RESULTS					
Location:	Banks	Barker	Delta	Sacramento River	San Joaquin River
Flow Type:	Pumping	Pumping	Outflow Index	Inflow	Inflow
Number of Observations:	204	182	204	203	204
Significance					
Alpha					
0.01	up	up	up	up	up
0.05	up	up	up	up	up
0.1	up	up	up	up	up
0.2	up	up	up	up	up

Figure 13. Trend Analysis of Flow Data

FLOW DATA USED IN TREND ANALYSIS

Date	Banks Pumping (TAF)*	Barker Pumping (TAF)	Delta Outflow (TAF)	Sac. River Inflow (TAF)	SJR Inflow (TAF)
1/1/1990	389	1.64	660	1162	36
2/1/1990	351	1.24	306	772	36
3/1/1990	389	1.60	271	795	53
4/1/1990	309	2.44	363	908	38
5/1/1990	21	2.55	377	641	39
6/1/1990	18	3.39	328	625	36
7/1/1990	150	3.79	249	830	35
8/1/1990	208	3.85	266	853	32
9/1/1990	147	3.80	143	600	26
10/1/1990	139	3.34	202	469	30
11/1/1990	130	3.68	265	467	36
12/1/1990	166	2.53	414	672	30
1/1/1991	180	2.40	401	578	52
2/1/1991	98	2.36	291	456	40
3/1/1991	364	2.66	1063	1578	107
4/1/1991	270	2.55	306	642	70
5/1/1991	79	2.81	296	457	65
6/1/1991	52	3.44	321	539	28
7/1/1991	45	3.58	273	578	29
8/1/1991	126	2.99	190	581	33
9/1/1991	132	3.42	230	594	38
10/1/1991	208	3.46	207	576	53
11/1/1991	64	2.51	245	413	65
12/1/1991	79	2.55	436	577	56
1/1/1992	185	2.70	395	650	60
2/1/1992	203	2.23	1286	1503	115
3/1/1992	386	2.73	746	1251	91
4/1/1992	71	3.37	432	559	86
5/1/1992	43	4.56	221	387	58
6/1/1992	56	3.43	233	498	30
7/1/1992	23	2.60	183	505	28
8/1/1992	91	2.73	156	533	29
9/1/1992	165	2.62	195	583	38
10/1/1992	43	2.49	252	418	53
11/1/1992	67	2.06	260	387	59
12/1/1992	170	1.72	579	774	61
1/1/1993	465	1.92	2512	2959	252
2/1/1993	284	1.50	2358	2698	167
3/1/1993	120	1.55	2851	3062	166
4/1/1993	161	2.16	2492	2575	203
5/1/1993	105	3.25	1442	1546	219
6/1/1993	121	3.76	1567	1840	138
7/1/1993	257	3.82	557	1268	94
8/1/1993	382	5.16	596	1370	122
9/1/1993	381	4.30	308	951	167
10/1/1993	396	3.33	276	859	188
11/1/1993	154	3.22	364	725	106
12/1/1993	385	2.29	712	1255	101
1/1/1994	213	2.55	695	881	109
2/1/1994	106	2.10	946	1122	112
3/1/1994	115	2.85	739	831	137
4/1/1994	20	3.46	439	498	110
5/1/1994	43	3.85	428	532	121
6/1/1994	19	5.24	248	480	65
7/1/1994	104	4.25	264	724	70
8/1/1994	210	4.59	177	745	56
9/1/1994	215	4.12	320	857	54
10/1/1994	170	4.48	190	534	84
11/1/1994	212	2.62	254	591	77
12/1/1994	240	2.85	628	1013	80
1/1/1995	458	1.74	3539	3832	267
2/1/1995	257	1.33	3446	3235	381
3/1/1995	31	0.93	10783	4420	865
4/1/1995	8	2.21	5391	3645	1192
5/1/1995	77	1.17	6174	3916	1353
6/1/1995	199	2.33	2999	2406	868
7/1/1995	364	4.05	1878	1872	639
8/1/1995	290	3.33	825	1198	280
9/1/1995	169	2.97	1297	1438	302
10/1/1995	181	3.01	796	909	355
11/1/1995	79	2.61	555	782	162
12/1/1995	3	1.76	1705	1573	155
1/1/1996	348	0.83	1907	2106	163
2/1/1996	171	0.54	742	4510	595
3/1/1996	174	1.93	5644	3606	897
4/1/1996	106	3.04	2571	2237	436
5/1/1996	157	4.99	2864	2545	512
6/1/1996	295	5.16	1060	1438	242
7/1/1996	370	5.28	623	1269	153
8/1/1996	380	4.57	651	1307	143
9/1/1996	345	4.05	501	1051	145
10/1/1996	336	2.53	301	783	173
11/1/1996	347	1.83	596	926	167
12/1/1996	211	1.51	4600	3594	684
1/1/1997	45	1.09	17093	5388	2007
2/1/1997	90	1.01	6622	3293	1793
3/1/1997	162	1.24	2079	1556	842
4/1/1997	106	2.01	829	830	261
5/1/1997	79	4.87	732	703	288
6/1/1997	153	5.30	496	903	173
7/1/1997	322	5.96	582	1287	116
8/1/1997	268	5.75	526	1170	104
9/1/1997	339	3.61	227	851	116
10/1/1997	266	3.37	301	759	157
11/1/1997	293	2.86	573	870	127
12/1/1997	420	2.24	925	1396	125
1/1/1998	197	1.38	4821	3089	331
2/1/1998	7	2.59	13595	4526	1514
3/1/1998	14	2.16	7076	3941	1209
4/1/1998	2	2.22	5443	3493	1306
5/1/1998	43	2.32	4086	2945	1097
6/1/1998	129	3.37	4384	3372	1071
7/1/1998	213	5.69	1983	1611	882
8/1/1998	263	5.86	1256	1551	344
9/1/1998	266	4.32	1188	1523	317
10/1/1998	295	2.08	754	1004	352
11/1/1998	129	1.66	1195	1217	219
12/1/1998	128	2.82	2892	2768	252
1/1/1999	85	2.67	2237	2086	262
2/1/1999	52	1.40	5861	3698	600
3/1/1999	183	0.92	4538	3575	524
4/1/1999	186	0.73	2082	1858	366
5/1/1999	99	2.97	1410	1236	357
6/1/1999	59	4.11	837	1033	189
7/1/1999	376	6.05	665	1372	136
8/1/1999	409	5.82	378	1128	119
9/1/1999	409	4.96	269	957	118
10/1/1999	304	5.13	266	781	148
11/1/1999	311	3.59	387	831	133
12/1/1999	234	4.24	665	1035	108
1/1/2000	396	3.95	1226	1456	127
2/1/2000	422	2.20	5625	3527	397
3/1/2000	343	1.34	6387	3724	778
4/1/2000	180	0.70	1702	1600	322
5/1/2000	98	2.44	1440	1285	305
6/1/2000	252	5.03	590	958	176
7/1/2000	359	5.88	604	1287	121
8/1/2000	377	5.85	402	1106	129
9/1/2000	388	6.73	294	922	139

Figure 13. Trend Analysis of Flow Data

FLOW DATA USED IN TREND ANALYSIS, CONTINUED

Date	Banks Pumping (TAF)	Barker Pumping (TAF)	Delta Outflow (TAF)	Sac. River Inflow (TAF)	SJR Inflow (TAF)
10/1/2000	307	4.24	357	723	171
11/1/2000	322	2.24	338	748	145
12/1/2000	292	3.23	427	860	136
1/1/2001	241	2.00	972	1061	150
2/1/2001	261	2.19	1033	1145	173
3/1/2001	361	1.05	1425	1579	224
4/1/2001	99	3.92	747	753	179
5/1/2001	34	4.16	639	572	228
6/1/2001	9	5.74	471	737	101
7/1/2001	218	6.38	310	925	86
8/1/2001	249	5.47	218	829	83
9/1/2001	213	4.38	256	750	82
10/1/2001	60	5.32	256	531	116
11/1/2001	192	3.96	492	741	123
12/1/2001	377	1.14	1385	1663	123
1/1/2002	397	0.99	2321	2356	166
2/1/2002	274	0.92	669	1013	105
3/1/2002	239	2.44	1040	1313	131
4/1/2002	125	3.47	720	863	155
5/1/2002	38	5.11	833	795	172
6/1/2002	128	5.79	402	822	85
7/1/2002	383	6.37	315	1157	78
8/1/2002	414	6.08	215	1042	71
9/1/2002	246	5.34	230	806	69
10/1/2002	106	4.16	252	611	96
11/1/2002	187	3.71	446	704	96
12/1/2002	254	1.45	1564	1795	120
1/1/2003	356	0.66	3115	3194	119
2/1/2003	353	1.65	1594	2005	107
3/1/2003	385	2.05	974	1412	135
4/1/2003	152	1.86	1259	1286	158
5/1/2003	54	4.34	2586	2493	165
6/1/2003	354	5.84	701	1323	133
7/1/2003	405	6.56	560	1376	91
8/1/2003	428	5.35	434	1201	88
9/1/2003	400	4.61	223	912	82
10/1/2003	180	4.71	269	680	119
11/1/2003	224	3.21	410	744	101
12/1/2003	259	4.72	1359	1711	93
1/1/2004	425	2.14	1902	2263	122
2/1/2004	366	1.57	3547	2557	104
3/1/2004	423	0.61	3590	2872	201
4/1/2004	123	2.34	1306	1416	164

FLOW DATA USED IN TREND ANALYSIS, CONTINUED

Date	Banks Pumping (TAF)	Barker Pumping (TAF)	Delta Outflow (TAF)	Sac. River Inflow (TAF)	SJR Inflow (TAF)
5/1/2004	45	5.88	710	769	165
6/1/2004	95	6.15	465	896	87
7/1/2004	382	6.86	404	1253	70
8/1/2004	405	6.80	274	1098	70
9/1/2004	299	6.63	224	868	67
10/1/2004	170	5.65	363	725	109
11/1/2004	228	4.70	345	684	97
12/1/2004	263	3.99	613	1047	96
1/1/2005	479	1.80	1772	2037	308
2/1/2005	271	1.32	1285	1334	298
3/1/2005	223		2221	1831	464
4/1/2005	224		1716	1269	594
5/1/2005	121		1786	2464	644
6/1/2005	327		1056	1708	614
7/1/2005	438		210	589	292
8/1/2005	434		-45		170
9/1/2005	424		235	1066	137
10/1/2005	388		83	974	146
11/1/2005	313		319	818	122
12/1/2005	401		2281	2082	216
1/1/2006	197		9477	4112	811
2/1/2006	268		3004	2789	361
3/1/2006	168		6545	4193	723
4/1/2006	162		10393	4453	1675
5/1/2006	117		5198	3249	1642
6/1/2006	216		2047	1660	956
7/1/2006	420		739	1223	361
8/1/2006	437		481	1186	225
9/1/2006	421		556	1096	182
10/1/2006	373		123	757	224
11/1/2006	320		206	706	149
12/1/2006	402		569	1065	143

* TAF = thousand acre feet

Appendix C:
Performance Measures and Stage 2 Action Plan

This Appendix pulls together the performance measures and stage 2 priorities identified in the Stage 1 Final Assessment report. The purpose of compiling this information in one document is to serve both as the initial draft of the Phase II Performance Measures Report for Drinking Water Quality and as an initial list of actions to review when Delta or CALFED Stage 2 strategic planning begins. The purpose of the Phase II Performance Measures Report is to identify an initial set of implementable performance metrics for the CALFED Program

Initial Performance Measures

The CALFED program also institutionalized two new concepts in program implementation: adaptive management and performance measurement. The Water Quality Program Plan (2000) describes adaptive management as an evolutionary and collaborative process that requires continous learning about and decision-making to solve the Bay-Delta estuary's problems. Figure 2-1 is a diagram of the adaptive management process as it was initially envisioned; Figure 2-2 is a recent evolution of this process. "Goals" and "targets" are used interchangeably in the ROD when discussing drinking water, and should not be interpreted in the same way as regulations or ecosystem water quality goals and targets are interpreted; "objectives" refer to desired programmatic-level outcomes.

CALFED defines Performance Measures as a means to gauge the progress of an action and Indicators of Success as a means of assessing progress toward endpoints or targets that are representative of when beneficial uses are no longer impaired. Performance Measures are quantified through a collection and assessment of performance metrics –data collected at a specific location and frequency for a specified purpose. These factors combine to answer the question, "Is water quality improving?" Performance measures can quantify administrative measures or input measures (funds, actions, projects), drivers (project implementation outcomes, natural phenomena), and outcome measures (program implementation outcomes, status and trends of environmental conditions).

As stated in the ROD, the goal of the WQP is to provide "safe, reliable, and affordable drinking water in a cost-effective way," with a target to "achieve either: (a) average concentrations at Clifton Court Forebay and other southern and central Delta drinking water intakes of 50 μg/L bromide and 3.0 mg/L total organic carbon (TOC), or (b) an equivalent level of public health protection using a cost-effective combination of alternative source waters, source control, and treatment technologies." The ROD identifies ten WQP commitments - a list of projects/activities necessary to make progress toward water quality for improvement during Stage 1.

The CALFED Water Quality Program has been developing a performance measures framework over the past three years, in parallel with the CALFED Science Program's effort to develop a performance measures framework for the entire CALFED Bay-Delta Program. Rather than developing a hypothetical framework, the WQP has used data gathering and assessment to inform the framework. Since late 2006, CALFED implementing agencies have been developing a "Phase I Report on Performance Measures" – essentially a workplan which identified program objectives, performance measure status, and resource needs. As part of this development, the WQP has identified an initial outline for the structure of its Phase II report on performance measures, which is meant to identify an initial set of performance measures for implementation. Information in the Stage 1 Final Assessment Report was reorganized according to these objectives, measures, and targets, with specific metrics identified under each target.

Objective 1: Provide safe and reliable drinking water by reducing disinfection byproduct formation.

Performance Measure 1: Reduce production of disinfection byproducts in treatment plants using Delta water as a source.

Target 1a: Running annual average of 50 µg/L bromide and

Target 1b: Running annual average of 3.0 mg/L total organic carbon at Delta intakes or

Level 3 Outcome Metrics:

Locations: Harvey O. Banks Pumping Plant
C.W. "Bill" Jones (Tracy) Pumping Plant
Contra Costa Water District Old River intake
Contra Costa Water District Rock Slough intake
Barker Slough Pumping Plant
City of Antioch San Joaquin River intake
California Aqueduct Check 13
Contra Costa Water District Victoria Canal intake (future)
City of Stockton Delta intake (future)
Volunteer reservoirs on the California Aqueduct

Constituents: bromide, µg/L
total organic carbon, mg/L
electrical conductivity, µS/cm
dissolved organic carbon, mg/L

Sampling frequency:
(currently monthly)

Analysis: running annual averages, based on monthly averages or single data
Frequency at which bromide is above 50 µg/L (days/water year)
Frequency at which bromide is above 100 µg/L (days/water year)
Frequency at which bromide is above 150 µg/L (days/water year)
Frequency at which bromide is above 250 µg/L (days/water year)
Frequency at which TOC is above 3 mg/L (days/water year)
Frequency at which TOC is above 6 mg/L (days/water year)
Frequency at which TOC is above 7 mg/L (days/water year)

Level 3 Driver Metrics:

Location: San Joaquin River at Vernalis

Constituents: bromide, µg/L
total organic carbon, mg/L
electrical conductivity, µS/cm
dissolved organic carbon, mg/L
(New Melones flow, cfs)

Sampling frequency:
(currently monthly)

Analysis: running annual averages, based on monthly averages or single data
Frequency at which bromide is above 50 µg/L (days/water year)
Frequency at which bromide is above 100 µg/L (days/water year)
Frequency at which bromide is above 150 µg/L (days/water year)
Frequency at which bromide is above 250 µg/L (days/water year)
Frequency at which TOC is above 3 mg/L (days/water year)
Frequency at which TOC is above 6 mg/L (days/water year)
Frequency at which TOC is above 7 mg/L (days/water year)
Use of New Melones flow to provide salinity dilution

Level 3 Driver Metrics:

Location: Sacramento River at Hood
Constituents: bromide, μg/L
total organic carbon, mg/L
electrical conductivity, μS/cm
dissolved organic carbon, mg/L
Sampling frequency:
(currently monthly)
Analysis: running annual averages, based on monthly averages or single data
Frequency at which TOC is above 3 mg/L (days/water year)
Frequency at which TOC is above 6 mg/L (days/water year)
Frequency at which TOC is above 7 mg/L (days/water year)
Location: key in-Delta islands, wetlands (determine through modeling of sensitivity of intakes to drainages and wetlands in the Delta)
Constituents: bromide, μg/L
total organic carbon, mg/L
electrical conductivity, μS/cm
dissolved organic carbon, mg/L
flow, cfs
Sampling frequency:
(monthly or daily)
Analysis: running annual averages, based on monthly averages or single data
Frequency at which TOC is above 3 mg/L (days/water year)
Frequency at which TOC is above 6 mg/L (days/water year)
Frequency at which TOC is above 7 mg/L (days/water year)
Average daily inflow and outflow, cfs

Level 2 Project Metrics (in-Delta projects):

Locations: Harvey O. Banks Pumping Plant
C.W. "Bill" Jones (Tracy) Pumping Plant
Contra Costa Water District Old River intake
Contra Costa Water District Rock Slough intake
Barker Slough Pumping Plant
City of Antioch San Joaquin River intake
Contra Costa Water District Victoria Canal intake (future)
City of Stockton Delta intake (future)
Constituents: bromide, μg/L
total organic carbon, mg/L
electrical conductivity, μS/cm
dissolved organic carbon, mg/L
Sampling frequency:
(currently monthly, if modeled monthly or daily, if fingerprint modeling or projects to reduce ocean salinity, then frequency and magnitude of seawater intrusion at intakes)
Analysis: running annual averages, based on monthly averages or single data
Frequency at which bromide is above 50 μg/L (days/water year)
Frequency at which bromide is above 100 μg/L (days/water year)
Frequency at which bromide is above 150 μg/L (days/water year)
Frequency at which bromide is above 250 μg/L (days/water year)
Frequency at which TOC is above 3 mg/L (days/water year)
Frequency at which TOC is above 6 mg/L (days/water year)
Frequency at which TOC is above 7 mg/L (days/water year)

Level 2 Project Metrics (source improvement projects):

Locations: Project endpoint
Constituents: full suite of water quality parameters, including
bromide, µg/L
total organic carbon, mg/L
electrical conductivity, µS/cm
dissolved organic carbon, mg/L
also economics
Sampling frequency:
Determined by project, comparable to level 3 monthly data
Analysis: Determined by project, target is to inform cost-effectiveness and relative contribution of project to large scale improvement

Target 1c: "An equivalent level of public health protection" at water treatment plants using Delta water (currently evaluated as the treated water quality goals that form the basis of Targets 1a and 1b or an equivalent source water measurement at the intake to the plant).

Level 3 Outcome Metrics:

Location: 54 WTPs identified in Appendix D, through data collected by CDPH, sampling location closest to WTP
Volunteer treatment plants within CALFED Solution area
Constituents: Total Trihalomethanes, µg/L
5 Haloacetic Acids, µg/L
Bromate, µg/L
Bromodichloromethane, µg/L
Bromoform, µg/L
Dibromochloromethane, µg/L
Chloroform, µg/L
Dichloroacetic acid, µg/L
Trichloroacetic acid, µg/L
Monobromoacetic acid, µg/L
Monochloroacetic acid, µg/L
Bromochloroacetic acid, µg/L
Disinfectants used
Percent Delta water treated
Sampling frequency:
Monthly or quarterly averages of monthly samples
Analysis: running annual averages of quarterly averages
NOTE: The WQP should continue to work with stakeholders to define a better definition of ELPH that is more representative of the treatability of Delta water quality

Level 3 Driver Metrics:
Location: Volunteer treatment plants within CALFED Solution area Distribution System Monitoring
Constituents: Total Trihalomethanes, μg/L
5 Haloacetic Acids, μg/L
Bromate, μg/L
Sampling frequency:
Monthly or quarterly averages of monthly samples
Analysis: locational running annual averages of quarterly averages – use to inform revision of ELPH targets

Level 3 Driver Metrics:
Location: SWP, CCWD intake monitoring for pathogens
Constituents: *Cryptosporidium*, MPN
Sampling frequency:
Per regulation
Analysis: use data to inform whether disinfection requirements will change

Level 2 Project Metrics (treatment demonstration projects):
Location: 54 WTPs identified in Appendix D, through data collected by CDPH, sampling location closest to WTP
Volunteer treatment plants within CALFED Solution area
Constituents: treated:
Total Trihalomethanes, μg/L
5 Haloacetic Acids, μg/L
Bromate, μg/L
Bromodichloromethane, μg/L
Bromoform, μg/L
Dibromochloromethane, μg/L
Chloroform, μg/L
Dichloroacetic acid, μg/L
Trichloroacetic acid, μg/L
Monobromoacetic acid, μg/L
Monochloroacetic acid, μg/L
Bromochloroacetic acid, μg/L
Disinfectants used
source:
bromide, μg/L
total organic carbon, mg/L
electrical conductivity, μS/cm
dissolved organic carbon, mg/L
SUVA254
Costs
Sampling frequency:
Determined by project design, comparable to level 3
Analysis: Reductions in DBP formation, changes in DBP speciation
Cost analysis
Identification of Scalability Issues

Objective 2: Provide aesthetically acceptable drinking water by reducing taste and odor events.

Performance Measure 2: Reduce presence of algae in treatment plant intakes and thus the number of taste and odor complaints.

Target 2a: Reduce frequency of presence of algae blooms in drinking water conveyances or

Work with the California Department of Water Resources' Department of Operations and Management to develop appropriate metrics in the SWP

Target 2b: Reduce the number of taste and odor events at water treatment plants using Delta water

Level 3 Outcome Metrics:

Location: Volunteer treatment plants within CALFED Solution area
Constituents: Taste and odor complaints
Sampling frequency: occurrence
Analysis: number/month or season

Objective 3: Provide reliable drinking water quality through cost-effective actions

Performance Measure 3: Implement actions that have been determined to be cost-effective.

Target 3: Still under development

Additional Performance Measures were recommended as a result of the Delta Drinking Water Quality Study, most of which would require new monitoring throughout the state. All of the water quality constituents would need to be measured frequently, at a number of key locations in the system. In addition to the Delta and WTP intakes, other key locations would be: downstream from significant storage facilities; downstream from other locations that could improve or degrade water quality; and after long residence times in conveyance. The frequency of monitoring at all locations should be sufficient to evaluate the water quality constituents on a seasonal and weekly basis. The analysis and frequency of monitoring should be at a daily level at the WTP intakes to identify changes in variability and concentration at the WTP level. Daily monitoring at the WTP would provide signals for initiating additional water quality monitoring and would help to identify potential problems within the system that may need to be monitored.

Ideally, TOC would be measured on a daily basis and with the same analytical method throughout the system. In addition to TOC measurements, DOC and UV254 measurements would be included to allow for a better characterization of organic carbon. These additions would provide enhanced information on the changes in DBP formation potential through the system. Salinity monitoring methods are currently not consistent throughout the system. Rather than using more indirect measures, it would be more beneficial to measure bromide, chloride, and iodide consistently and at a regularly frequency - perhaps daily - throughout the system. This is particularly important as the public health concern over idodated and bromated THM and HAAs grows. Directly monitoring bromide and chloride are more useful for identifying salinity challenges and concerns than monitoring for EC or TDS alone.

Turbidity can be monitored continuously with simple on-line analyzers, throughout the system. These turbidity measurements could provide a measure of daily variability for WTPs, which are often operated according to incoming turbidity values. Alkalinity measurements in the Delta and at other locations within the system are needed to provide a better understanding of seasonal and monthly changes in alkalinity.

Reports of year round algae growth and associated T&O indicate that year round, weekly monitoring of algae and algae by-products is merited. When higher levels of algae growth occur, algae counts and measurements for algae by-products should be conducted more than weekly. Additional nutrient monitoring on a weekly basis would help in understanding the nutrient thresholds at which problems occur in the Delta system. Daily-to-weekly measurements to augment WTP intake pathogen and indicator microorganism monitoring can provide information about Delta concentrations and how they change through the system. Currently, little is known about pathogens and indicator microorganism throughout the system.

Sampling should be conducted at the location nearest to the outlet of each WTP for both regulated and non-regulated THMs and HAAs on a weekly basis. Concerns regarding idodated and brominated DBPs are growing industry wide. Understanding the nature of their occurrence at Delta WTPs, which use source water with high concentrations of iodide and bromide DBP precursors, could be important in meeting future regulations. Monitoring for these sets of parameters throughout the system at the above-recommend frequency would be expensive; development of this ideal set of performance measures did not consider costs, but outline a longterm objective.

As recommended above, analysis would continue on a yearly basis for the ideal set of performance measures, in order to develop an annual report. The evaluation would include an investigation of changes in variability and median constituent concentrations at sampling locations as well as at the WTP intakes. At the Delta intakes, WTP intakes, and some key locations in conveyance and storage facilities, seasonal and weekly variability should be analyzed. As the database and analysis grows, numeric targets for reductions in variability and concentration can be set. To assist participating WTPs, a user friendly database would need to be developed such that the WTPs can download data to the database directly.

Stage 2 Priorities Identified in the Stage 1 Final Assessment report

The following is an outline of identified priorities and actions.

Watershed Projects (still important to maintain or improve intake water quality)
- Central Valley Drinking Water Policy
- Focused funding on smaller regions to evaluate and reduce drinking and ecological water constituents of concern
- Westside Drainage Plan, San Luis Feature Reevaluation
- Monitor urban and industrial discharges in the Sacramento River
- Legislation to regulate and/or funding actions to implement best management practices in new urban developments to reduce urban runoff or improve the water quality of urban runoff

In-Delta Projects (still important to maintain or improve intake water quality)
- Central Valley Drinking Water Policy
- Delta Conveyance Projects (Delta Cross Channel, Franks Tract with regulatory changes)
- Low-Intensity Chemical Dosing
- Recirculation
- Require funded levee improvements to obtain critical water quality and flow data
- Monitor discharges of urban stormwater and wastewater close to Delta intakes

Treatment Demonstrations
- Delta and NBA Regional Treatment Demonstration Plants
- Evaluate WTPs with effective TOC removal and low DBP production and share findings
- Evaluate the trade offs between membrane and conventional treatment
- Improve outreach to smaller and disadvantaged WTPs

IRWMP Projects
- Alternative intake for the North Bay Aqueduct
- Alternative intake for the City of Antioch
- Lining of the Contra Costa Canal
- SBA Watershed Protection
- Projects that better match water quality to water use
- Develop CALFED drinking water quality guidelines for IRWMP plans and project selection, so that regional drinking water quality management plans can be developed and funded

CALFED Projects with potential or known drinking water quality benefits
- Delta levee maintanence
- Alternative Delta conveyance
- North of Delta Offstream Storage (with regulatory changes)
- Expanded Los Vaqueros Reservoir
- Changes to SWP and CVP pumping to improve San Luis Reservoir water quality

Information Gaps
- Sensitivity of Delta intakes to Delta island drainage locations

Analysis of data collected through the Central Valley Regional Water Board's Irrigated Lands Program
San Luis Complex water quality drivers
Clifton Court Forebay water quality drivers
Better descriptions of and performance metrics for future conditions
Numerical model for water quality and water supply through the Delta system that has the ability to model population changes, demand pattern changes, sea level rise, and regional climate change effects on drinking water constituents of concern
Watershed models to better assess sources and sensitivities to sources under different conditions
Expertise on development of cost-effectiveness performance measures

Delta conveyance Considerations:

1. There are six existing intakes that receive water conveyed through the Delta and two additional intakes planning to do the same.
2. Only a portion of this water is used for drinking, other portions are used for domestic, industrial, commercial, landscaping, and agricultural purposes, which may have different water quality considerations.
3. The multiple barrier approach should be used to protect drinking water under any scenario.
4. Drinking water quality in the Delta has historically focused on salinity, but needs to focus on a broader spectrum of parameters to avoid redirected water quality impacts and to understand impacts on the recipient water treatment plants.
5. Monthly sampling may not be adequate to understand water quality conditions at a location.
6. The variability of the Delta will change with climate change and with food web changes, these changes need to be better understood.
7. Restricting intakes to a smaller watershed increases the importance of source control within the watershed, as well as the importance of understanding sources that cannot be controlled and should instead be managed for.
8. Solutions should incorporate uncertainty, and maintain or increase flexibility to manage for water quality and water supply.

Appendix D:
Technical Memorandum: Identifying Water Treatment Plants using Delta Water as a Major Source

(Appendix D) Technical Memorandum - Draft

Date: July 19, 2007

Subject: Identifying Water Treatment Plants using Delta water as a Major Source

Author: Lisa M. Holm, P.E.
CALFED Water Quality Program

In early 2005, the Central Valley Drinking Water Policy Project Work Group initiated efforts to develop economic information related to water treatment and identified constituents of concern, as well as to develop conceptual model information from Delta diversions to treatment plants. CALFED Water Quality Program staff, in coordination with the CVDWP and CALFED implementing agencies, took on the initial task in coordination with the development of its Final Stage 1 Assessment project, in the hopes of both better describing the population of treatment plant processes

The California Department of Health Services (now the California Department of Public Health, DPH), one of the CALFED Water Quality implementing agencies, offered the use of its centralized database "PICME" – which contains data accounting for treatment plants, their processes and source waters, and even some water quality samples. Karen Larsen, CVRWQCB and leader of the CVDWP, developed a list of the counties covered by the Central Valley Regional Water Quality Control Board. With this list, and a list of counties receiving Delta water through federal or state water projects, Dr. David Spath, DPH, worked with DPH database staff to develop a list of all water systems within the geographically defined area. From this list, Dr. Spath eliminated systems relying solely on groundwater sources, resulting in a list of 627 water systems.

The list was organized into Regions/Counties, and further refined by eliminating systems that were small (by size or population), were using a spring or well as a source, or were coded as inactive, resulting in a total of 347 water systems (Figure 1). The regions were examined for the distribution of treatment plant sizes, using the information on service populations (Figures 2-6). Treatment systems, however, are categorized by retail populations (populations served treated water directly from the plant), whereas a number of large treatment systems can be entirely wholesale to other agencies for distribution, or a combination of wholesale and resale. This fact, as well as the missing population for a number of systems, makes the distributions less than perfect. Figures 2-6 indicate that the largest populations are served by the State Water Project and Bay-Area plants.

Having identified the geographic area of interest, and now aware of the large numbers of systems within that area, Elaine Archibald, working for CUWA and the CVDWP, and Leah Godsey-Walker, DPH, used their expertise in watershed assessments and sanitary survey to identify representative treatment systems within each of the desired regions. This resulted in a list of 54 treatment plants, which were then further explored using the PICME database.

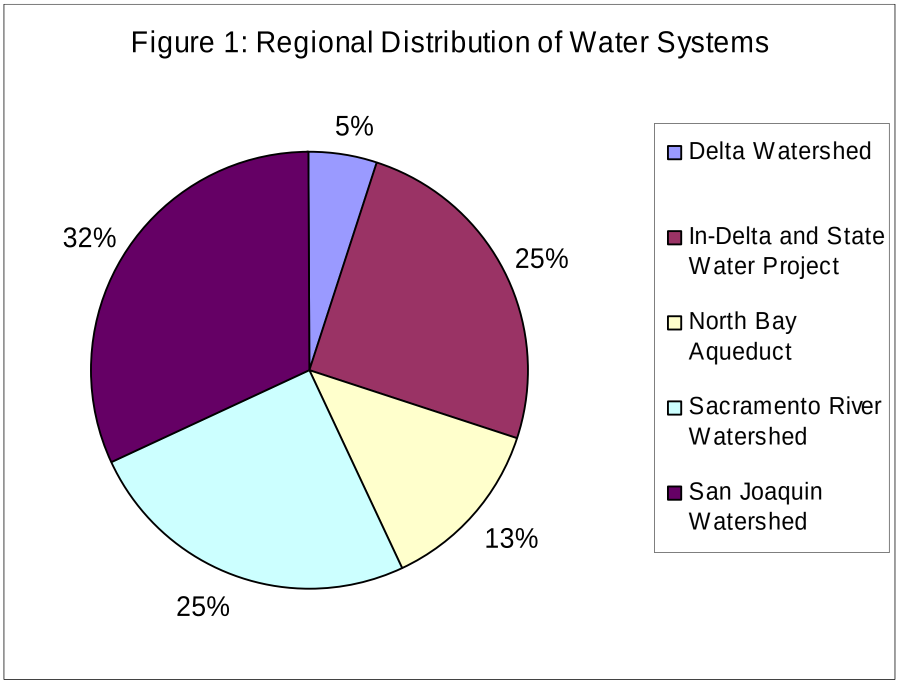


Figure 1: Regional Distribution of Water Systems
5%
25%
13%
25%
32%
Delta Watershed
In-Delta and State Water Project
North Bay Aqueduct
Sacramento River Watershed
San Joaquin Watershed

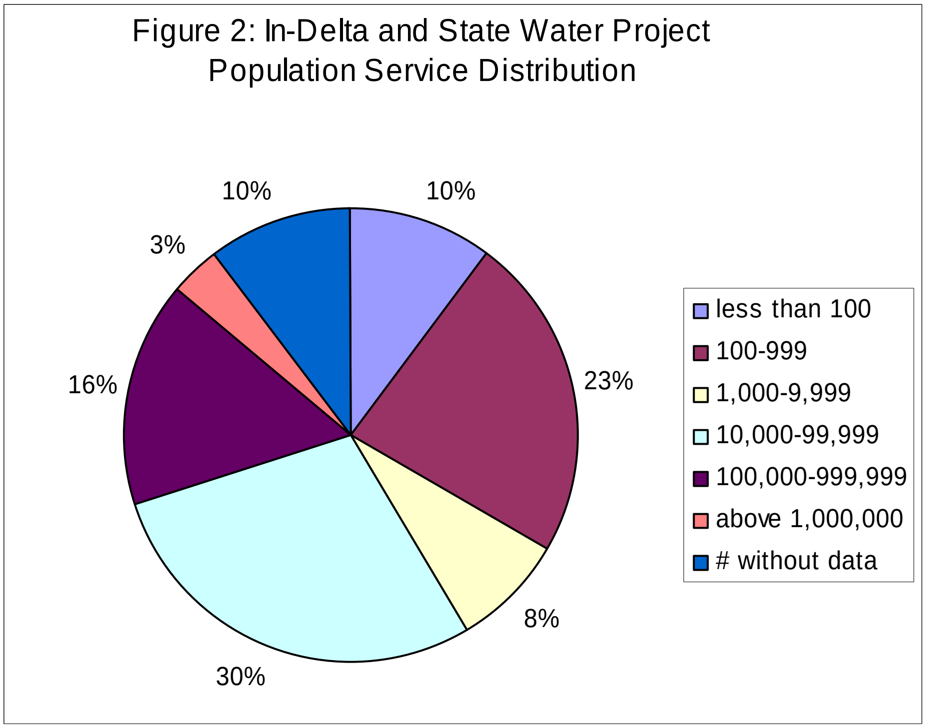


Figure 2: In-Delta and State Water Project Population Service Distribution
10%
23%
8%
30%
16%
3%
10%
less than 100
100-999
1,000-9,999
10,000-99,999
100,000-999,999
above 1,000,000
without data

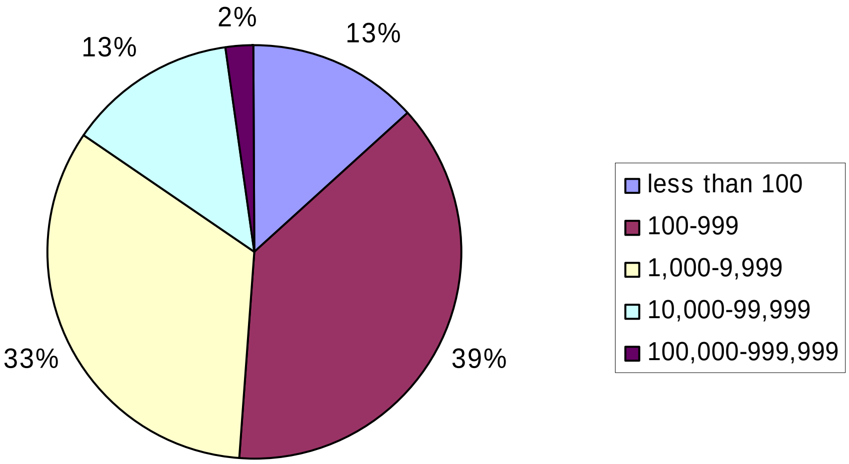


Figure 3: North Bay Aqueduct Systems' Populations

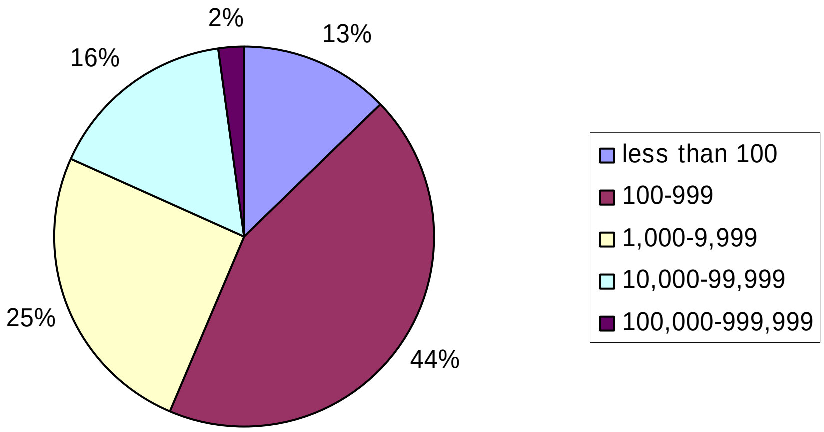


Figure 4: Sacramento River Watershed Systems' Populations

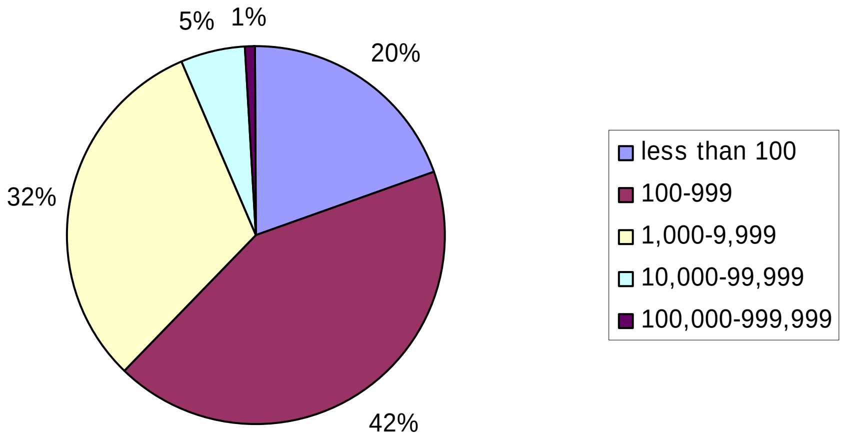


Figure 5: San Joaquin Watershed Systems' Populations

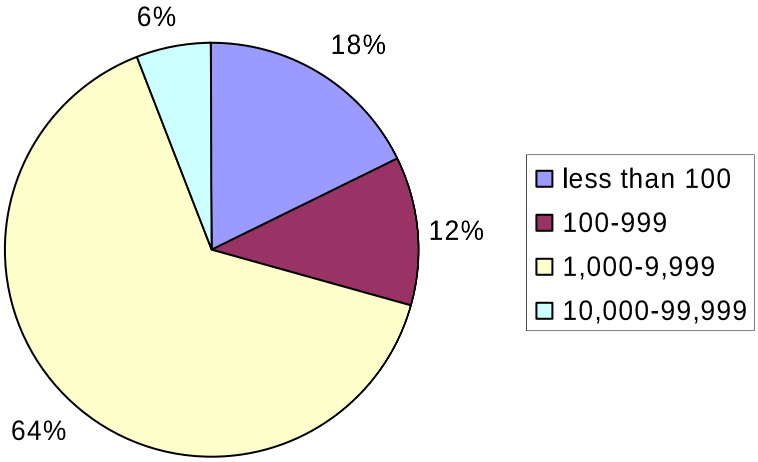


Figure 6: Delta Watershed Systems' Population

Appendix A is a table of the identified 54 representative treatment plants. For the CALFED Final Stage 1 Assessment, the interest was in determining the range of treatment for Delta waters, the range of influent (source) water quality, and the range of resulting treated water quality. The

CALFED Water Quality Program goals are to achieve either raw water quality targets for bromide and organic carbon or to achieve an equivalent level of treated water quality. It would therefore be useful to know how far away treatment plants are from achieving this equivalent level of treated water quality. CALFED staff therefore pulled the exisiting PICME data on the treatment plant processes for the 54 plants.

CALFED and CDPH staff joined CALFED consultant Brown and Caldwell to discuss the 54 representative treatment plants, their infrastructure, their intake locations, and their treatment processes, collectively referred to as "conceptual models". It became clear that the PICME data was out-of-date or unclear for some plants, so the "conceptual models" were organized into a memorandum and both CDPH District Engineers and utility staff were invited to provide corrections. Utility staff were requested to provide some additional information, not collected by CDPH, regarding the percentage of Delta water used by the plant and the amount of retail/wholesale water supplied by the plant. The corrected "conceptual models" are presented in Appendix B. The utility questionnaire is attached as Appendix C.

Remarks received through both efforts were assembled into a large spreadsheet. The results were also used to assemble descriptive bar charts of the sizes of plants and use of disinfectants and filtration processes. Figure 7 shows the distribution of the 54 treatment plants among the defined regions (the majority are in the Upper Watershed and California Aqueduct regions). Figure 8 shows the distribution of Delta water use by region (to the degree that this information was provided by utility staff). Figures 9 and 10 show the distribution of filtration and disinfection types among the regions; filtration categories are not always specific in the PICME database. If the 54 treatment plants are truly representative of the larger population of treatment plants using surface water from the Delta and its tributaries, then the most common practices are conventional treatment plants and chlorine disinfection. It is possible that many of the plants use chlorine as their primary disinfectant and then add ammonia to achieve a chloramine residual, and that the PICME does not adequately capture this detail. This also indicates that our range of treatment processes and disinfectants is not especially large, and would seem to indicate that it is possible to use representative plants to understand the larger treated water quality reality. Figure 11 illustrates the distribution of plant sizes by the defined regions.

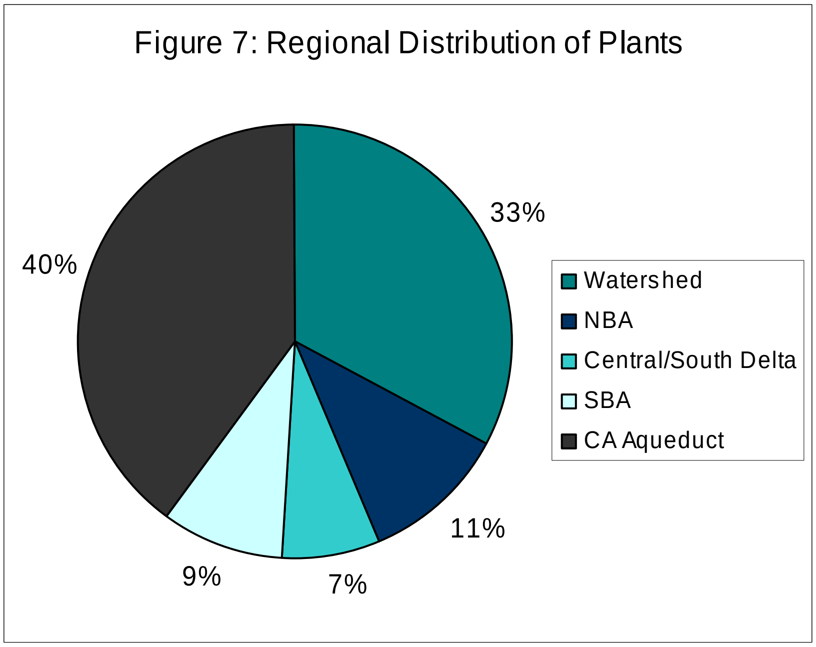


Figure 7: Regional Distribution of Plants
33%
40%
11%
9%
7%
Watershed
NBA
Central/South Delta
SBA
CA Aqueduct

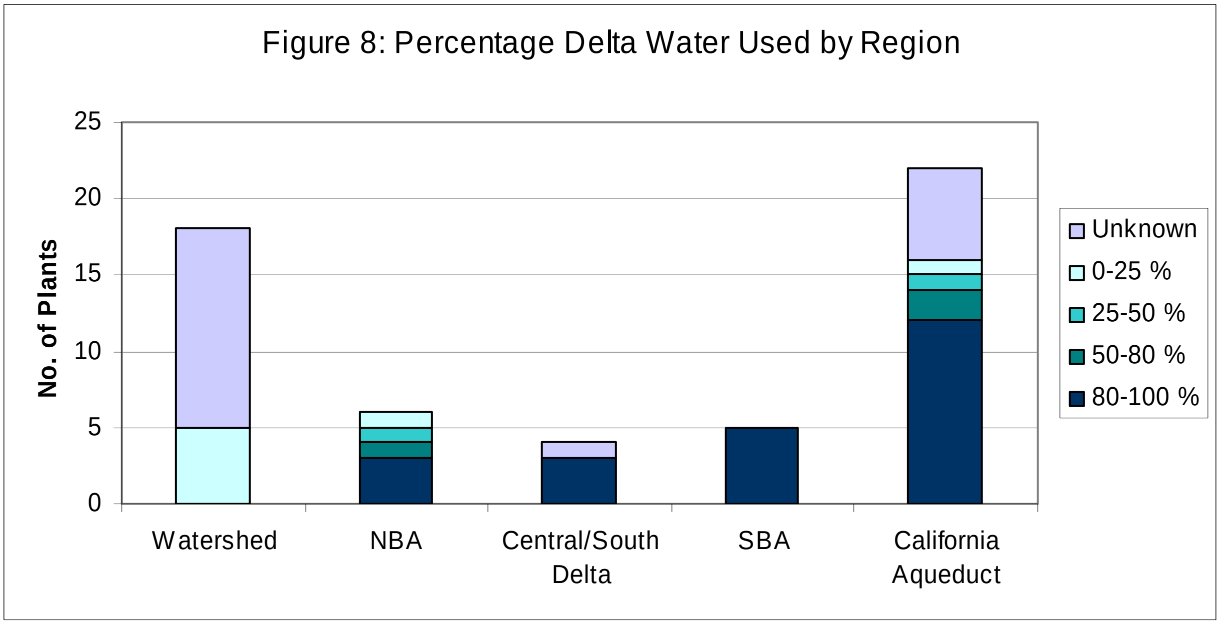


Figure 8: Percentage Delta Water Used by Region
No. of Plants
0
5
10
15
20
25
Watershed
NBA
Central/South Delta
SBA
California Aqueduct
Unknown
0-25 %
25-50 %
50-80 %
80-100 %

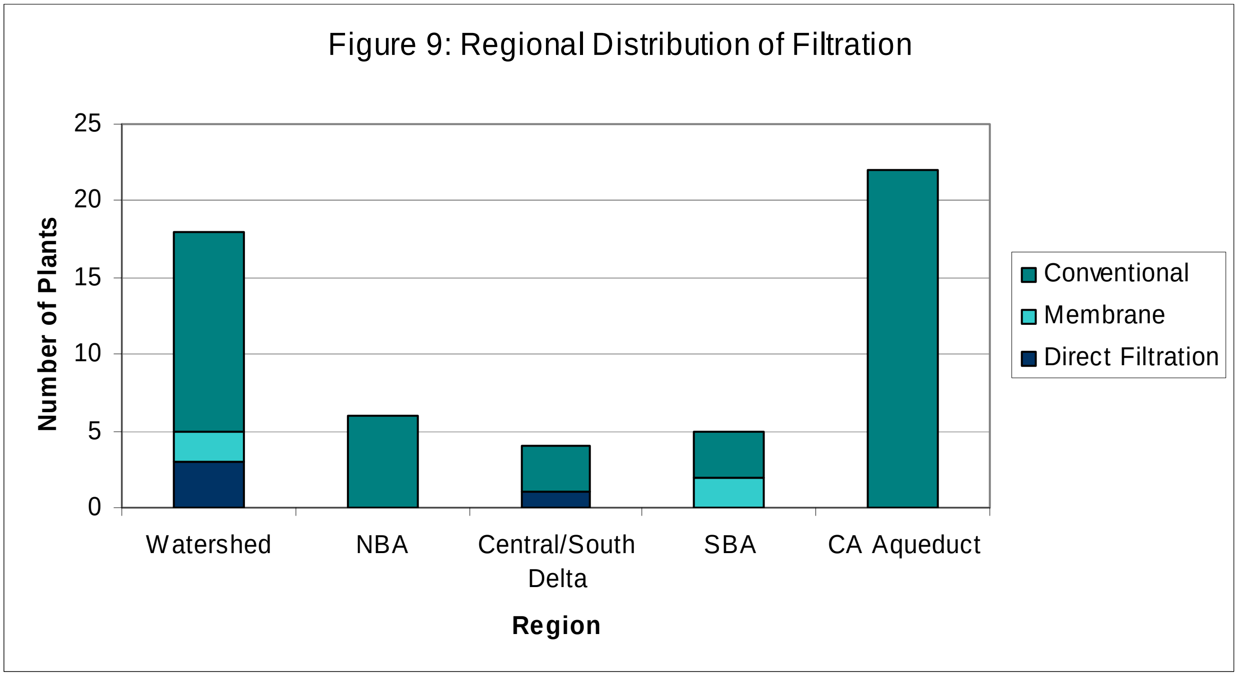


Figure 9: Regional Distribution of Filtration
25
20
15
10
5
0
Number of Plants
Watershed
NBA
Central/South Delta
SBA
CA Aqueduct
Region
Conventional
Membrane
Direct Filtration

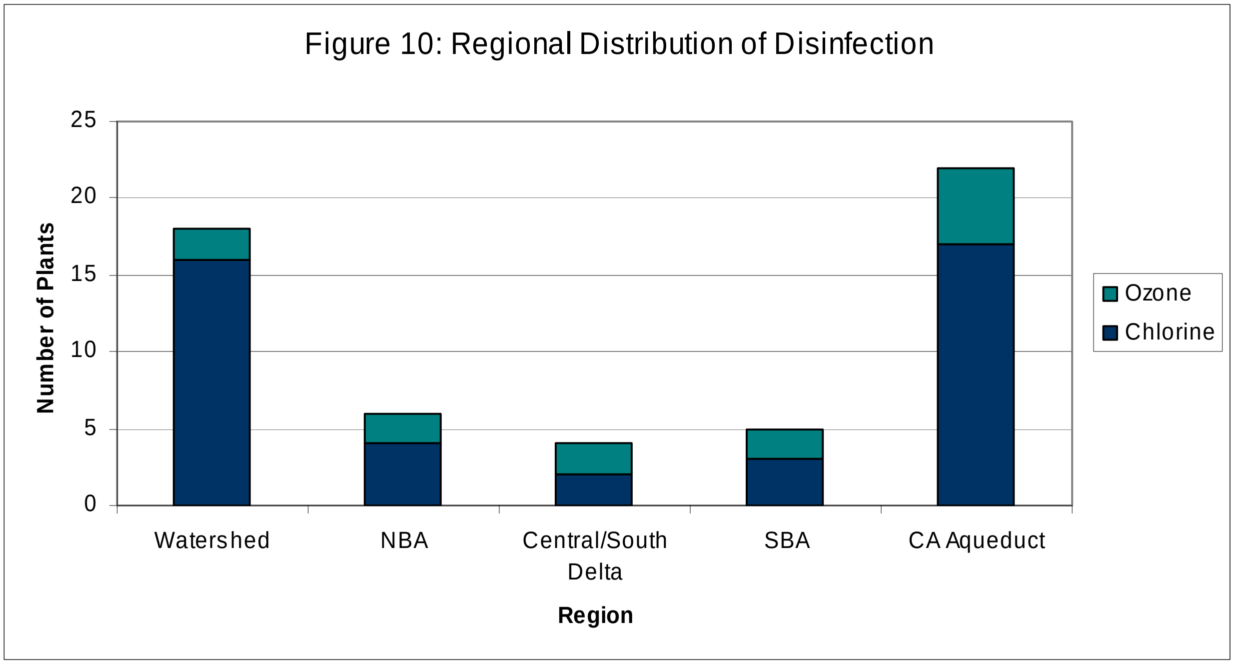
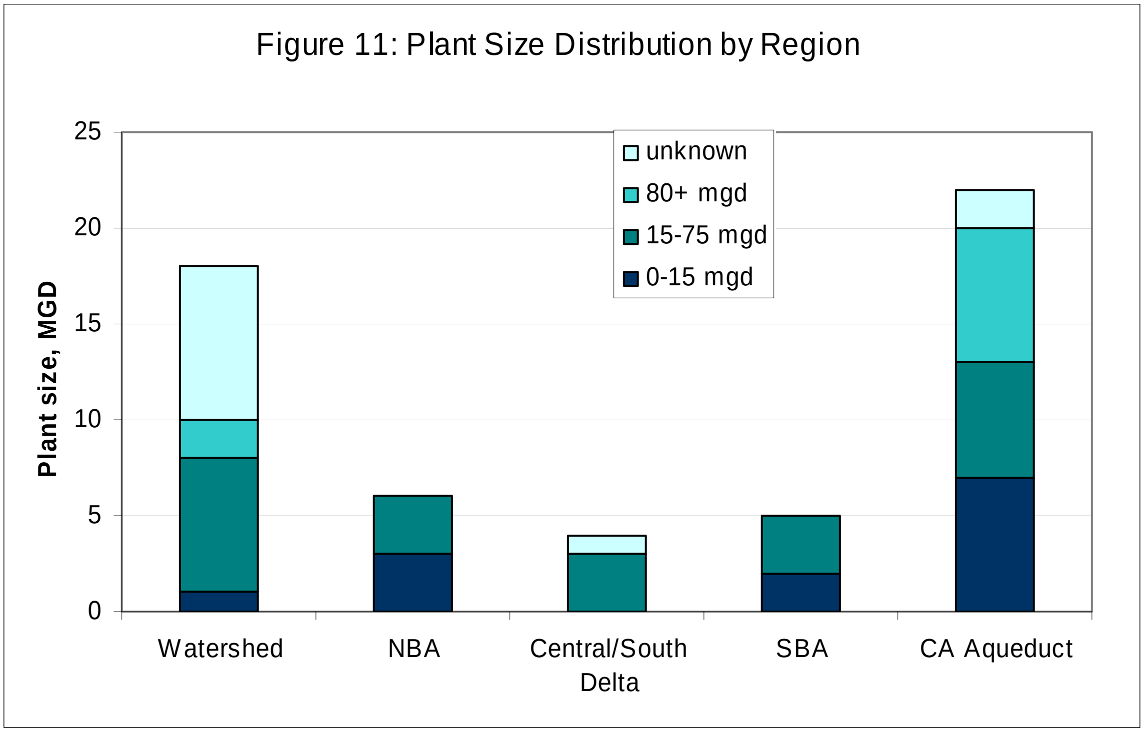


Figure 10: Regional Distribution of Disinfection
25
20
15
10
5
0
Number of Plants
Watershed
NBA
Central/South Delta
SBA
CA Aqueduct
Region
Ozone
Chlorine



The next step in data mining was to explore the water quality data for the 54 representative water treatment plants. Water quality data was available for treatment plant effluent, influent and source waters, at varying degrees of frequency. PICME water quality data captures instantaneous samples for a large variety of parameters, and this search focused on disinfection by-products, by-product precursors, and related parameters such as salinity and alkalinity. Table 1 contains a list of the

Table 1: Water Quality Parameters

Treated Water Quality Parameters			Raw Water Quality Parameters
Alkalinity (Total) as CaCO3	Total Dissolved Solids	Total Organic Carbon (TOC)	Alkalinity (Total) as CaCO3
Color	Turbidity, Laboratory	Odor Threshold @ 60 C	Total Organic Carbon (TOC)
Carbon Tetrachloride	Dibromomethane	Bromide	Total Dissolved Solids
Bromodichlormethane (THM)	Dibromoacetic Acid (DBAA)	Monochloroacetic Acid (MCAA)	Turbidity, Laboratory
Bromoform (THM)	Trichloroacetic Acid (TCAA)	Haloacetic Acids (5) (HAA5)	Bromide
Dibromochloromethane (THM)	Bromochloromethane	Dichloroacetic Acid (DCAA)	
Chloroform (THM)	Bromochloroacetic Acid (BCAA)	DCPA (Total Di & Mono Acid Degradates)	
Total Trihalomethanes	Monobromoacetic Acid (MBAA)		

parameters investigated in treated and source water quality. Appendix D is a compilation of the available number of data points for each plant for the parameters downloaded.

Although the water quality data is not as comprehensive as desired, some statistical and graphical analyses were performed to more closely examine the data. For many plants, there were few or no points for many of the parameters. It should also be noted that this data analysis does not correspond with how treated water quality is analyzed for compliance with drinking water regulations. Because the CALFED Water Quality Program focuses on disinfection byproducts and their precursors, timeseries of the available data on both byproducts and precursors were generated for each region. In the timeseries figures, plants are not specifically identified, and numbers do not necessarily correlate between figures. The figures were produced merely to illustrate the range of water quality available in each region through the DHS database. The figure scales are set so that all figures can be directly compared, and the time period is 1990-2006 for the purposes of displaying available information over a longer hydrologic period. Statistical Evaluations and Charts were also prepared and follow the time series section.

The Upper Watershed:
Treatment Plants located on the Sacramento and San Joaquin Rivers are grouped as "Watershed Plants", and essentially represent plants that deal with the more normal anthropogenic sources of drinking water constituents of concern, without seawater intrusion. This limited data set suggests that all investigated parameters are the lowest in this region's source water, with occasional higher organic carbon/turbidity events. Figures 12-16 show the disinfection byproduct precursors, turbidity, alkalinity, and total dissolved solids data for these plants. There were also a couple plants that relied on local watersheds, and these data are presented in Figures 17 – 20. The local watersheds appear to have water quality in a range similar to the upper watershed, with significantly higher alkalinity and slightly higher total dissolved solids. Appendix E contains the list of plants whose data is presented in these plants.

Figure 12: Bromide in Watershed Source Water

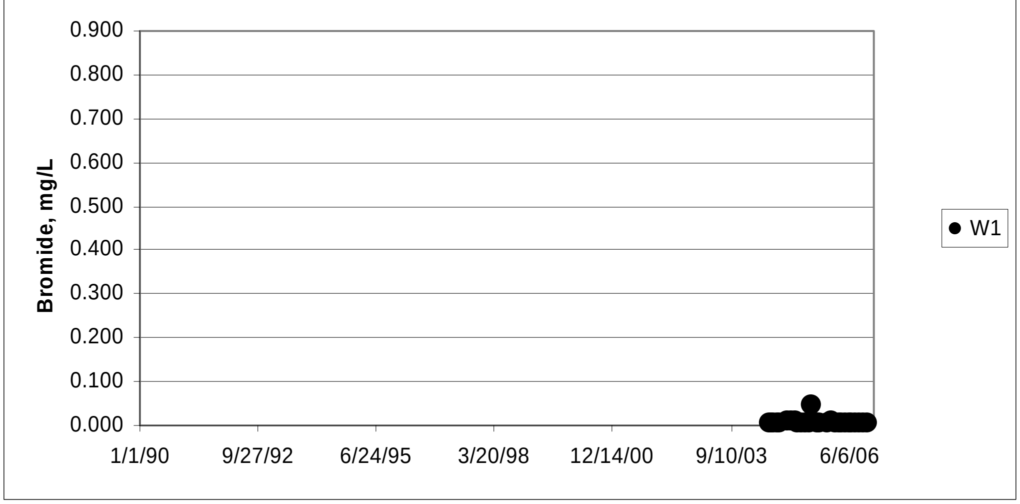


Figure 13: TOC in Watershed Source Waters

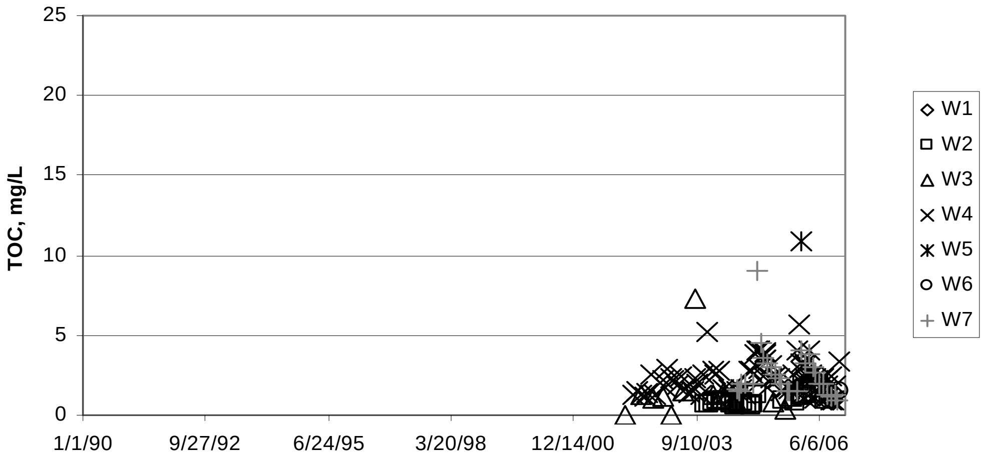


Figure 14: Turbidity in Watershed Source Waters

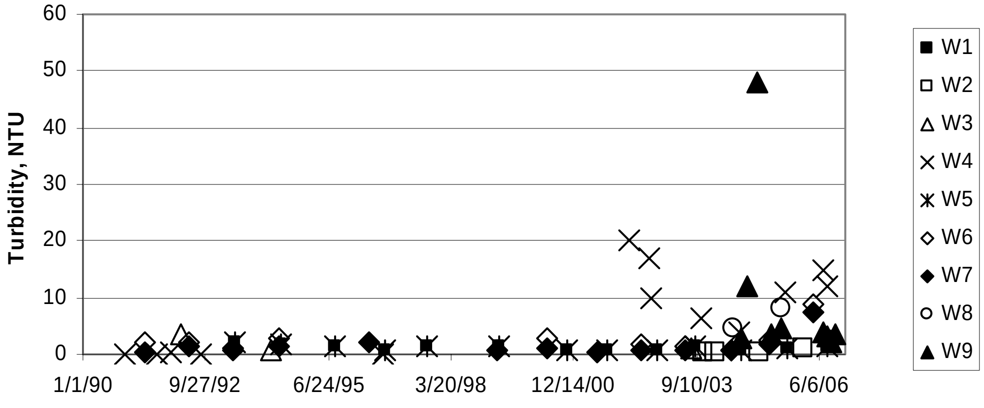


Figure 15: Alkalinity in the Watershed

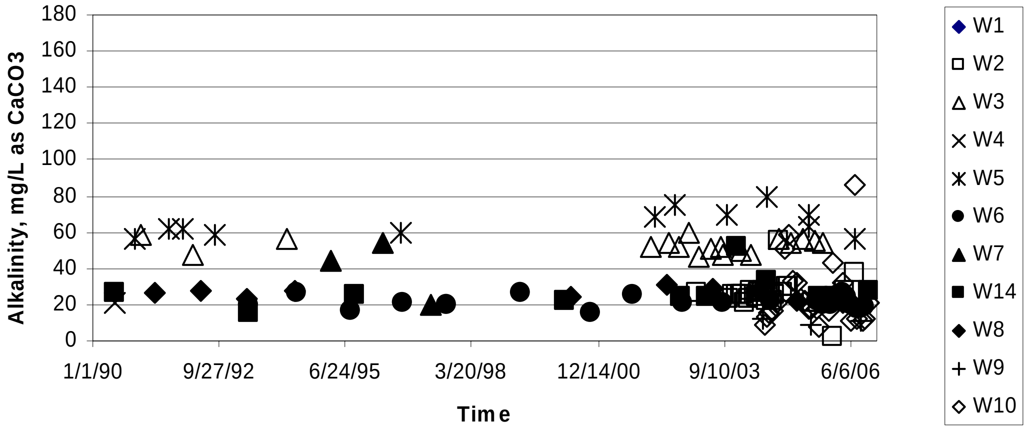


Figure 16: TDS in Watershed Source Water

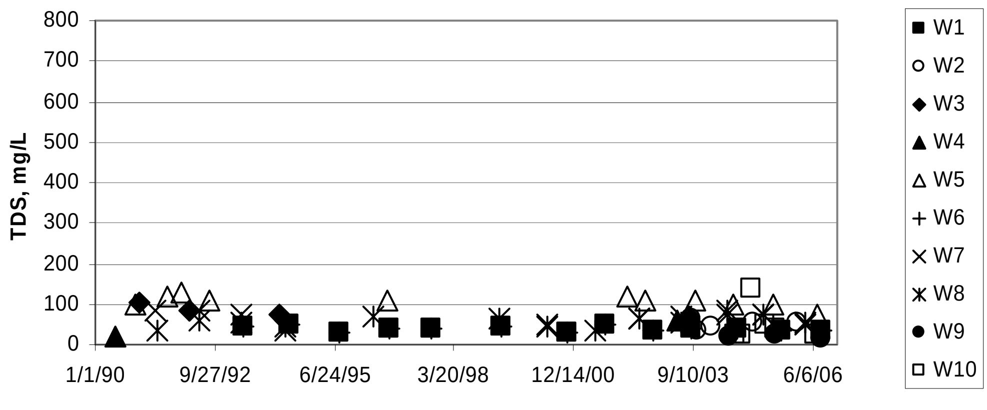


Figure 17: Bromide in Local Reservoir Source Water

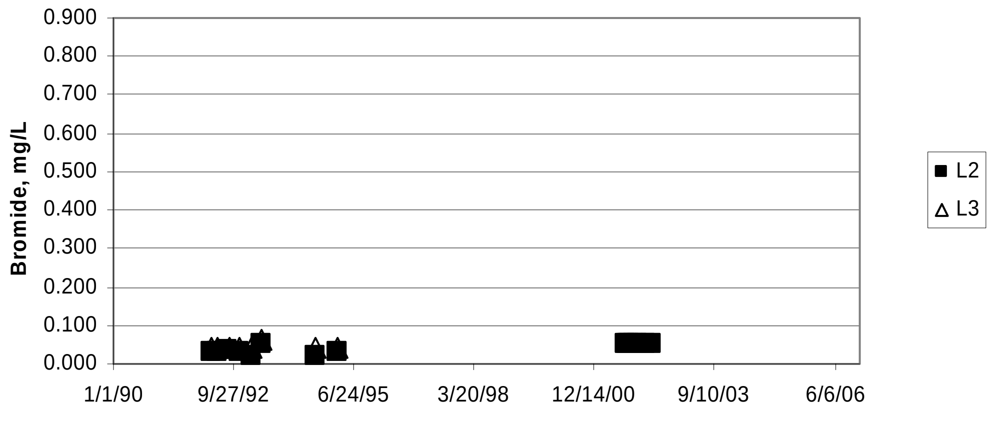
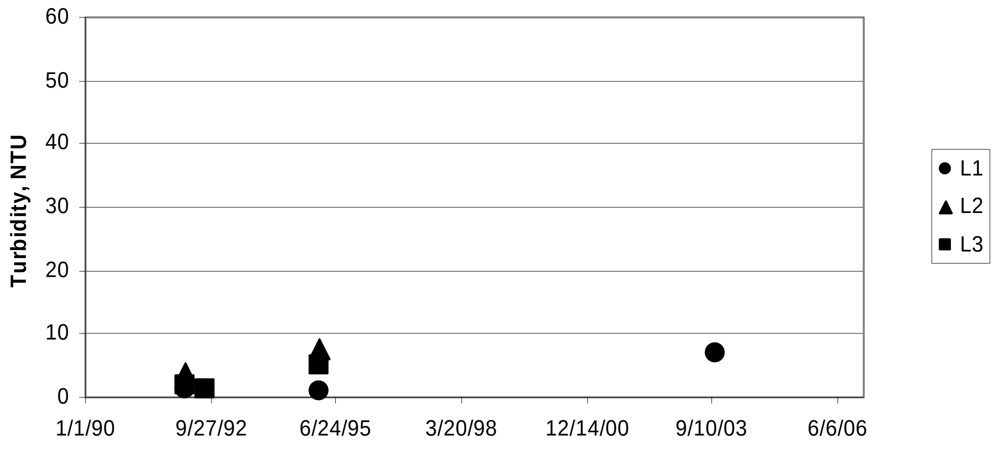
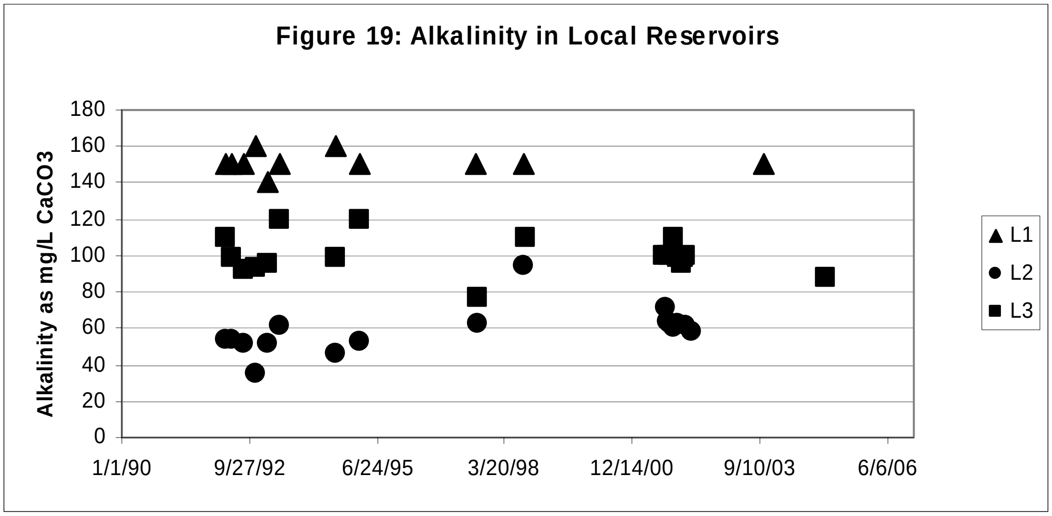
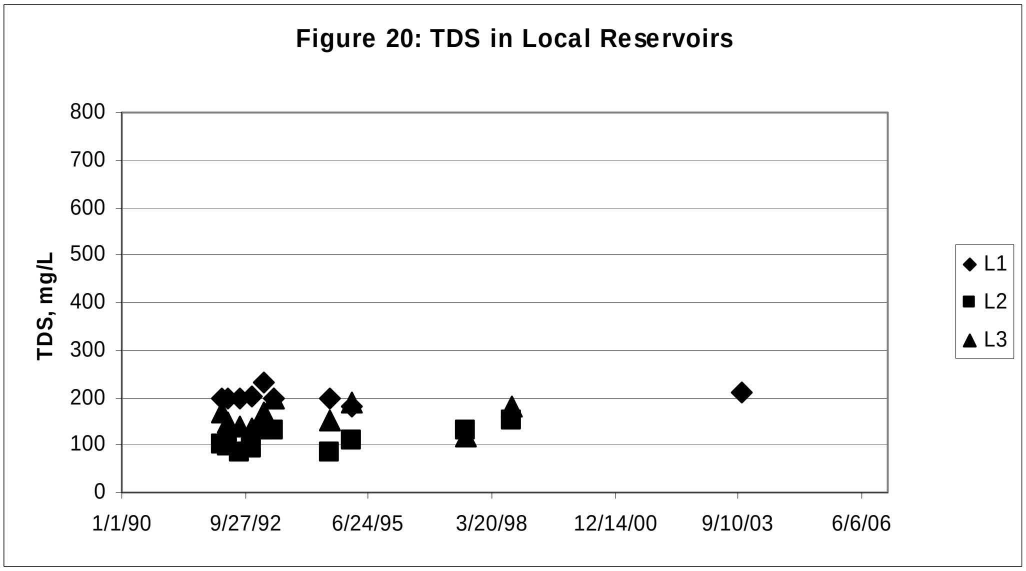


Figure 18: Turbidity in Local Reservoirs







The DPH database also contains data on treated water quality from these water treatment plants (WTPs). Figures 21-26 show the data for total trihalomethanes (TTHMs- the sum of 4 trihalomethane species), five haloacetic acid species (HAA5s), bromate, and turbidity, total dissolved solids (TDS), and total organic carbon (TOC). Current regulatory levels of TTHMs, HAA5s, and bromate are annual average of quarterly averages of 80 µg/L, 60 µg/L, and 10 µg/L respectively. CALFED source water quality targets are based on achieving 40 µg/L TTHMs, 30 µg/L HAA5, and 5 µg/L bromate. Although these data are not averaged appropriately, and regulation of these constituents changes over the period of time graphed, it does give some small indication of how treated water is meeting these goals. For example, since 2004, the data suggest that watershed and local watershed plants have been meeting these CALFED goals, with the exception of one bromate data point. Figures 27-30 are time series plots of the finished water of Local Reservoir WTPs. Turbidity, TDS, and TOC of finished water provides an indication of the aesthetic qualities of the water, which are very good in this region.

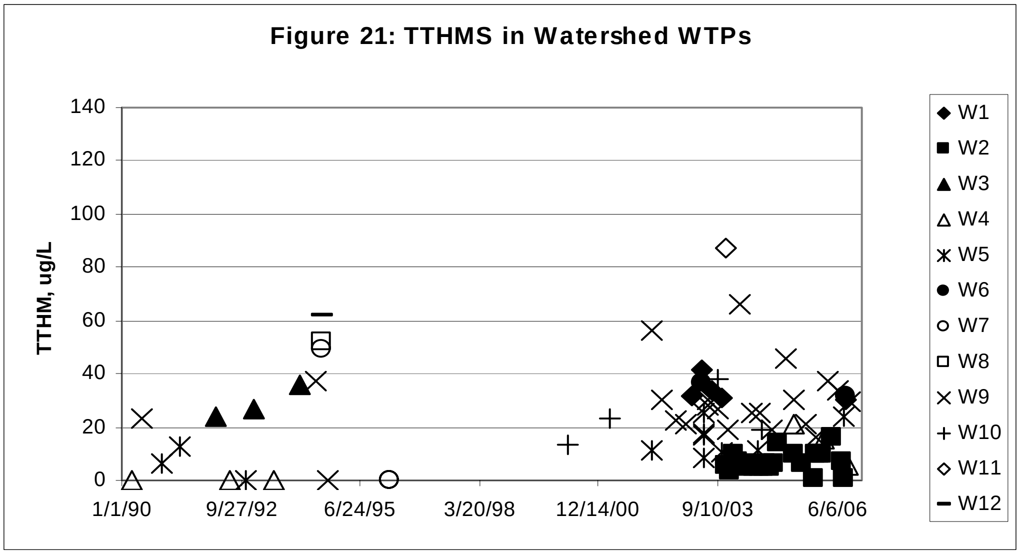


Figure 21: TTHMS in Watershed WTPs
TTHM, ug/L
0
20
40
60
80
100
120
140
1/1/90
9/27/92
6/24/95
3/20/98
12/14/00
9/10/03
6/6/06
W1
W2
W3
W4
W5
W6
W7
W8
W9
W10
W11
W12

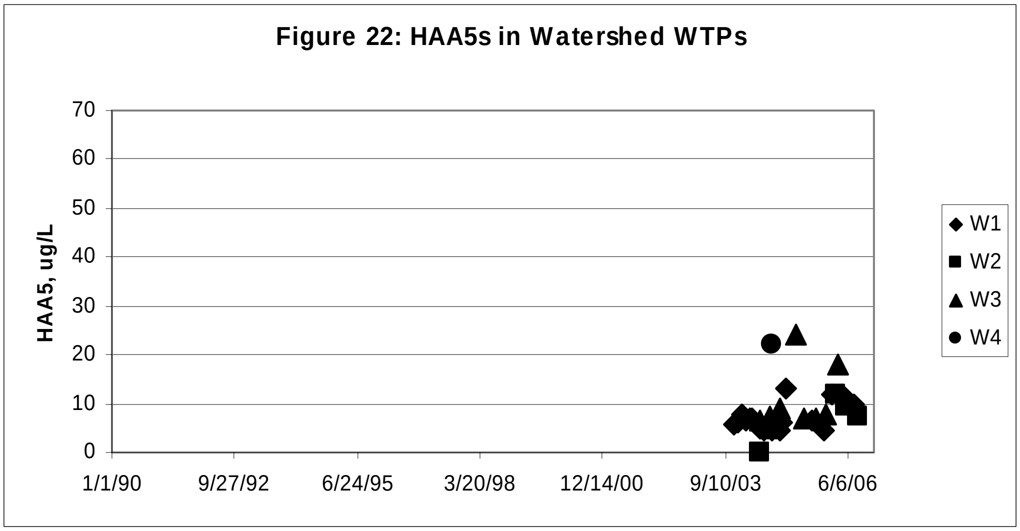


Figure 22: HAA5s in Watershed WTPs
HAA5, ug/L
0
10
20
30
40
50
60
70
1/1/90
9/27/92
6/24/95
3/20/98
12/14/00
9/10/03
6/6/06
W1
W2
W3
W4

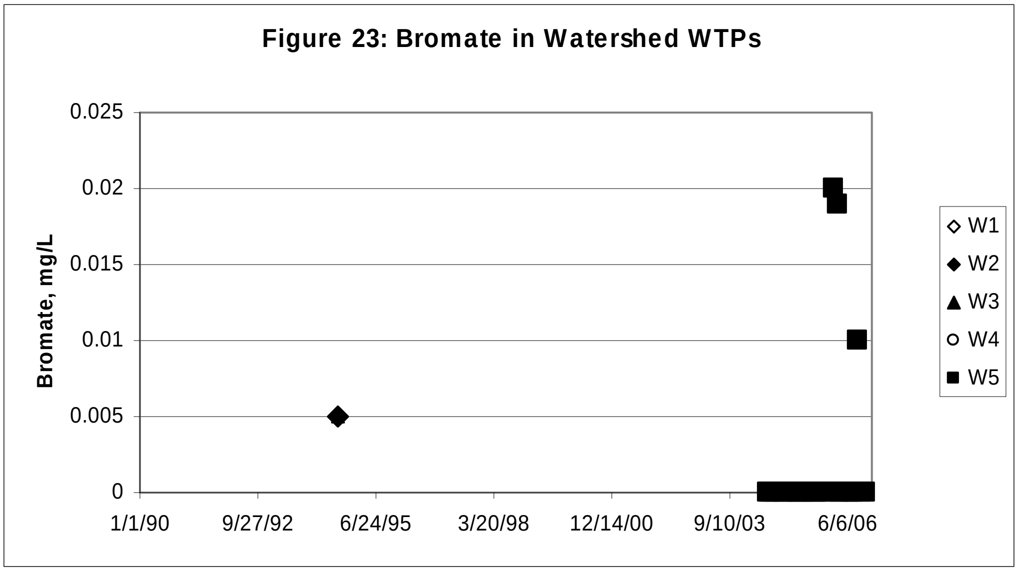


Figure 23: Bromate in Watershed WTPs
Bromate, mg/L
0
0.005
0.01
0.015
0.02
0.025
1/1/90
9/27/92
6/24/95
3/20/98
12/14/00
9/10/03
6/6/06
W1
W2
W3
W4
W5

Figure 24: Turbidity in Watershed WTPs

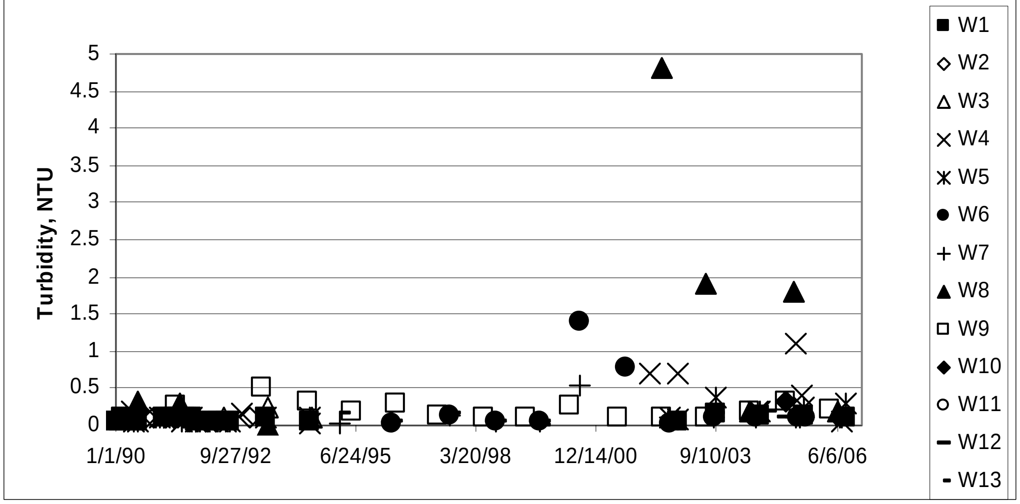


Figure 25: Total Organic Carbon in Watershed WTPs

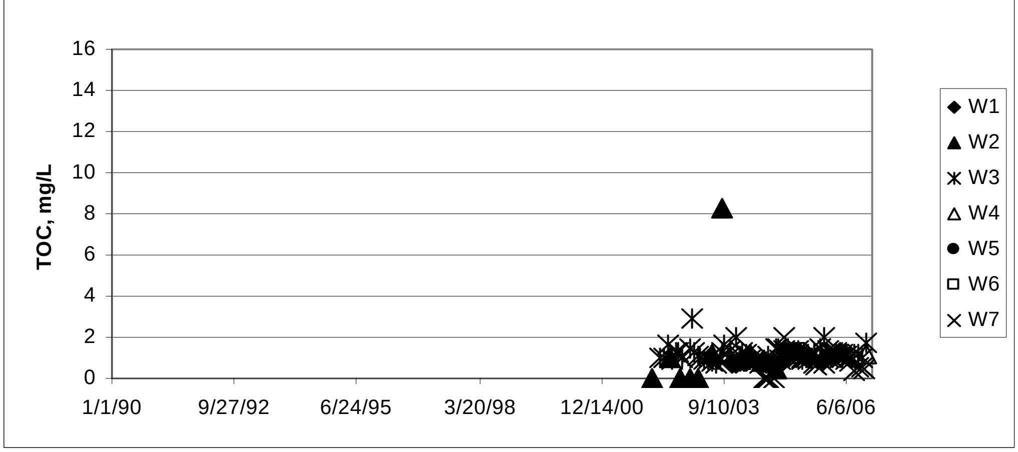


Figure 26: Total Dissolved Solids in Watershed WTPs

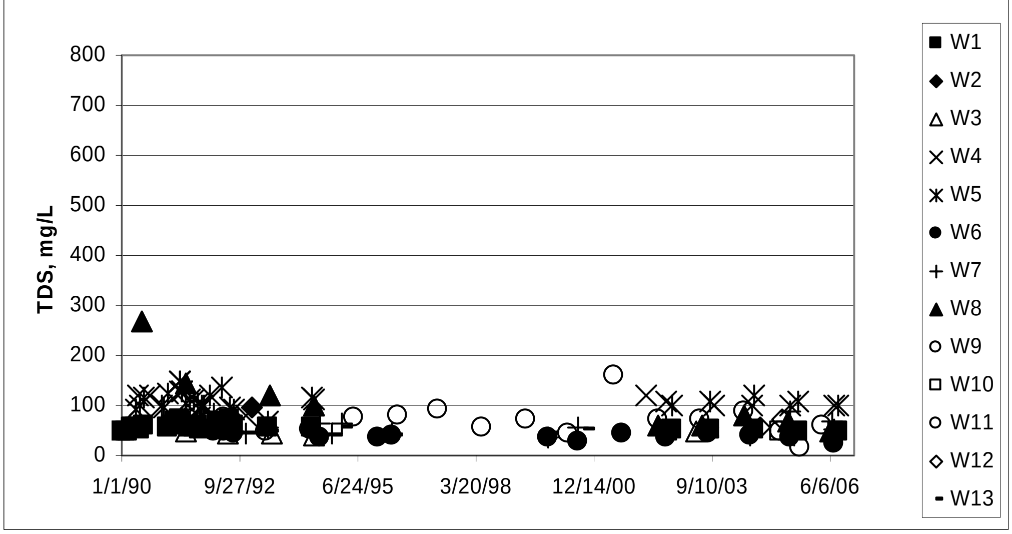


Figure 27: TTHMs in Local Watershed WTPs

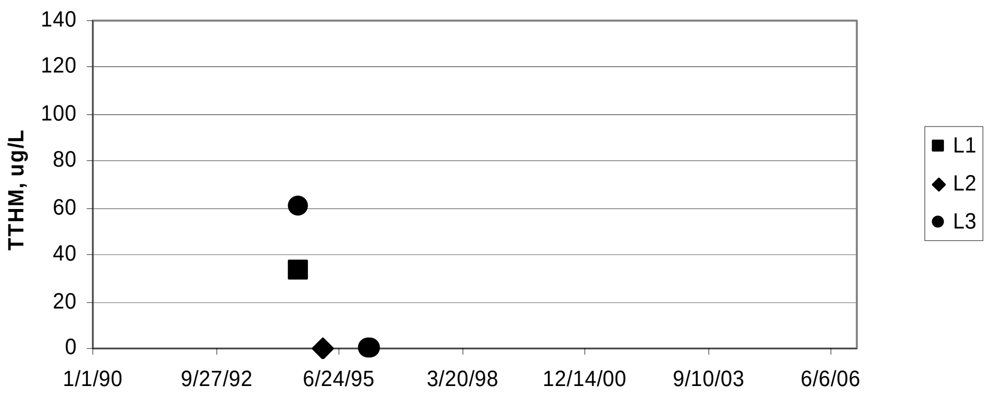


Figure 28: Bromate in Local Reservoir WTPs

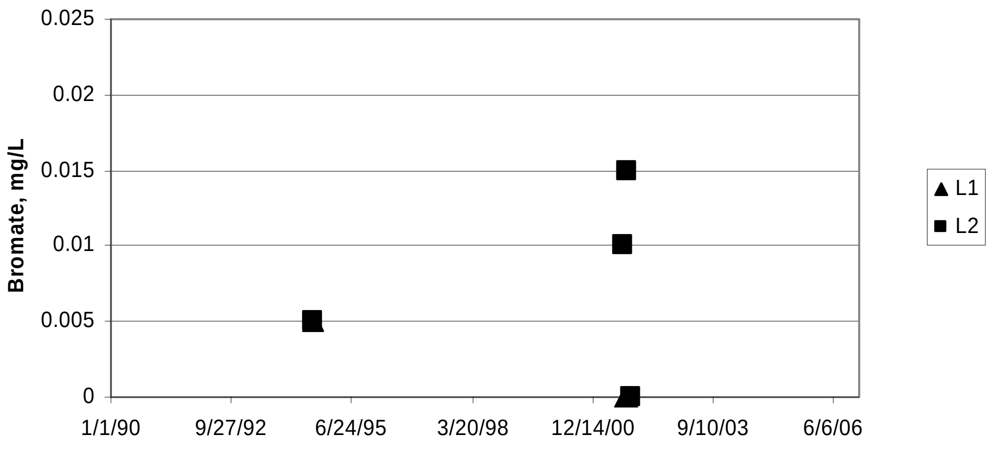
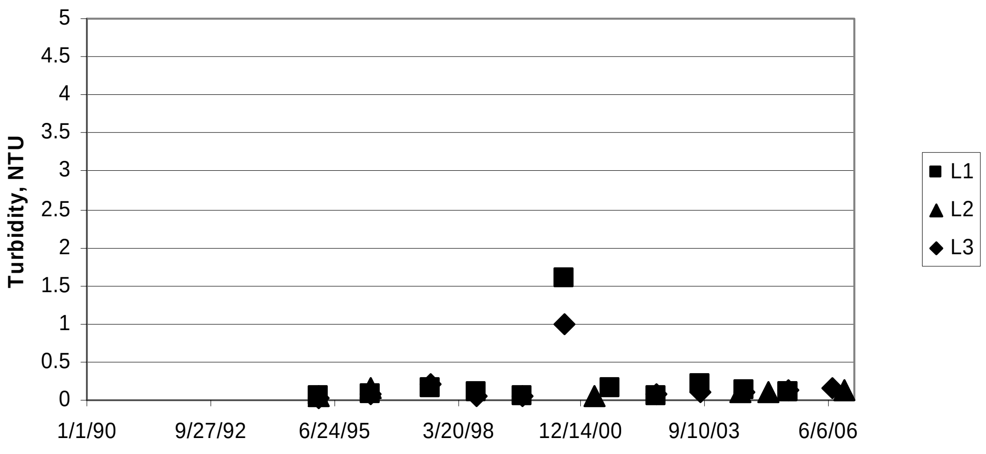
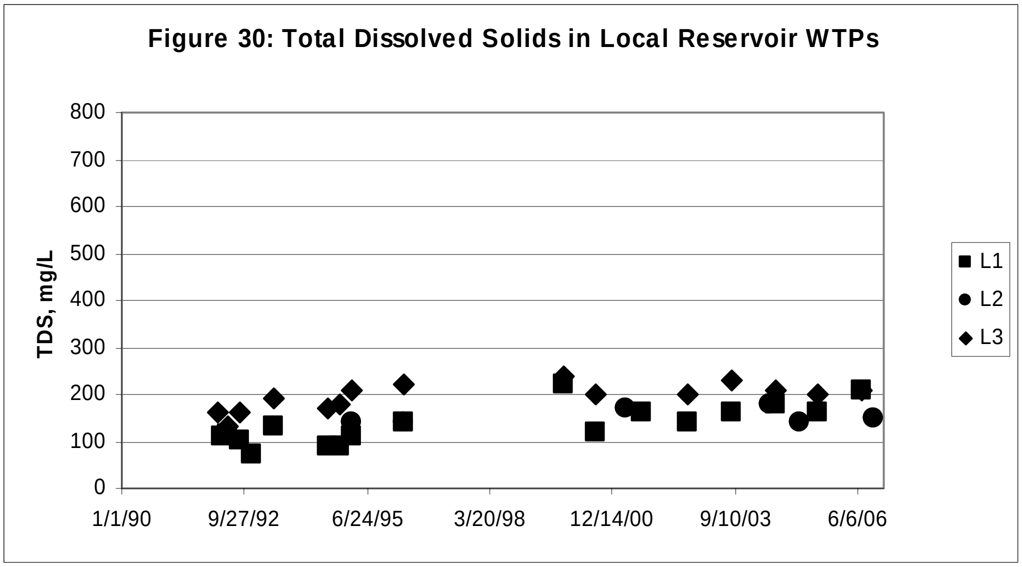


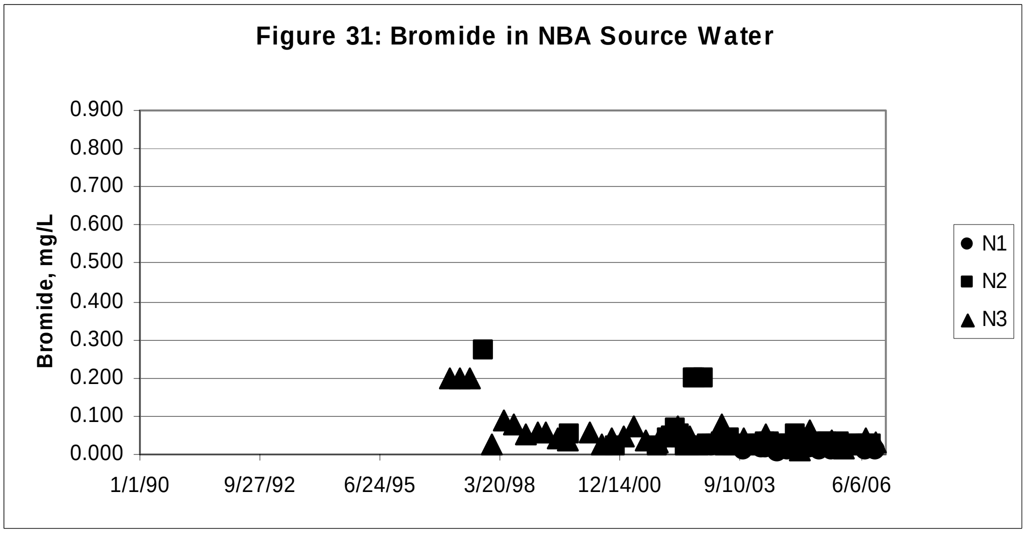
Figure 29: Turbidity in Local Reservoir WTPs





North Bay Aqueduct Region:

Treatment Plants utilizing water from the North Bay Aqueduct are grouped as "North Bay Aqueduct Plants", and represent plants that deal with organic carbon levels that far exceed CALFED source water targets but bromide levels that generally meet CALFED source water targets, with periodic excursions above the targets. Figures 31-35 show disinfection byproduct precursors, turbidity, total organic carbon, and total dissolved solids data for these plants. TOC and turbidity concentrations in the NBA exceed any other region examined. Alkalinity is very high and variable, but TDS is similar to local watershed ranges.



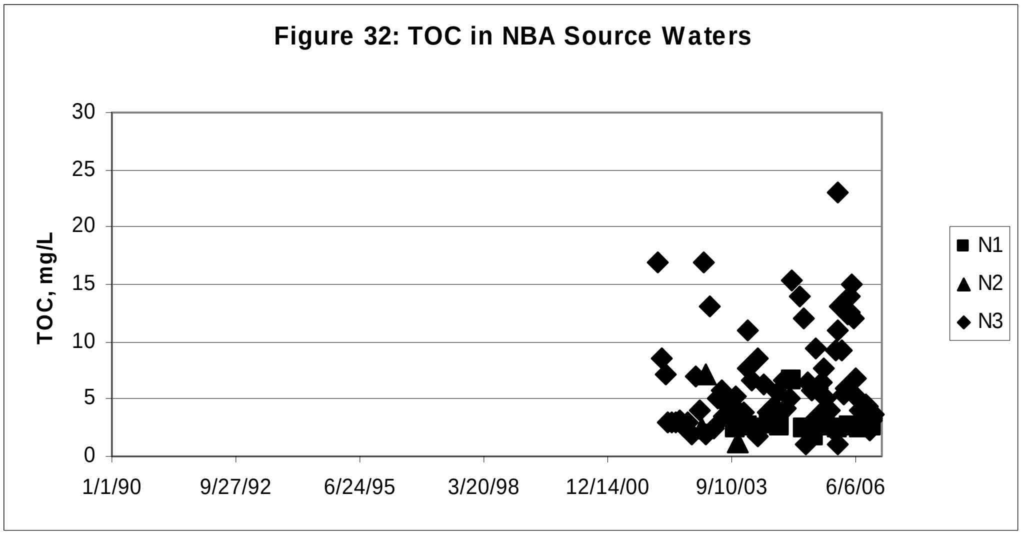


Figure 32: TOC in NBA Source Waters

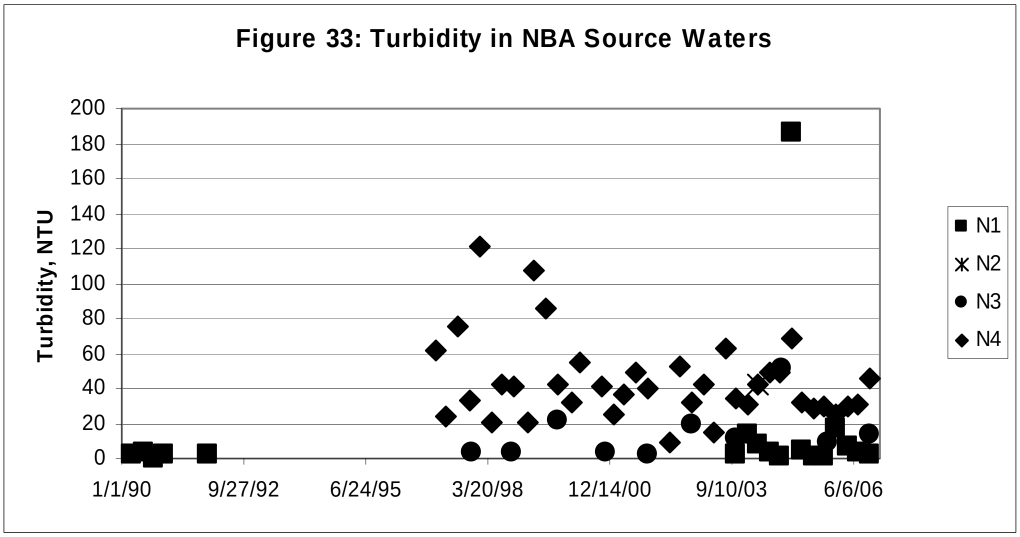


Figure 33: Turbidity in NBA Source Waters

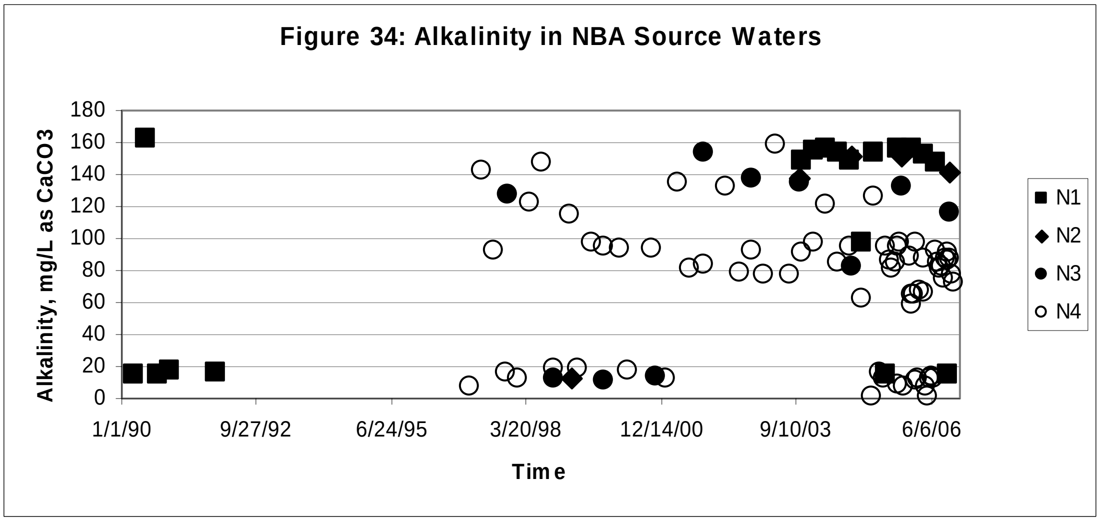
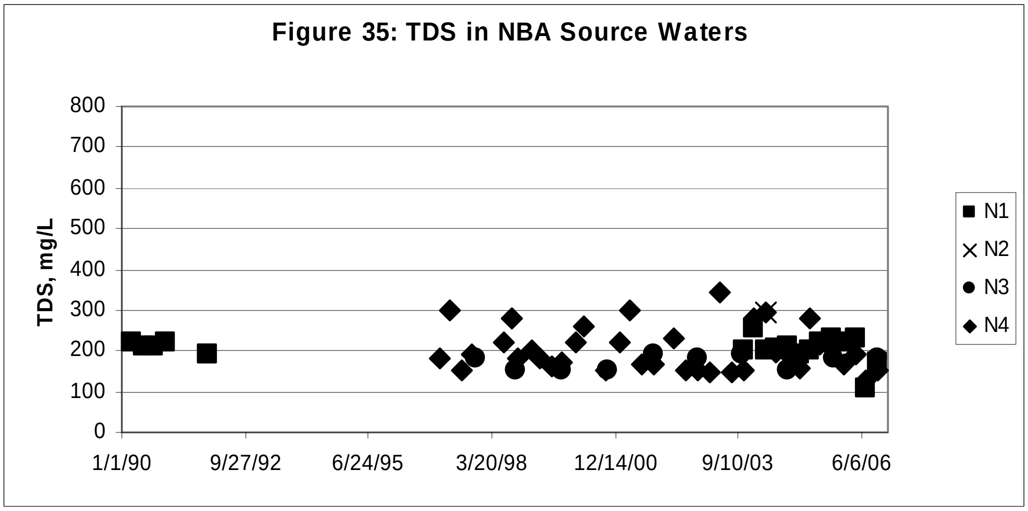


Figure 34: Alkalinity in NBA Source Waters



The DPH database also contains data on treated water quality from these water treatment plants (WTPs). Figures 36-41 show the data for TTHMs, HAA5s, bromate, turbidity, TDS, and TOC. Data for the NBA plants are particularly sparse, with some small indication that NBA plants may be meeting or be close to meeting these CALFED goals. Turbidity, TDS, and TOC of finished water provides an indication of the aesthetic qualities of the water, which are good in this region, but the TOC variability in finished water suggests higher potential for disinfection byproduct formation in distribution systems with longer residence times.

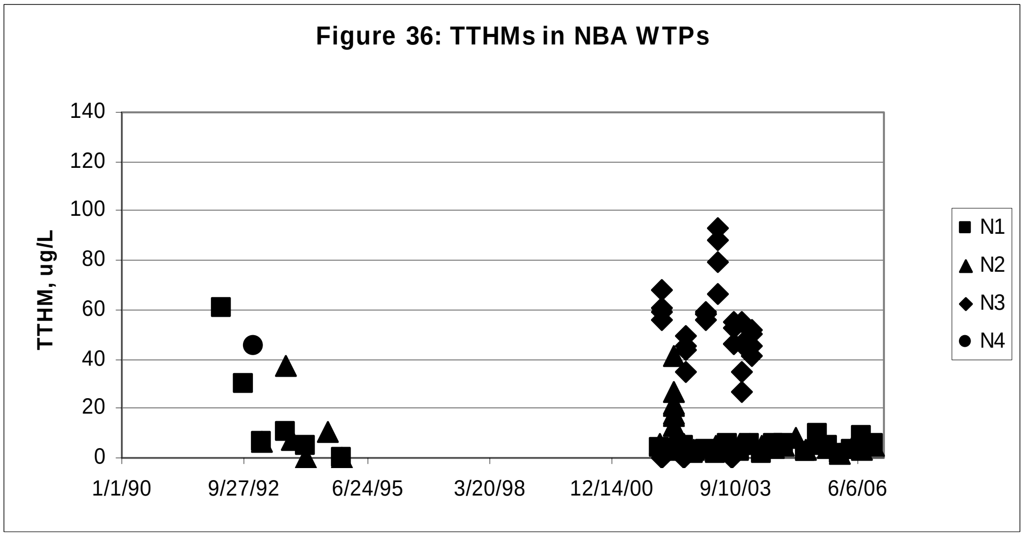


Figure 37: HAA5s in NBA WTPs

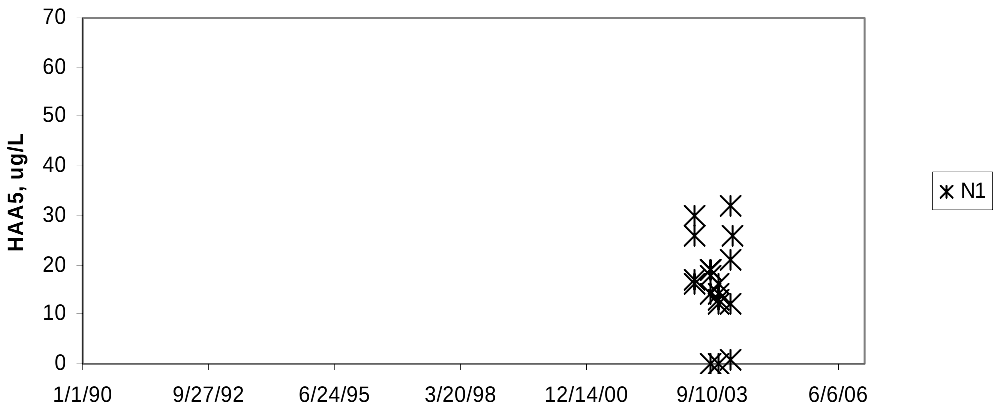


Figure 38: Bromate in NBA WTPs

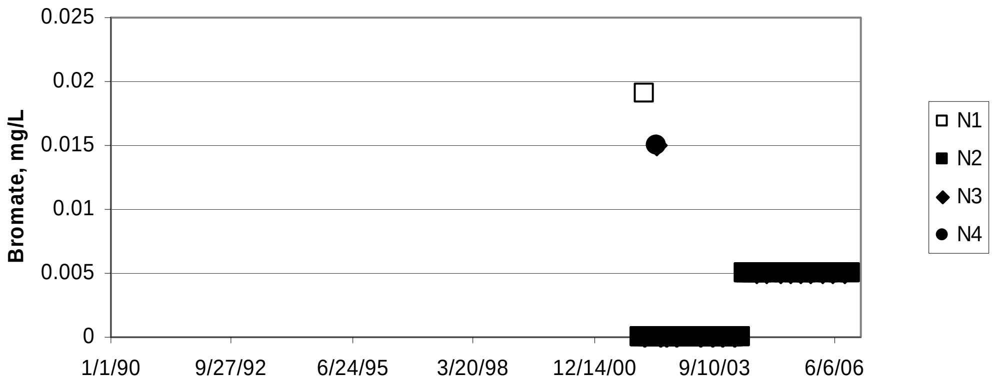


Figure 39: Turbidity in NBA WTPs

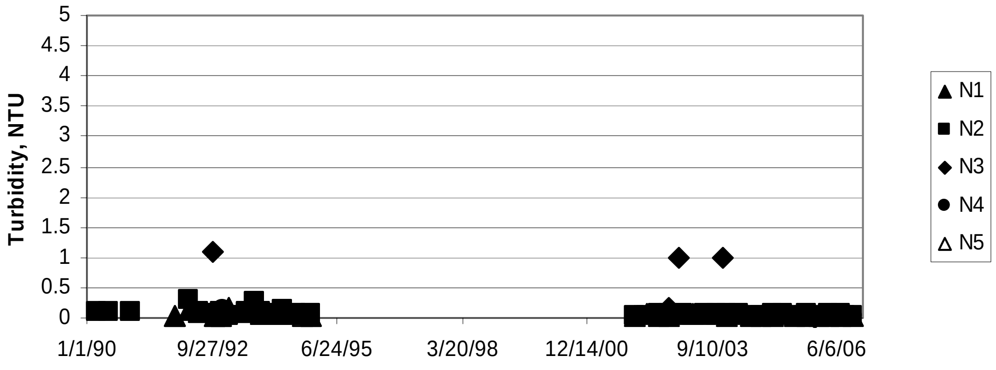


Figure 40: Total Dissolved Solids in NBA WTPs

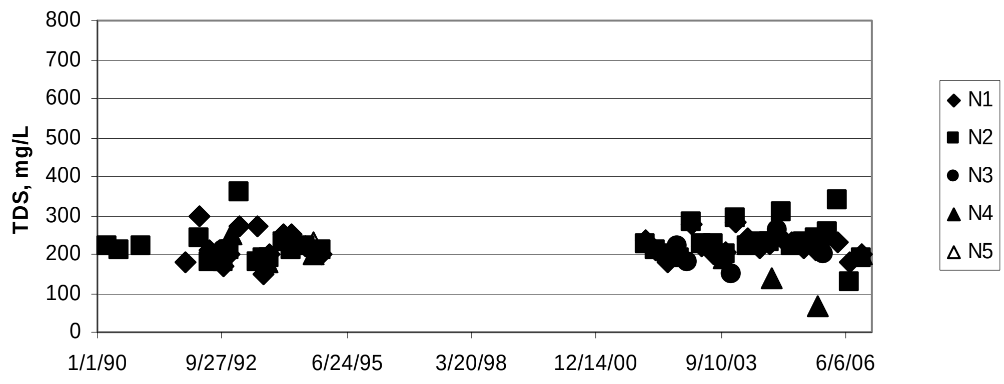
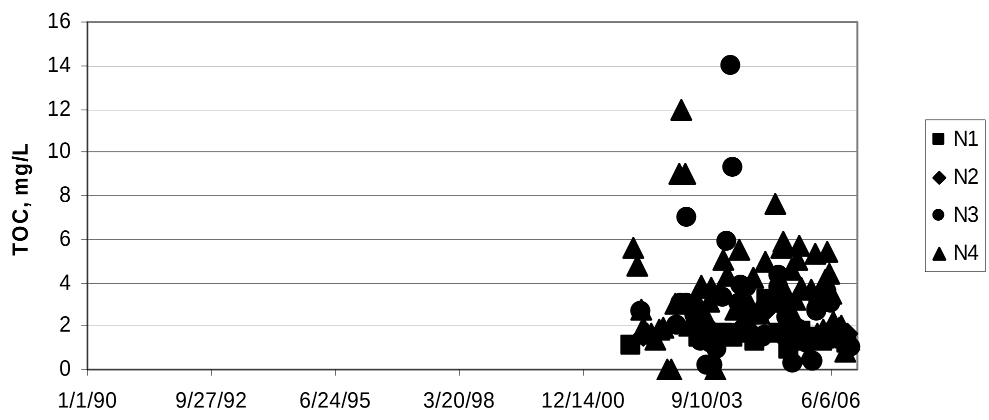


Figure 41: Total Organic Carbon in NBA WTPs



Central Delta/South Bay Aqueduct Region:

Treatment Plants utilizing water directly from the Delta (Contra Costa Water District, City of Antioch, City of Tracy) and South Bay Aqueduct are grouped as "Central Delta/South Bay Aqueduct Plants", and represent plants that deal with highly variable water that can significantly exceed CALFED source water targets. Figures 41-45 show the precursor, turbidity, alkalinity, and total dissolved solids data for these plants. This data suggest that bromide levels can widely vary over short periods of time, and organic carbon averages are clearly above CALFED source water targets, though well below the variability seen on the North Bay Aqueduct. Turbidity data suggest that organic carbon can be higher than seen in this data, alkalinity data ranges higher than the upper watershed but lower than the NBA, and total dissolved solids range higher than either.

Figure 42: Bromide in Delta/SBA Source Water

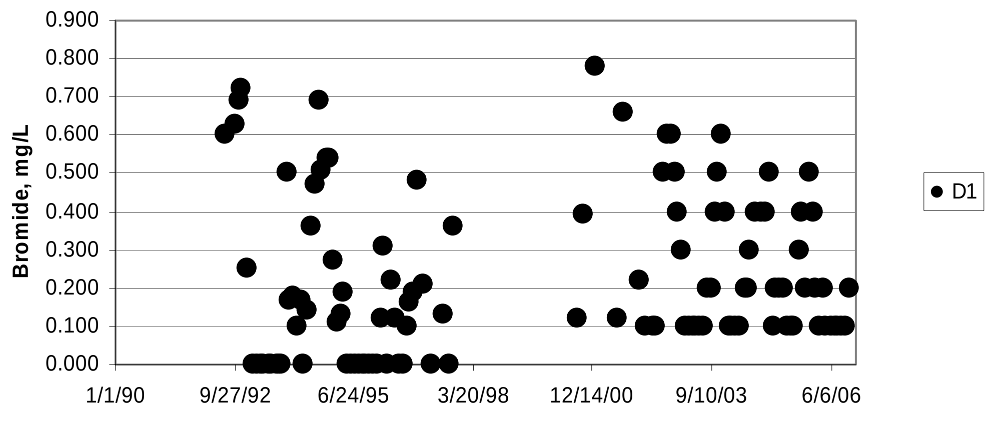


Figure 43: TOC in Delta/SBA Source Waters

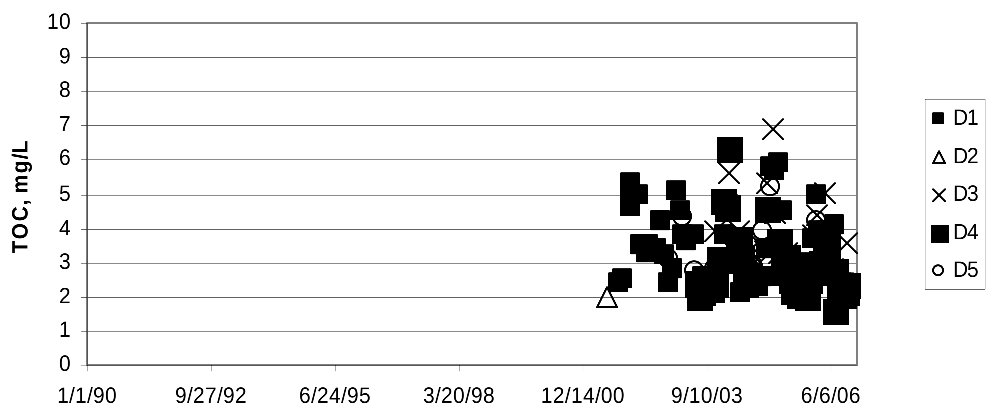
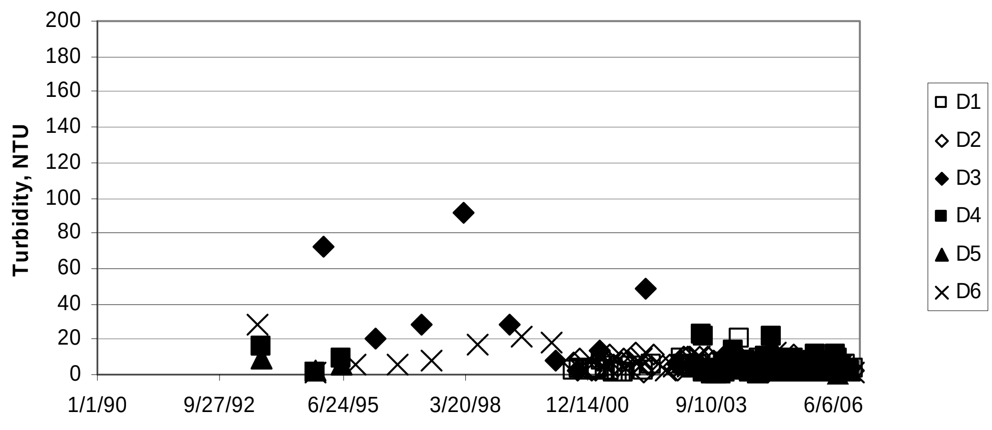
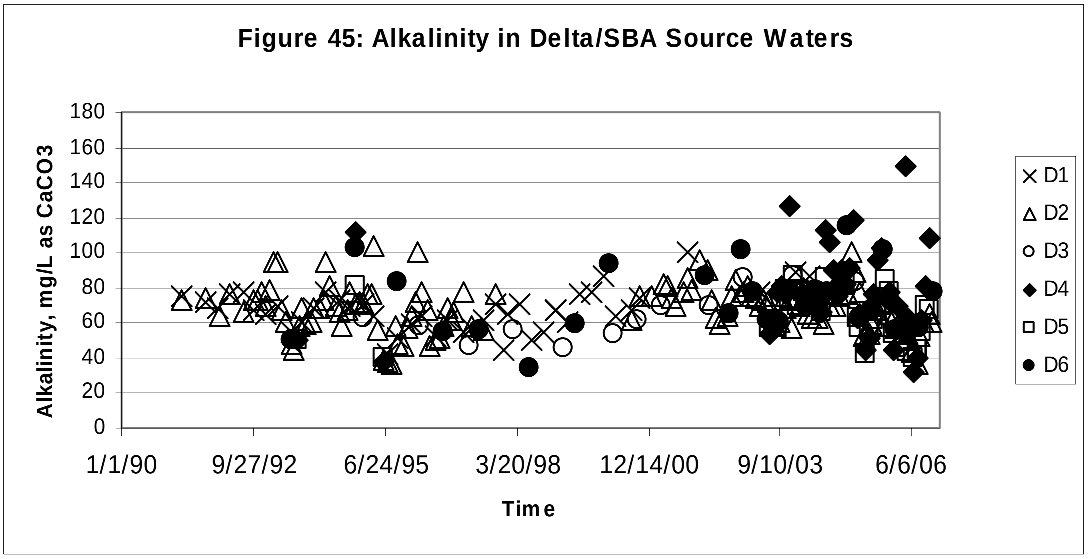
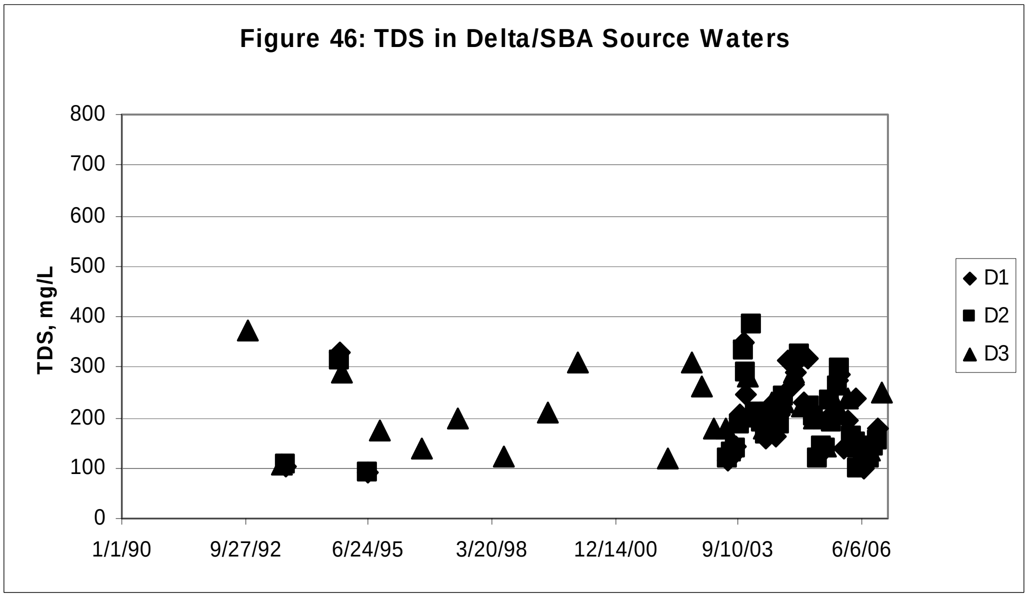


Figure 44: Turbidity in Delta/SBA Source Waters







The DPH database also contains data on treated water quality from these water treatment plants (WTPs). Figures 47-51 show the data for TTHMs, HAA5s, bromate, turbidity, TDS, and TOC. Data for the Delta and South Bay Aqueduct (SBA) plants suggest that these plants are not meeting CALFED TTHM or bromate goals, although the more recent (2006) data is much closer to these goals. HAA5 data is sparser and suggests that HAA5s targets are being met. Turbidity, TDS, and TOC of finished water provides an indication of the aesthetic qualities of the water, which appear relatively good and stable in this region, except for the salinity, which is similar to the source water salinity and more saline than the Watershed and NBA regions.

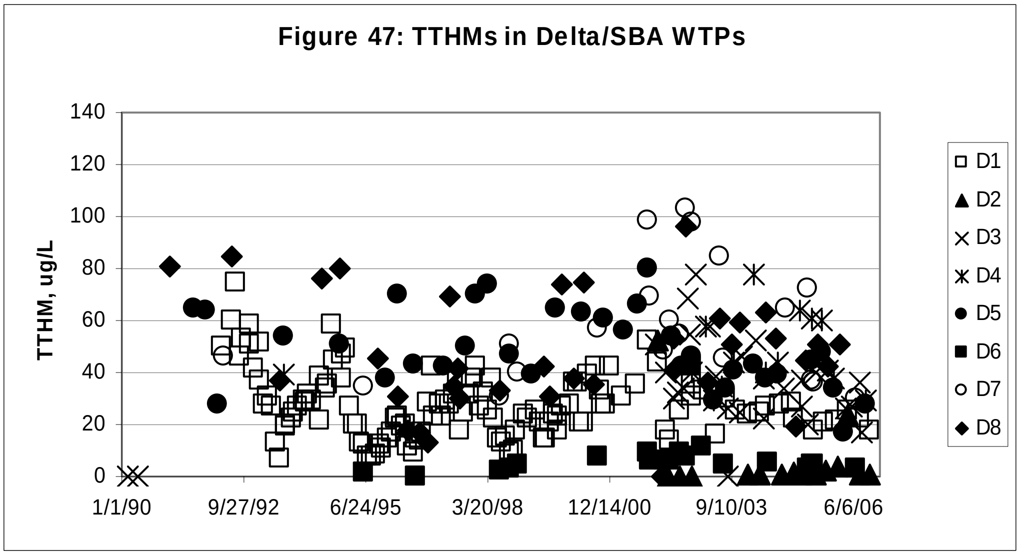


Figure 47: TTHMs in Delta/SBA WTPs

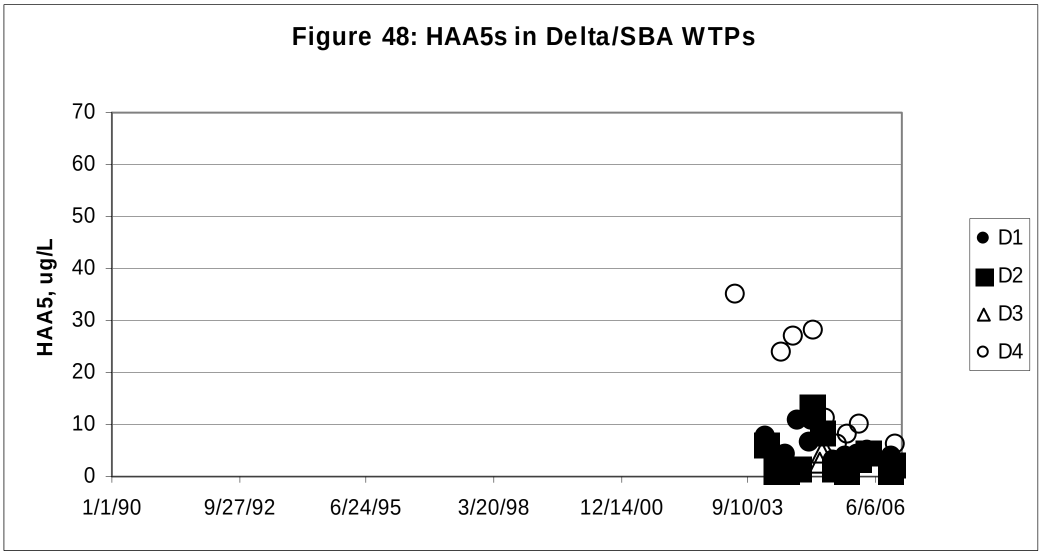


Figure 48: HAA5s in Delta/SBA WTPs

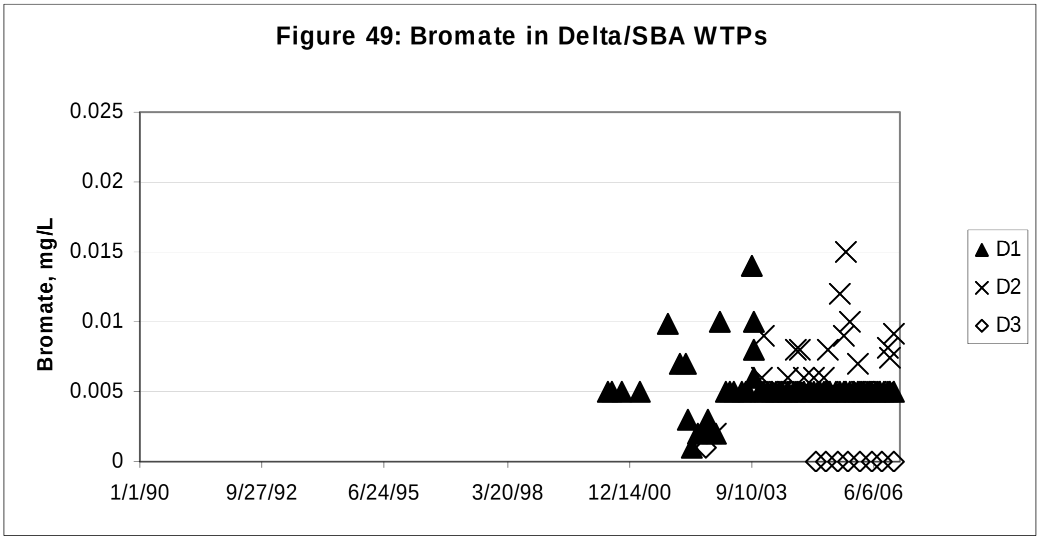


Figure 49: Bromate in Delta/SBA WTPs

Figure 50: Turbidity in Delta/SBA WTPs

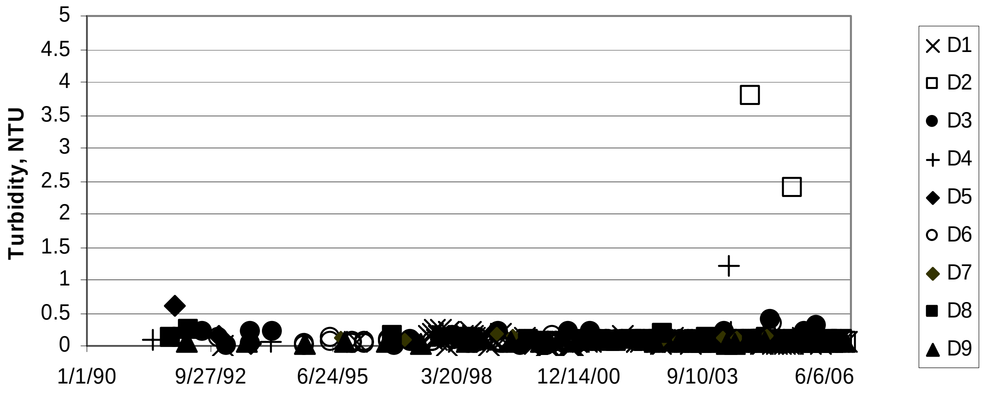


Figure 51: TOC in Delta/SBA WTPs

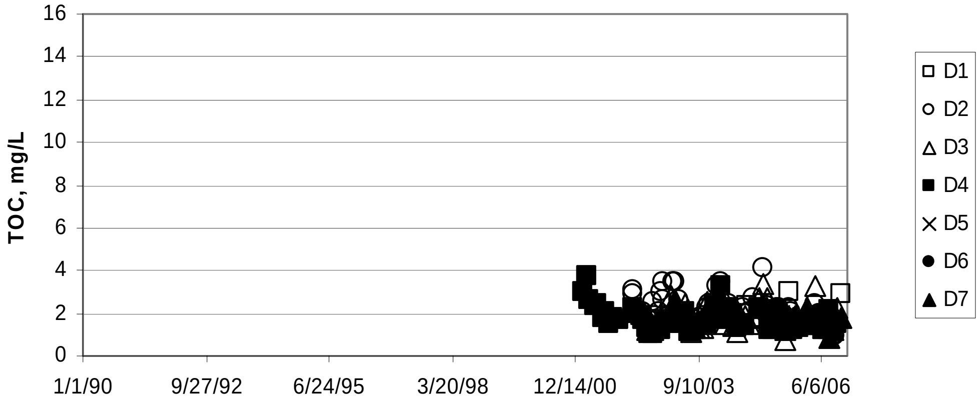
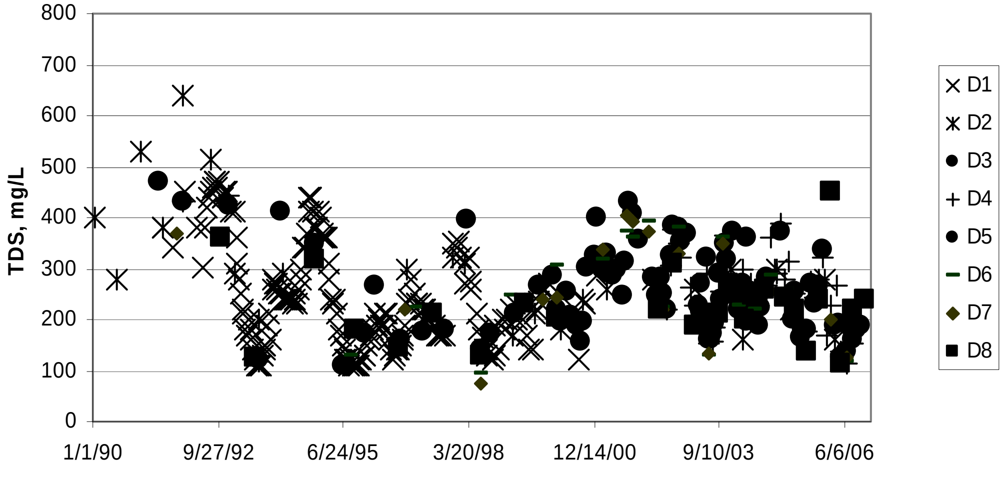


Figure 52: TDS in Delta/SBA WTPs



California Aqueduct Region:

Treatment Plants utilizing water from the Delta through the State Water Project, after it has been pumped at Banks Pumping Plant or Tracy Pumping Plant and travelled through the San Luis Reservoir complex are grouped as "California Aqueduct Plants", and represent plants that deal with highly variable water that can significantly exceed CALFED source water targets. Figures 53-57 show the precursor, turbidity, alkalinity, and total dissolved solids data for these plants. These data are more difficult to interpret, as bromide levels are both less variable and at lower concentrations than the Delta/SBA intakes, or perhaps somehow attenuated within the conveyance system. Organic carbon averages are clearly above CALFED source water targets and more variable than the Delta/SBA data, with occasional spikes similar to NBA data. Alkalinity data appears to be similar in range but less variable than the Delta/SBA data (higher than the upper watershed but lower than the NBA), and total dissolved solids are the highest of any region.

Figure 53: Bromide in California Aqueduct Source Waters

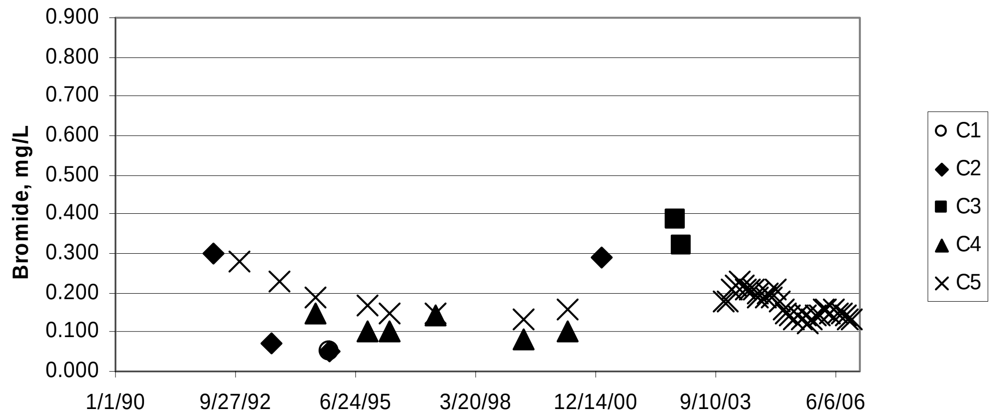
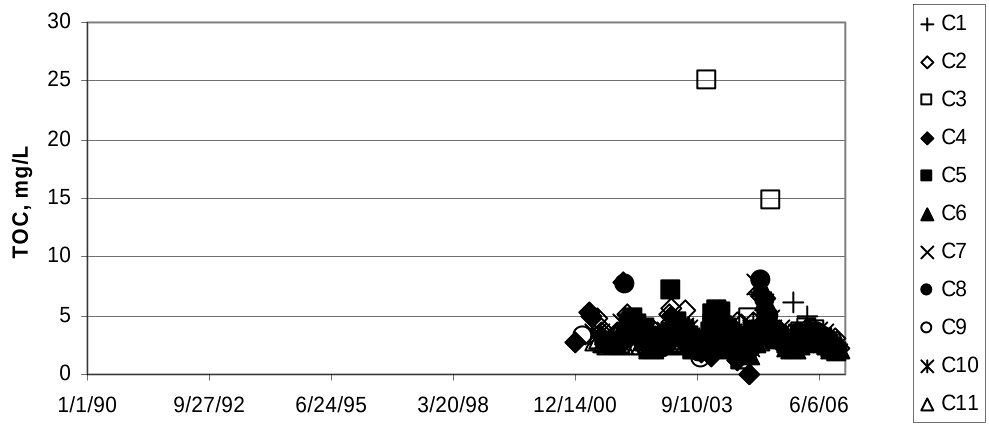


Figure 54: TOC in California Aqueduct Source Waters



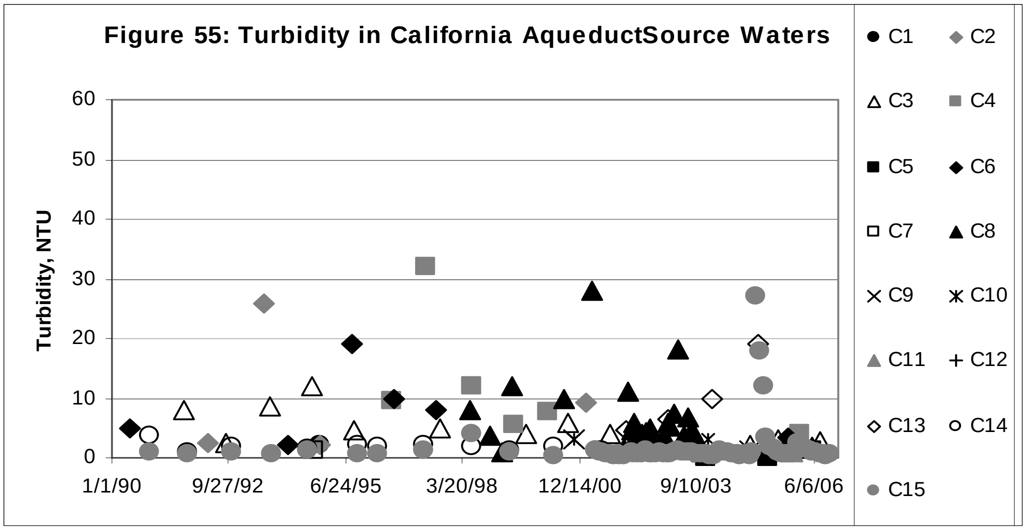


Figure 55: Turbidity in California AqueductSource Waters

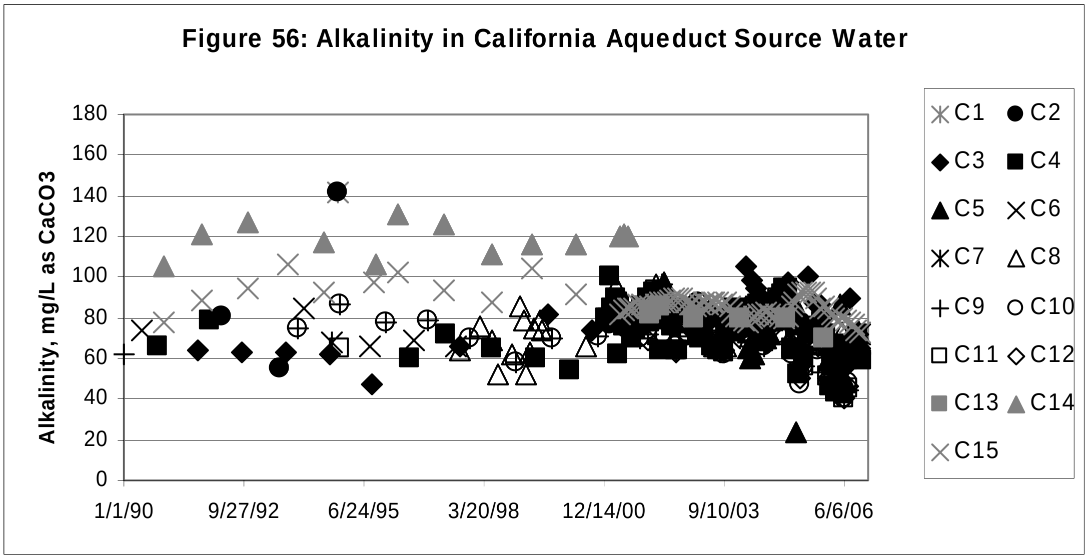


Figure 56: Alkalinity in California Aqueduct Source Water

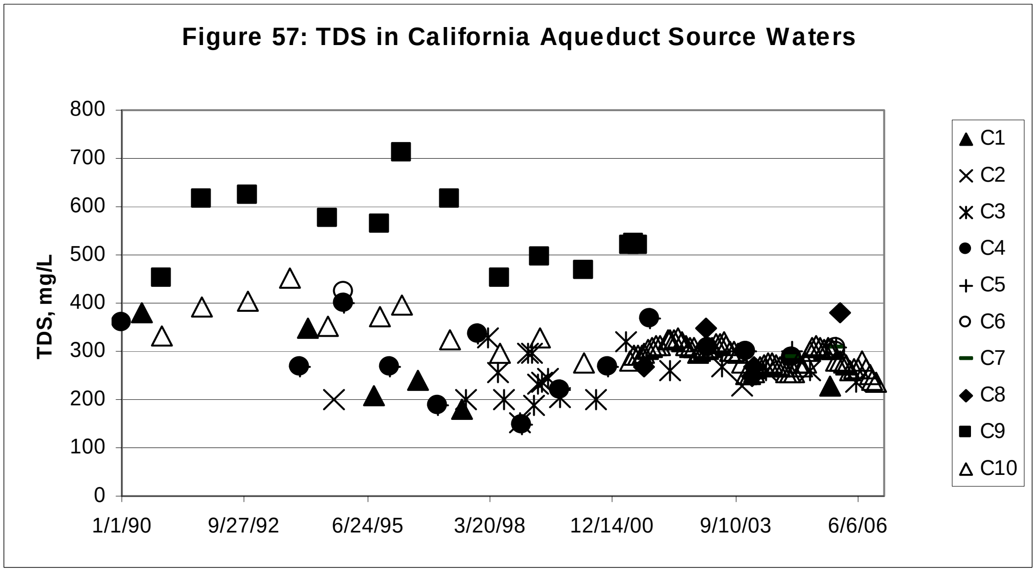


Figure 57: TDS in California Aqueduct Source Waters

The DPH database also contains data on treated water quality from these water treatment plants (WTPs). Figures 58-63 show the data for TTHMs, HAA5s, bromate, turbidity, TDS, and TOC. Data for the Calfornia Aqueduct plants suggest that these plants are generally not meeting CALFED TTHM or HAA5 goals, although the data for HAA5 and bromate are extremely sparse for such a large region. Very sparse bromate data suggest either bromate targets are being met or that these data are from plants not using ozone. Turbidity, TDS, and TOC of finished water provides an indication of the aesthetic qualities of the water, which appear similar to the Delta/SBA region, except for the salinity, which is the highest in this region.

Figure 58: TTHMs in California Aqueduct WTPs

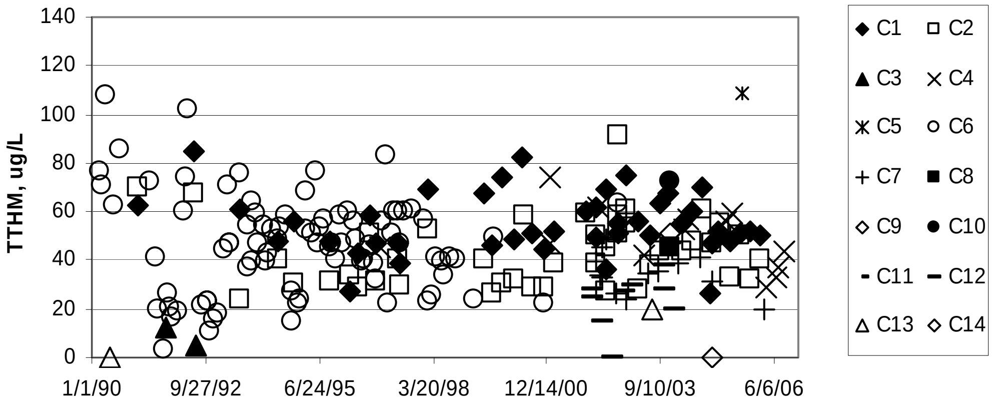
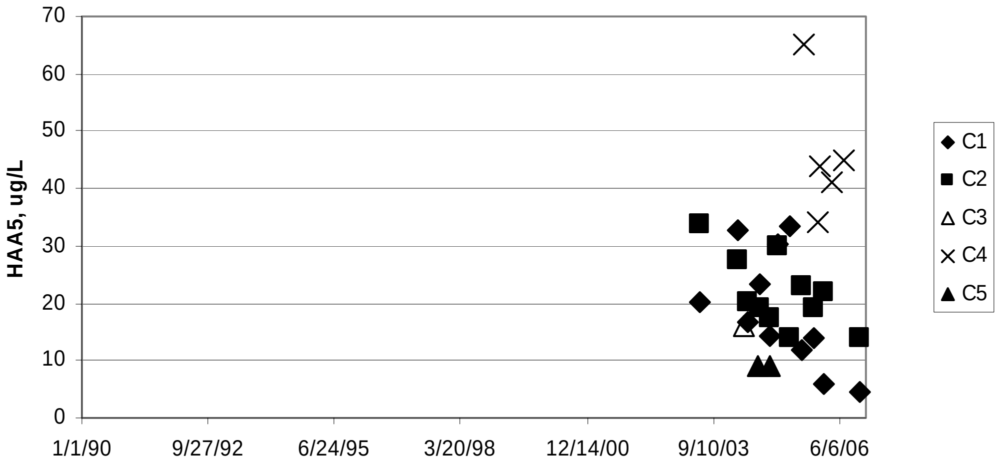


Figure 59: HAA5s in California Aqueduct WTPs



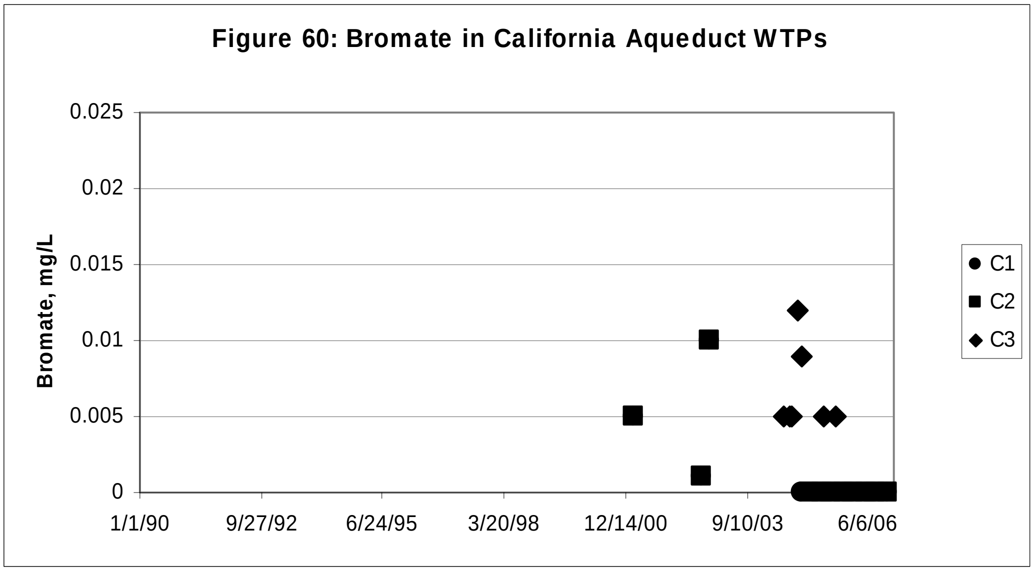


Figure 60: Bromate in California Aqueduct WTPs

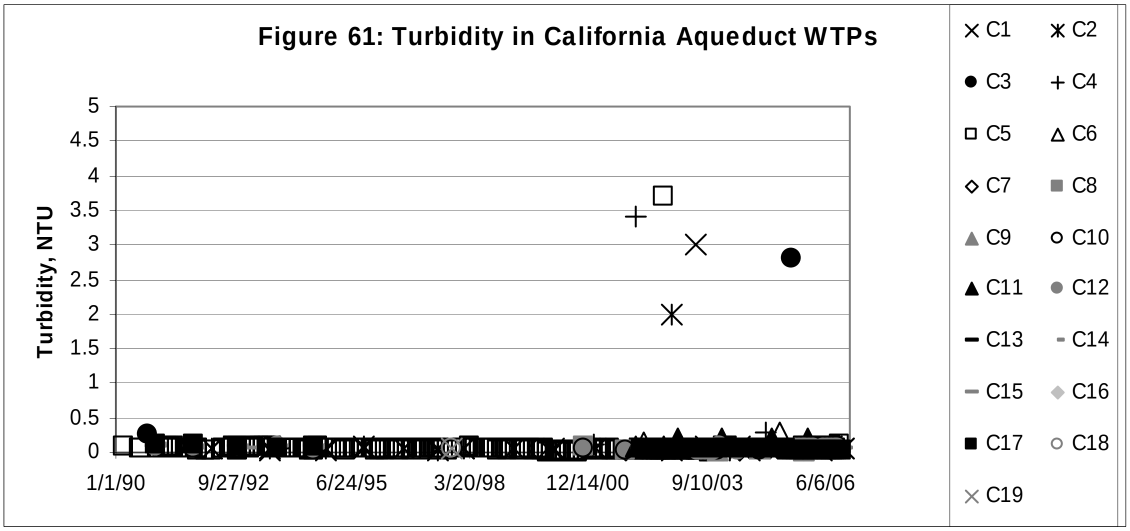


Figure 61: Turbidity in California Aqueduct WTPs

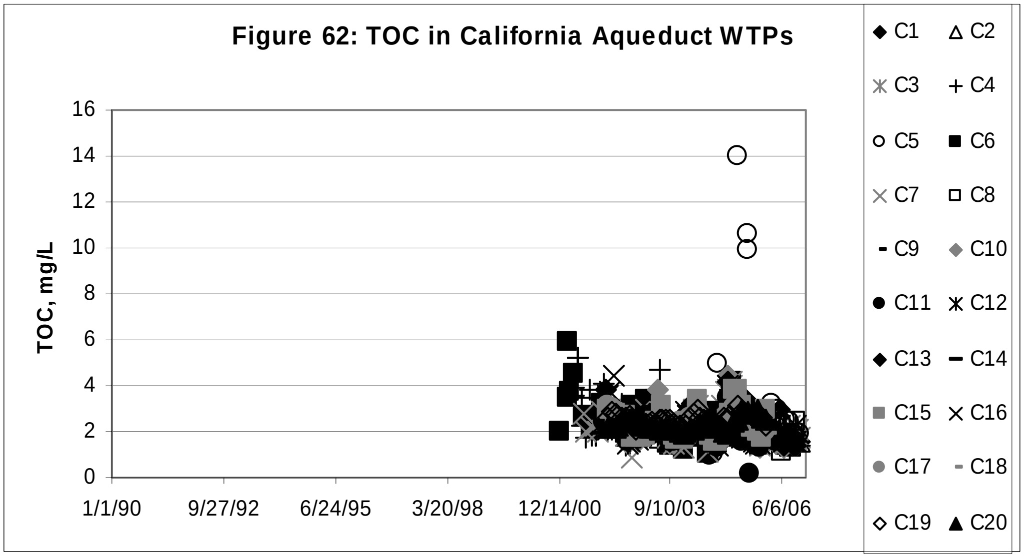


Figure 62: TOC in California Aqueduct WTPs

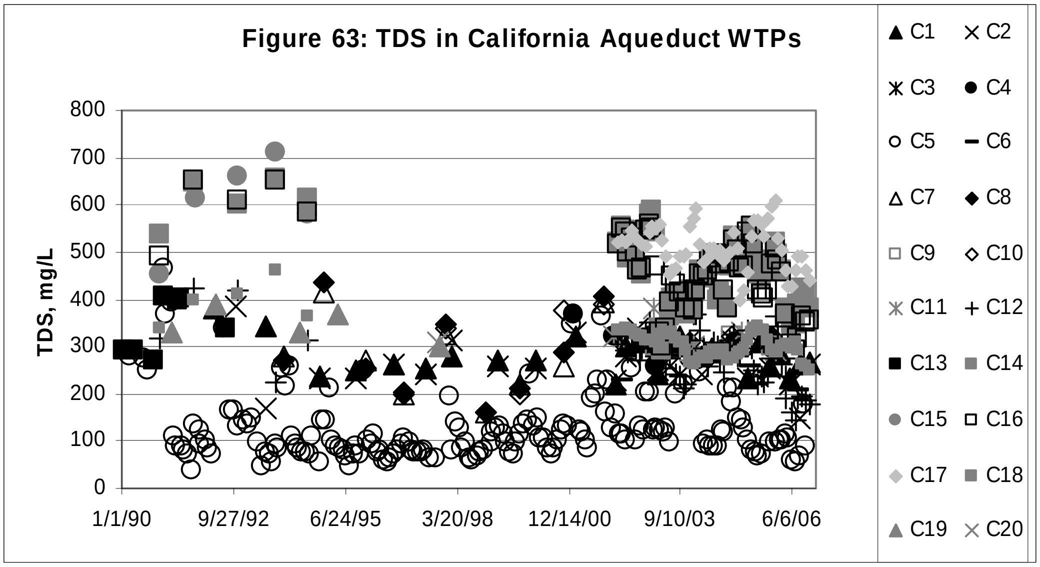


Figure 63: TDS in California Aqueduct WTPs

Using this limited amount of coupled data points, the correlation between TTHMs and TOC or Bromide, as well as HAA5s and TOC were graphed for a visual examination. Figure 64 shows clustering of watershed and NBA plants below both of CALFED's source and treated water quality goals, with only one point illustrating the TOC range for the NBA which can greatly exceed these source goals. Delta/SBA and California Aqueduct plants have a much higher variability, and appear to frequently to exceed both goals, with a generally rise in THMs and TOC increases.

Figure 64: TOC as a Source of TTHM

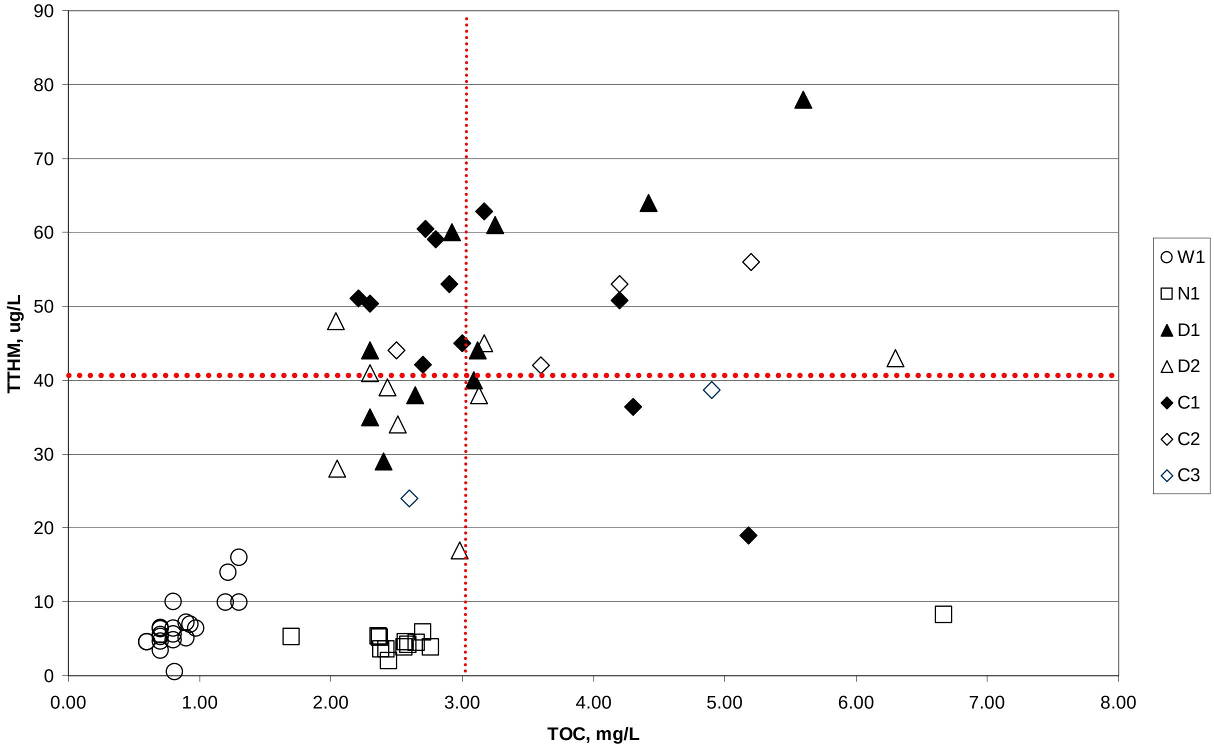


Figure 65 reveals a much sparser data set for looking at bromide as a driver of THM production – too sparse to suggest any correlations.

Figure 65: Bromide as a Source of THMs

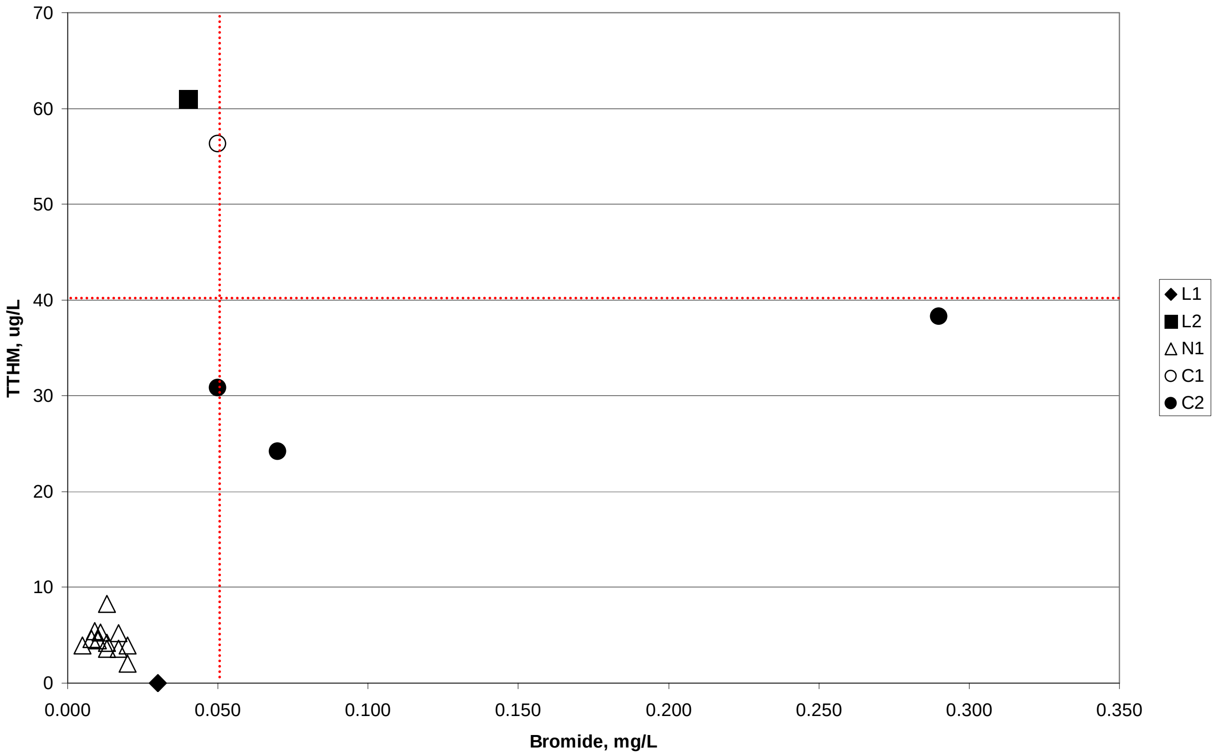
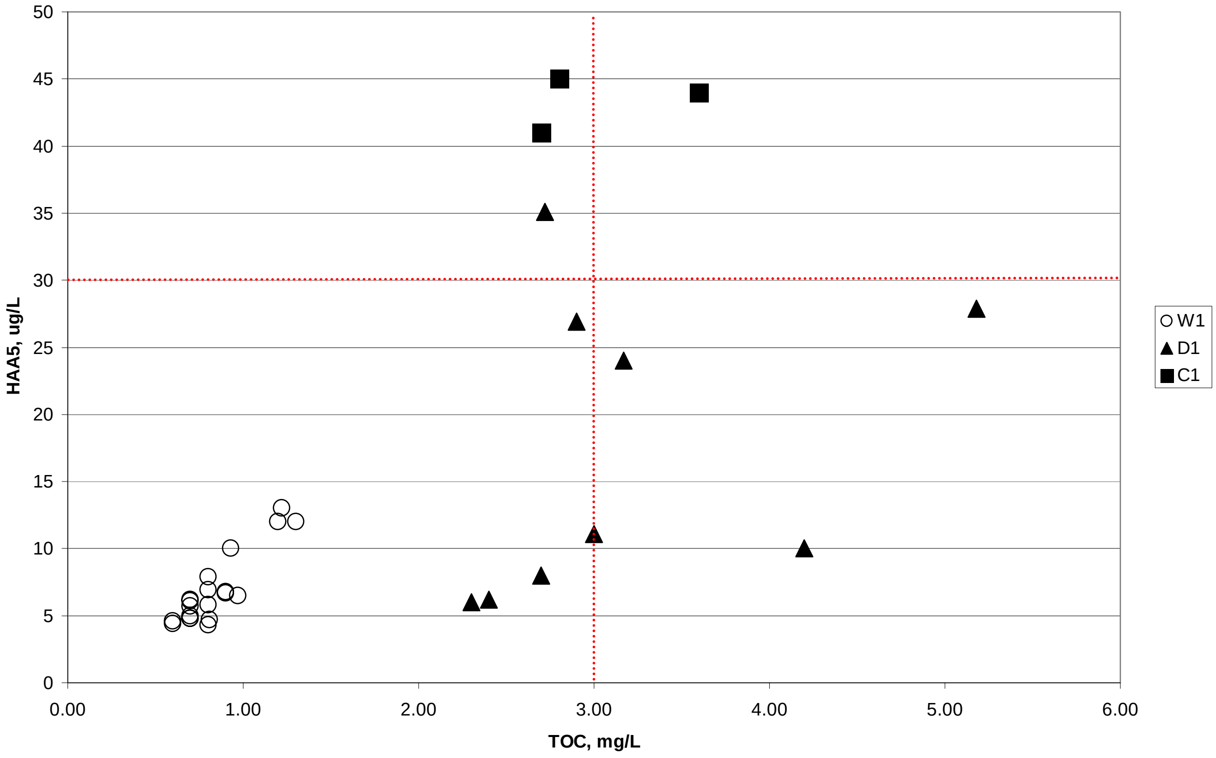


Figure 66 shows data available for only 3 plants, but each in a different region. The watershed plant data clearly cluster in the low TOC/low HAA5 quadrant, whereas the Delta plant is more variable in both TOC and HAA5 with no clear trend.

There are also data of the individual constituents of regulated TTHMs (bromodichlormethane, bromoform, dibromochloromethane, and chloroform) and HAA5s (Dichloroacetic Acid DCAA, Trichloroacetic Acid TCAA, Monobromoacetic Acid MBAA, Monochloroacetic Acid MCAA, and BCAA), so a small investigation into the presence of bromide and the speciation can be carried out. Many plants had data for only one or two plants, so individual species were grouped together by region, and the majority of the data is from 2003-2006.

Figure 66: TOC as a Source of HAA5



Figures 67 – 71 show the range of values for the four THM species in the different regions (Watershed, NBA, Delta, and California Aqueduct. These box plots show the transition of speciation from chlorinated species to a wider range of brominated species as one moves from the watershed through the Delta to the California Aqueduct.

Figure 67: Bromodichloromethane (THM)

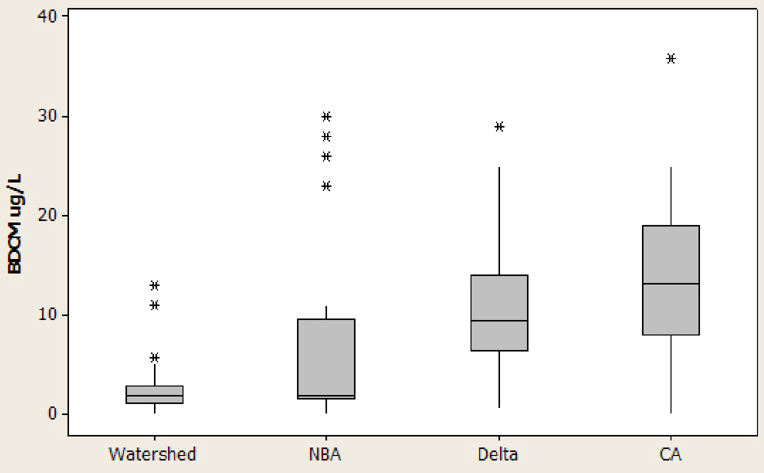


Figure 68: Bromoform (THM)

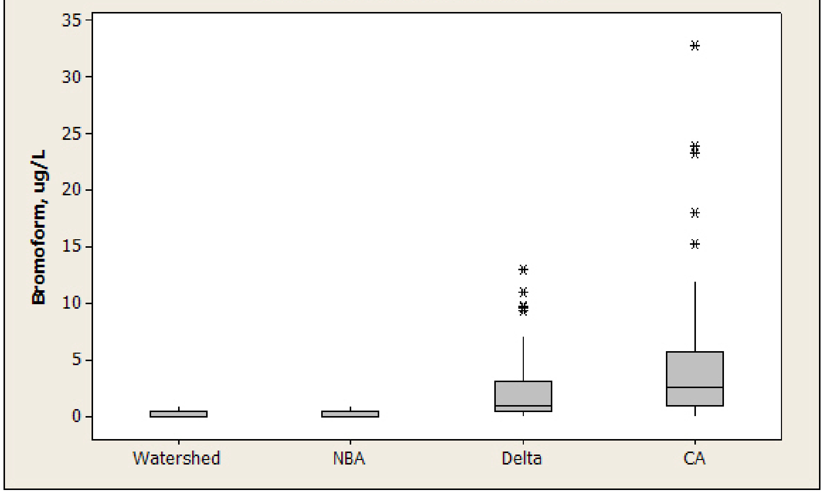


Figure 69: Chloroform (THM)

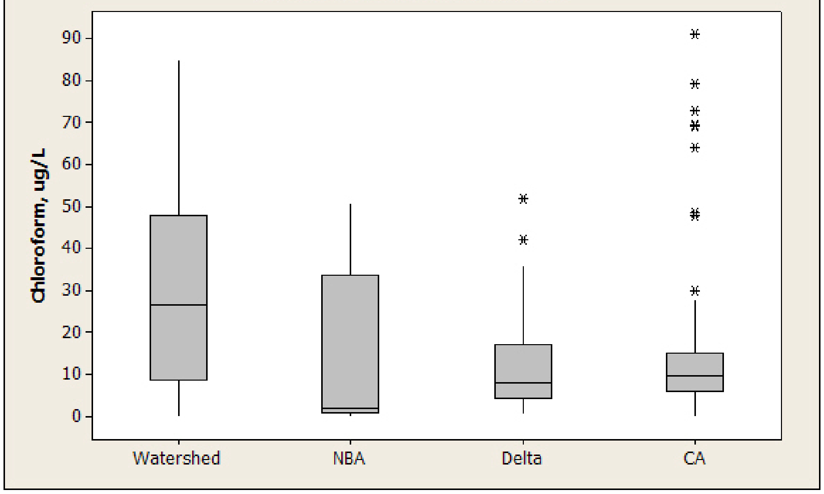
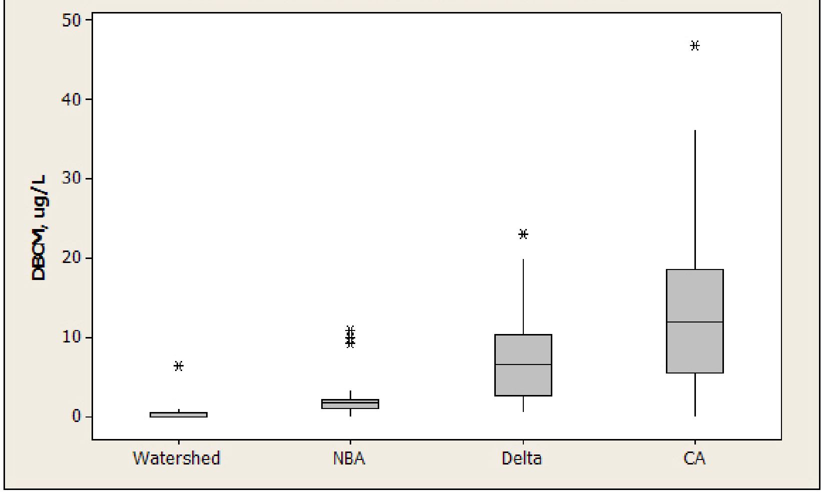


Figure 70: Dibromochloromethane (THM)



Figures 71-74 show the range of values for the five HAA species in the different regions (Watershed, NBA, Delta, and California Aqueduct. The predominant species for all regions appears to be dichoro- and trichloro-acetic acids, with higher acetic acid production in regions with higher organic carbon in their source water. There were very little data on bromochloroacetic acid, and only from those regions with higher bromide in their source water, but this appears to be the third most common species. Least present in every region are the monochloro- and monobromo- acetic acids, where medians are at or below detection levels. In the box plots, non-detections were left at detection levels.

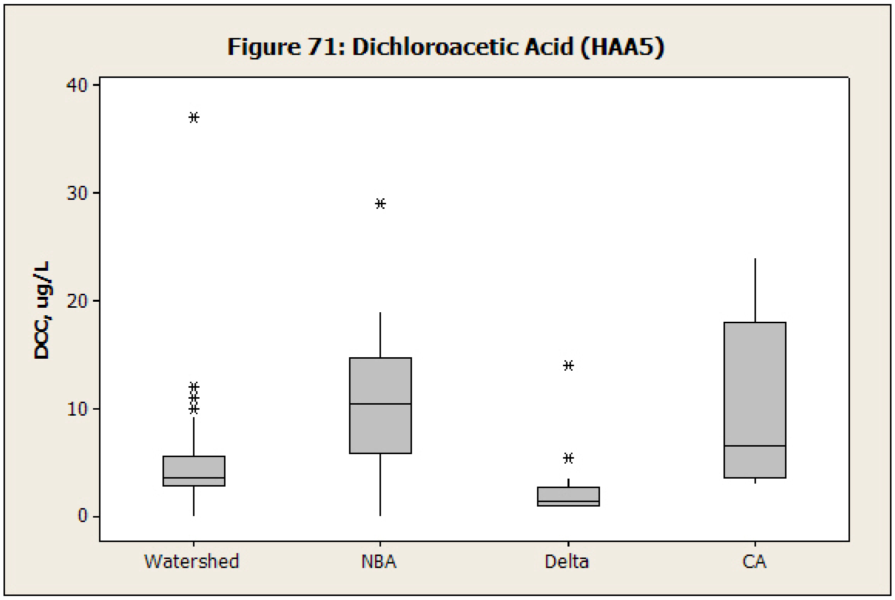


Figure 71: Dichloroacetic Acid (HAA5)

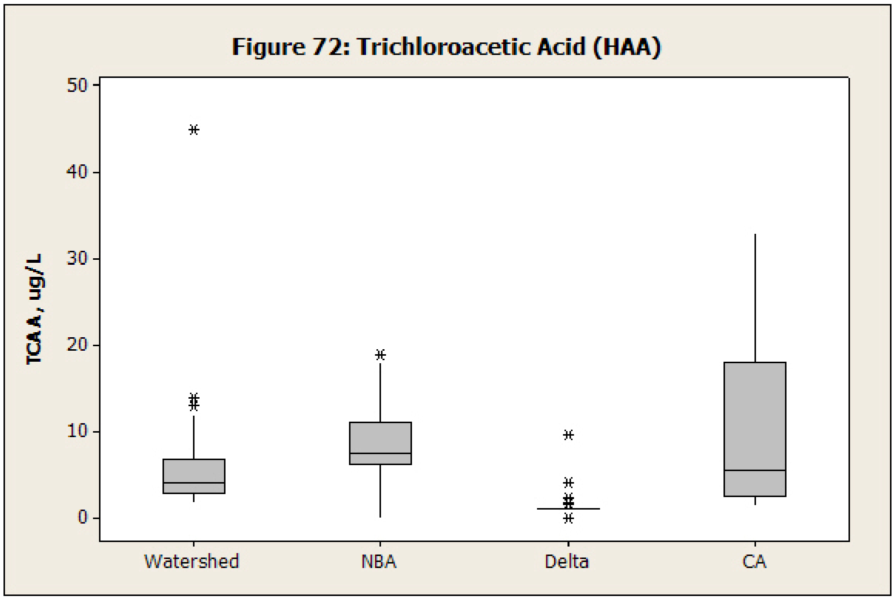


Figure 72: Trichloroacetic Acid (HAA)

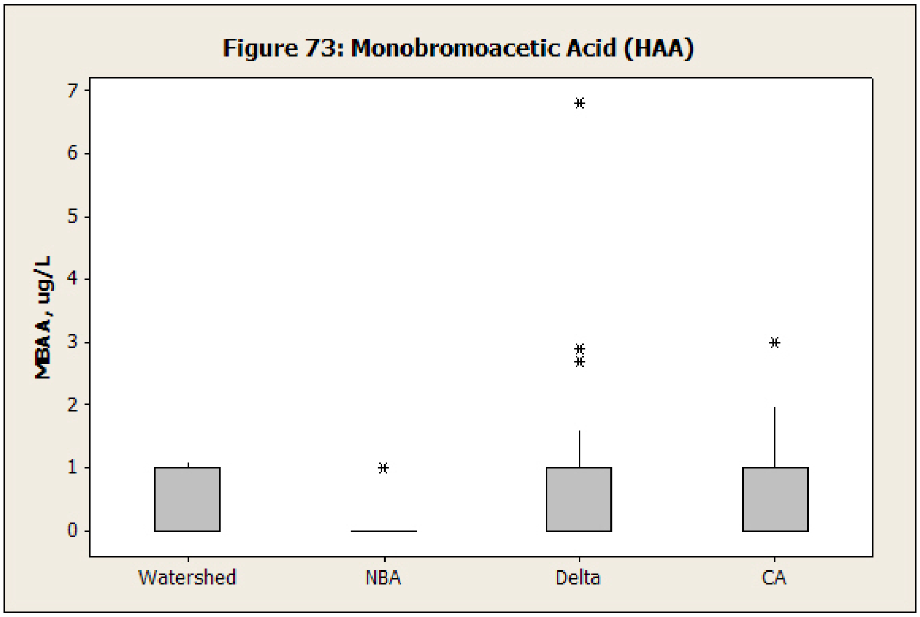


Figure 73: Monobromoacetic Acid (HAA)

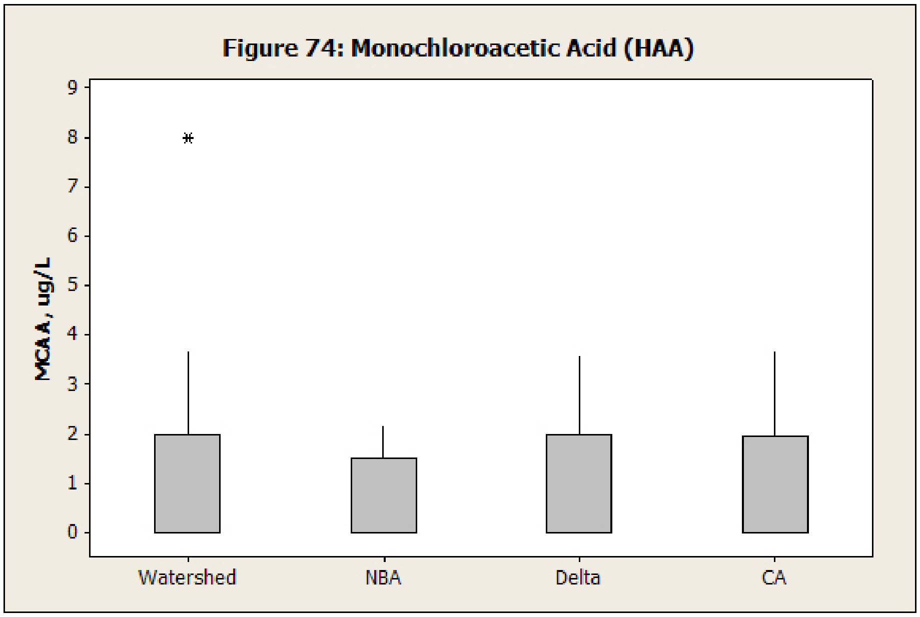


Figure 74: Monochloroacetic Acid (HAA)

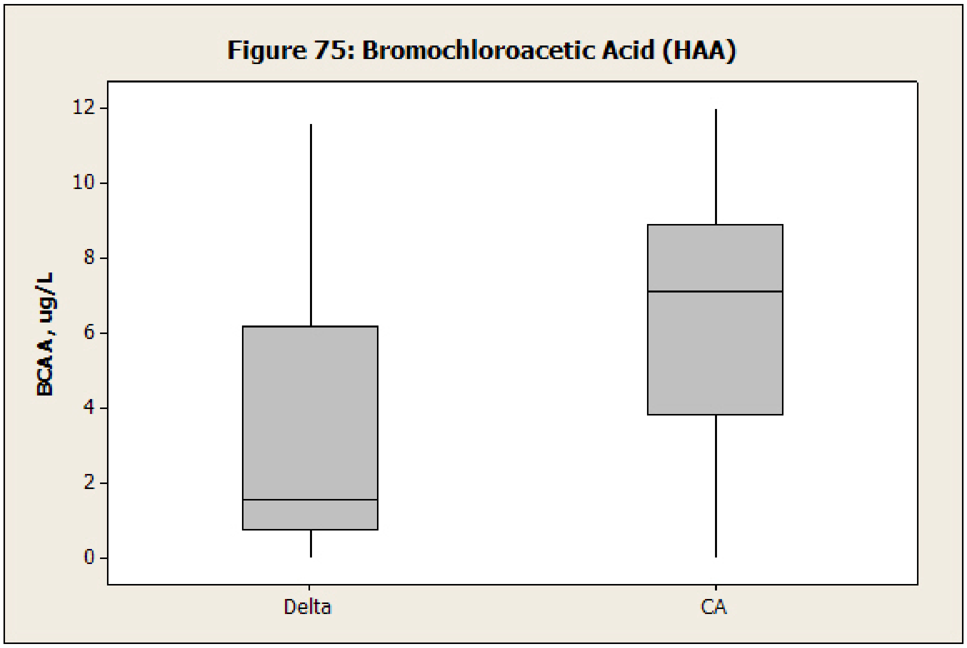
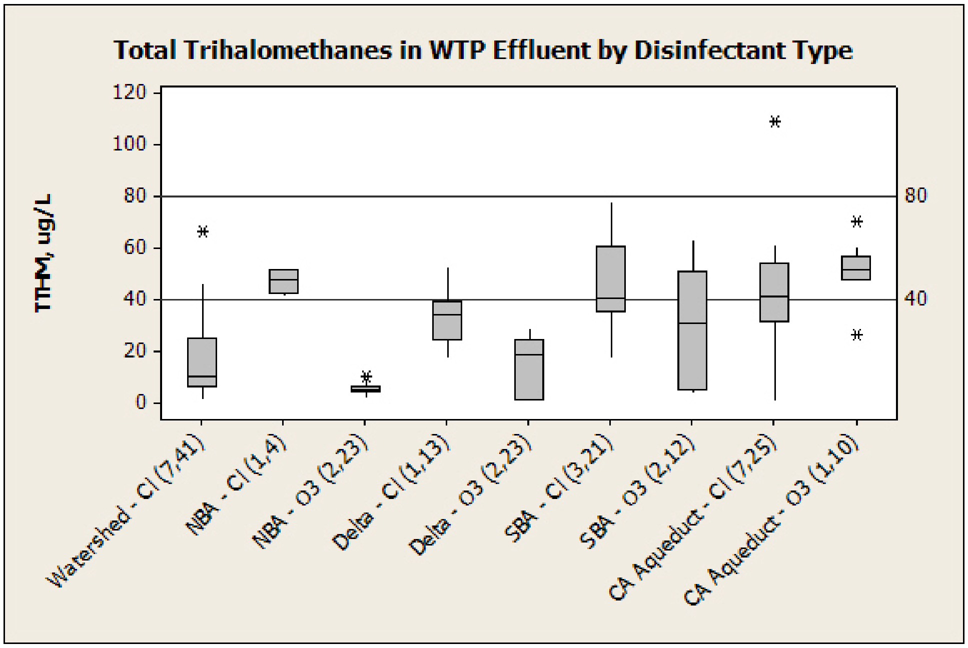


Figure 75: Bromochloroacetic Acid (HAA)

Data were also evaluated to see if treated water quality changed significantly due to the type of filtration process employed or disinfectant used. TTHMs, HAA5s, bromate and TDS of treated water, by region and process, were organized into boxplots. Figure 76 illustrates the reduction in TTHMs when using ozone in addition to chlorine or chloramination in all but the California Aqueduct regions. Data from 2004-2006 were used.

Figure 76



Total Trihalomethanes in WTP Effluent by Disinfectant Type

Figure 77 shows that there are not enough plants in each region to make an initial conclusion for HAA5 – in the California Aqueduct region the ozone plant is producing lower HAA5 than the chlorine plants. Figure 78 illustrates that bromate is more frequently produced by ozone.

Figure 77: **HAA5 in WTP Effluent by Disinfectant Type**

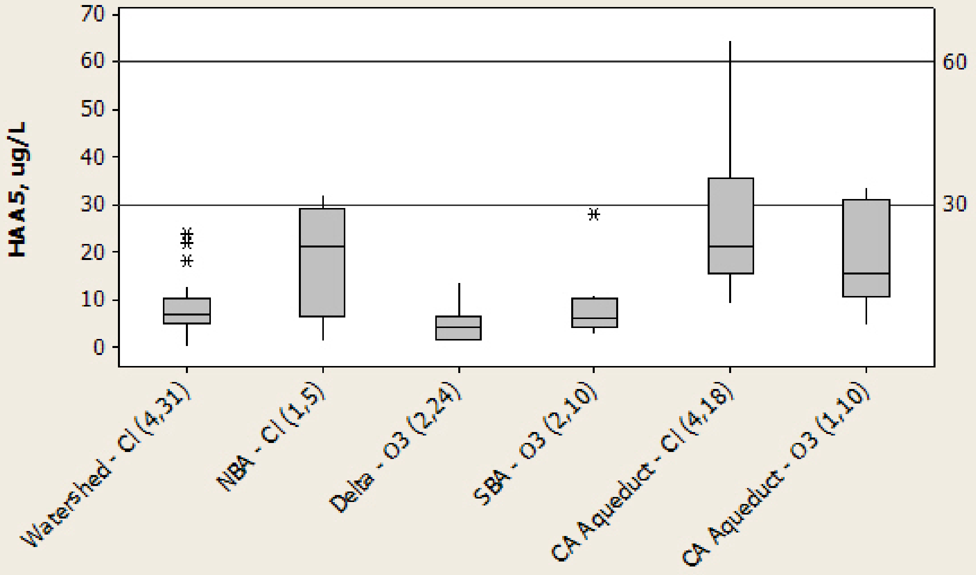
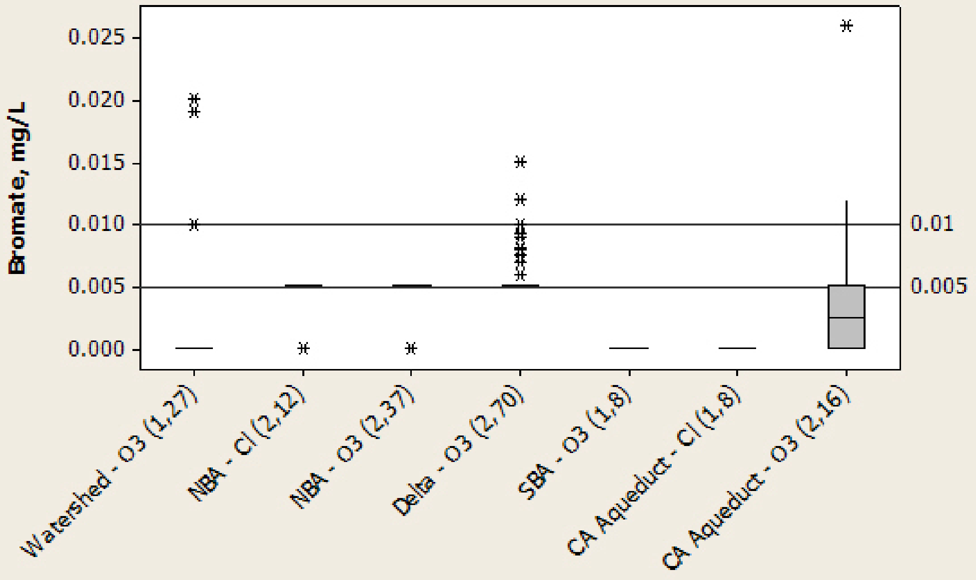


Figure 78: **Bromate in WTP Effluent by Disinfectant Type**



Analysis of filtration types did not show much variation by filtration category – which could be because there are only a few plants that are not conventional filtration - and are therefore not included in this memorandum. This may be due to the very general filtration categories, to the limited number of alternative filtration plants, or a simple lack of relevant water quality data.

Finally, box plots and maps were produced to visually compare water quality characteristics of the different regions (in this case the SBA and Delta plants are separated, as the combining of these groups into one region happened later in the analysis). Maps are attached as Appendix F. Figure 79 shows the range of bromide in the source waters of the plants examined, Delta plants clearly receive the highest concentrations with the greatest variability in the higher range. Figures 80 and 81, on the other hand, show that the NBA plants receive the highest concentrations of organic matter, with the greatest variability. Both figures 79 and 80 illustrate that the majority of WTPs are using source water that does not meet CALFED source water targets.

Figure 79 **Bromide in Source Waters (# Plants, # Data)**

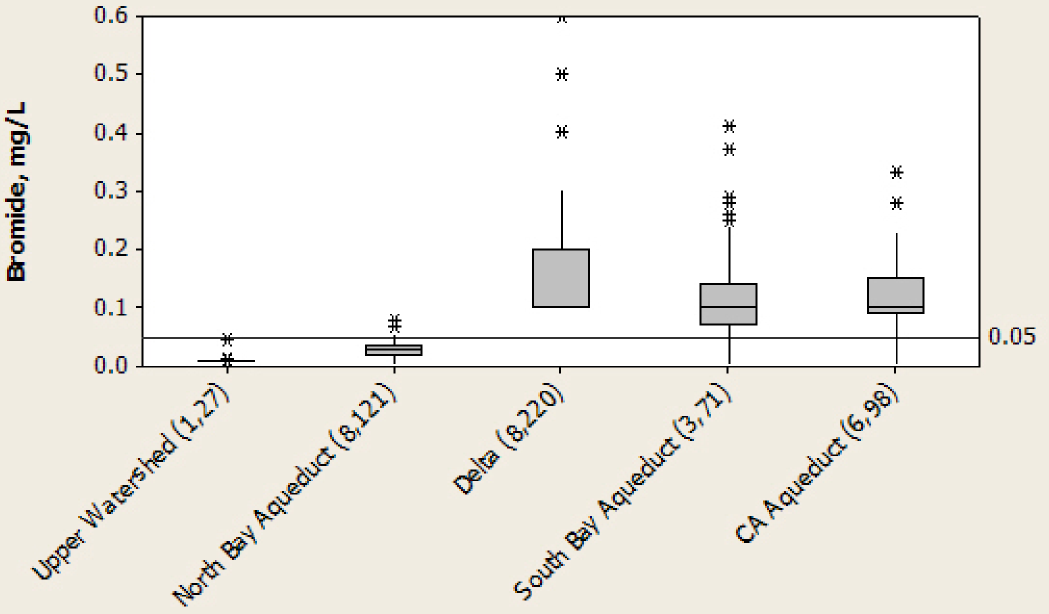


Figure 80 TOC in Source Water (# Plants, # Data)

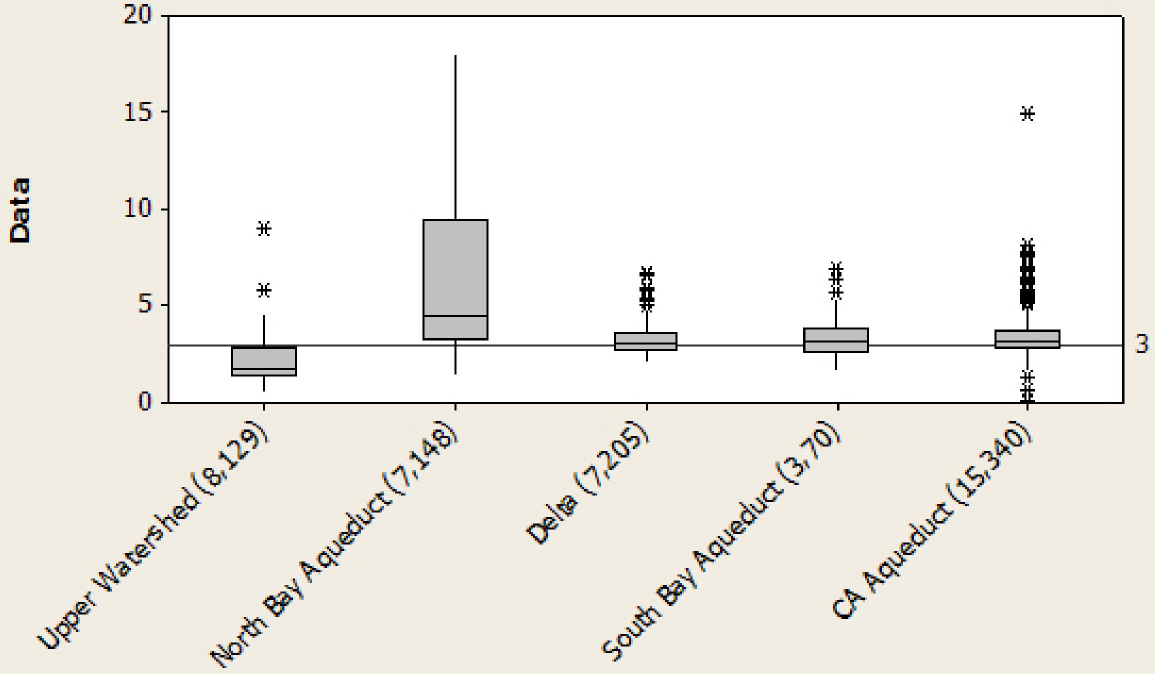


Figure 81 Turbidity in Source Waters (# Plants, # Data)

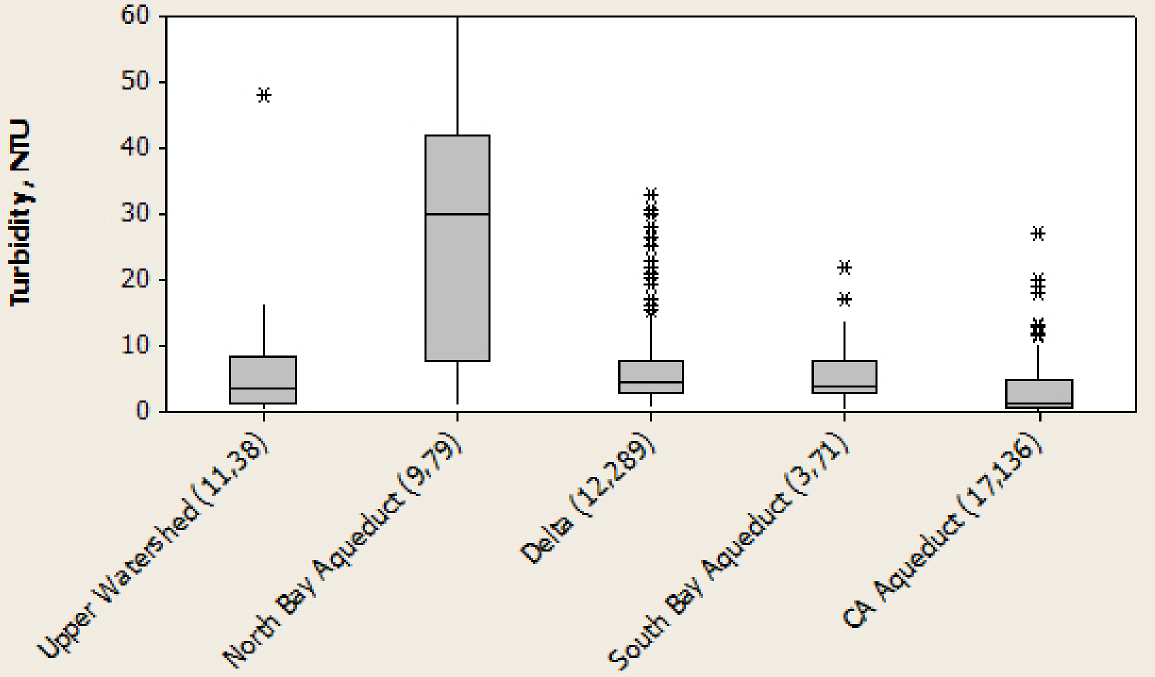
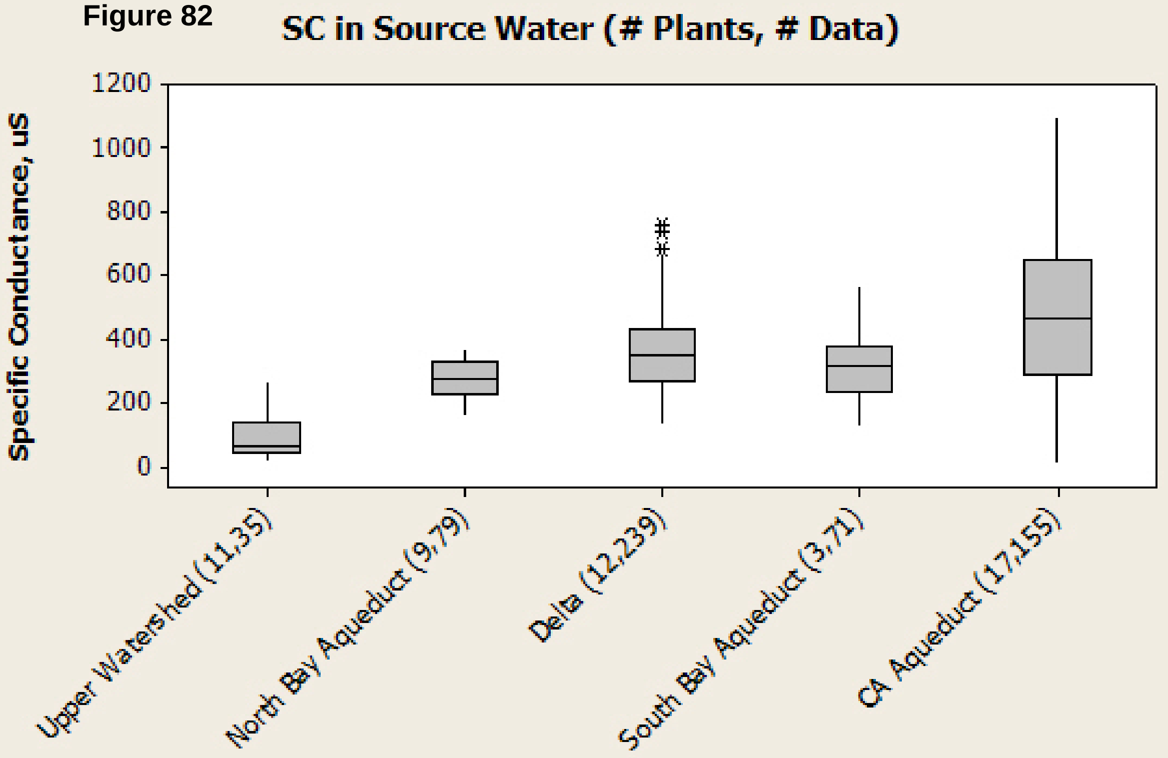


Figure 82 illustrates the increasing salinity as water travels from the upper watershed, encounters anthropogenic sources and then an estuary (the greatest variation is at Delta intakes, which are closest to this tidal signature) and is transported hundreds of miles to WTPs on the California Aqueduct system.

Figure 82



Conclusions and Next Steps:
This initial look at the centralized DPH database for 54 representative plants confirmed that plants in the Delta and on the NBA are not using water that meets or exceeds CALFED source water quality targets. These source water quality targets were developed by an expert panel retained by the California Urban Water Agencies[1], based on existing (in 1998) levels of water treatment and projected treated water quality targets of 40 ug/L TTHMs, 30 ug/L HAA5, and 5 ug/L bromate. The CALFED WQP has not had the resources before now to investigate whether WTPs were meeting these projected treated water quality targets, as some measure of the achievement of its treated water quality goal "an equivalent level of public health protection." The treated water quality information gathered through this effort suggests that a) the use of ozone enables plants to meet TTHM targets of 40 ug/L but causes these same plants to exceed bromate targets of 5 ug/L, and b) that HAA5 targets of 30 ug/L are generally being met and either are of lower importance as CALFED targets, or could be treated as a focused goal for a specific region not meeting the targets.

---

[1] The ***Bay-Delta Water Quality Evaluation - Draft Final Report.*** Malcolm Pirnie, Inc., Camp, Dresser and McKee, University of Cincinnati. June 1998.

This data analysis was used in several ways. First, it was used to select ten out of the 54 treatment plants for further study as part of the CALFED Water Quality Program's Final End of Stage 1 Assessment Project. The U.S. Bureau of Reclamation-funded consultant, URS (with Brown & Caldwell as the primary subcontractor), along with DPH and WQP staff used the analysis to develop hypotheses of the linkages between raw water quality and treated water quality which will be tested with information from the ten selected plants. The analysis was used to brief the CALFED Independent Science Board as part of a briefing on the development of water quality performance measures, a piece of which is to develop quantitative measures for "an equivalent level of public health protection." The analysis will inform the development of performance measures, the development of a conceptual model of water quality from the Delta intakes to WTPs, and the development of the Central Valley Drinking Water Policy.

	System Name	Facility	Size (MGD)	Population	Connections	Status	Plant Type
Upper Sacramento basin or tributary to Sacramento R - high quality source							
1	City of Sacramento	Amer R WTP - Treated (Lab Tap #08) (Fairbairn)		454,330	137,796	Active Treated.	Conventional
2	Carmichael Water District	Bajamont SWTP - Treated		39,339	11,101	Active Treated.	Membrane
3	City of Redding	Sacramento River @ Foothill WTP-Treated	28	85,703	26,080	Active Treated.	Conventional
4	Yuba County Water District	Treatment Plant - Treated				Active Treated.	Alternative technology
Lower Sacramento basin - still high quality but downstream of ag and urban land uses							
5	City of West Sacramento	Sacramento River - Treated		32,500	11,851	Active Treated.	Conventional
6	City of Sacramento	Sac R WTP - Treated (Lab Tap #12)		454,330	137,796	Active Treated.	Conventional
Upper San Joaquin basin or tributary to San Joaquin R. - high quality source							
7	East Bay MUD	Lafayette WTP-Mokelumne Aqueduct - Trtd	25	1,300,000	377,098	Active Treated.	Direct Filtration
8	East Bay MUD	Orinda TP-Mokelumne Aqueduct Water-Trtd	175	1,300,000	377,098	Active Treated.	Direct Filtration
9	East Bay MUD	Sobrante WTP-San Pablo Water - Treated	60	1,300,000	377,098	Active Treated.	Conventional
10	East Bay MUD	Upper San Leandro WTP-USL Water-Treated	60	1,300,000	377,098	Active Treated.	Conventional
11	East Bay MUD	Walnut Creek WTP-Mokelumne Aqueduct-Trtd	91	1,300,000	377,098	Active Treated.	Direct Filtration
12	Modesto Irrigation District	Modesto Reservoir - Treated	45	16	1	Active Treated.	Conventional
13	Stockton East Water District	Treatment Plant - Final Treated-SA5	45	50	4	Active Treated.	Conventional
14	C.C.W.D., West Point	West Point WTP - Effluent				Combination/Blend Treated.	Conventional
15	Clovis, City of	Clovis SWTP - Treated	15	89,972	26,630	Active Treated.	Conventional
16	Fresno, City of	Fresno SWTF - Treated		484,087	123,826	Active Treated.	Conventional
17	Cal Water	NE Bakersfield					Membrane

	System Name	**Facility**	**Size (MGD)**	**Population**	**Connections**	**Status**	**Plant Type**
North Delta							
18	City of Fairfield	North Bay Regional WTP - Treated	40	80,000	23,480	Active Treated.	Conventional
19	City of Fairfield	Waterman WTP-Finished Water	22.5	80,000	23,480	Active Treated.	Conventional
20	City of Benicia	Benicia WTP - Treated	12	28,000	8,913	Active Treated.	Conventional
21	City of Vallejo	Fleming Hill WTP - Treated	42	134,000	35,000	Active Treated.	Conventional
22	City of Vallejo	Travis WTP - Treated	7.5	134,000	35,000	Active Treated.	Conventional
23	American Canyon, City of	Treatment Plant_American Canyon - Treated	2.5+3.0	15,300	5,491	Active Treated.	Conventional/Membrane
Central/South Delta							
24	Contra Costa Water District	Canal/Mallard-Sampled at Bollman-Treated	75	200,000	58,119	Active Treated.	Conventional
25	Randall-Bold Water Treatment Plant	Randall Bold WTP - Treated	40	0	3	Active Treated.	Direct Filtration
26	City of Antioch	Contra Costa Canal/Muni Res-Antioch WTP	26	84,485	27,464	Active Treated.	Conventional
Delta Mendota Canal							
27	Tracy, City of	Treatment Plant Effluent		78,640	21,769	Active Treated.	Conventional
South Bay Aqueduct							
28	Zone 7 Water Agency	Del Valle CWE-Treated Water	44	176,400	40	Active Treated.	Conventional
29	Zone 7 Water Agency	Patterson Pass CWE-Treated Water	21	176,400	40	Active Treated.	Conventional/UF
30	Alameda County Water District	Water Treatment Plant #2 - Treated	21	324,838	79,088	Active Treated.	Conventional
31	Alameda County Water District	Mission San Jose WTP	8	324,838	79,088		Ultrafiltration
32	Santa Clara Valley Water District	Penitencia WTP	42			Active Treated.	Conventional
California Aqueduct - O'Neill Forebay and San Luis Reservoir							
33	Santa Clara Valley Water District	Santa Teresa WTP	100				Conventional
34	Santa Clara Valley Water District	Rinconada WTP	80				Conventional

	System Name	Facility	Size (MGD)	Population	Connections	Status	Plant Type
California Aqueduct - San Luis Reach, O'Neill Forebay to Check 21							
35	Dos Palos-City	Dos Palos WTP - Treated		4,417	2,443	Active Treated.	Conventional
36	Coalinga-City	Plant Effluent	12	16,684	3,260	Active Treated.	Conventional
37	Huron, City of	Huron Plant No. 2 Effluent - Treated		6,306	860	Active Treated.	Conventional
38	Avenal, City of	Treatment Plant No. 2 - Treated	3.1	16205	1851	Active Treated.	Conventional
39	Avenal, City of	Treatment Plant No. 1 - Treated	2.2	16205	1851	Active Treated.	Conventional
California Aqueduct - San Joaquin Field Division, Check 21 to Check 39							
40	Kern County Water Agency	ID4 Treated - T1 (Henry Garnett WTF)	45	0	3	Active Treated.	Conventional
Coastal Branch							
41	Central Coast Water Authority	State Water Project - Treated (Polonio Pass WTP)	43	0	43	Active Treated.	Conventional
East Branch - Check 42 to Check 66							
42	Antelope Valley E Kern Wtr Agy	Rosamund WTP - Treated	14	0	47	Active Treated	Conventional
43	Antelope Valley E Kern Wtr Agy	Quartz Hill WTP - Clear Well - Treated	65	0	47	Active Treated.	Conventional
44	Antelope Valley E Kern Wtr Agy	Acton Plant - Treated Effluent	4	0	47	Active Treated.	Conventional
45	Antelope Valley E Kern Wtr Agy	Eastside Plant - Treated Effluent	10	0	47	Active Treated.	Conventional
46	Palmdale Water Dist.	Filter Plant - Effluent	30	109,845	25,991	Active Treated.	Conventional
East Branch - Silverwood Lake							
47	Metropolitan Water Dist. of So. Cal.	Mills Plant Effluent - Treated	160	0	647	Active Treated.	
48	CLAWA	Lake Silverwood WTP	5 or 3			Active Treated.	Conventional
East Branch - Diamond Valley Lake, Lake Perris							
49	Metropolitan Water Dist. of So. Cal.	Diemer Plant Effluent - Treated	520	0	647	Active Treated.	Conventional
50	Metropolitan Water Dist. of So. Cal.	Skinner Plant Effluent #1 - Treated	630	0	647	Active Treated.	Conventional
51	Metropolitan Water Dist. of So. Cal.	Weymouth Plant Effluent - Treated	520	0	647	Active Treated.	Conventional

	System Name	Facility	Size (MGD)	Population	Connections	Status	Plant Type
West Branch - Castaic Lake							
23	Metropolitan Water Dist. of So. Cal.	Jensen Plant Effluent - Treated	750	0	647	Active Treated.	Conventional
53	Castaic Lake Water Agency	Earl Schmidt WTP Effluent - Treated	56	0	18	Active Treated.	Conventional
54	Castaic Lake Water Agency	Rio Vista WTP Effluent - Treated	30	0	18	Active Treated.	Conventional

The CALFED Water Quality Program committed to developing a final program assessment in the CALFED Program 10-Year Action Plan, released in early 2006. The initial program assessment, completed in July 2005, focused on assessing the results of funded projects and progress toward specific ROD goals. This final program assessment will take a systemic look at drinking water quality and the Delta and attempt to describe the status of our knowledge, including watershed sources and timing, drinking water treatment, and potential improvement actions. In parallel with this project, the program is also developing a performance measure system and working closely with the Central Valley Drinking Water Policy project. The U.S. Bureau of Reclamation has retained the services of Brown and Caldwell to support development of the final program assessment, focusing on three tasks.

The California Department of Health Services provided CALFED staff with a copy of the PICME database and with several queries of Central Valley utility information. Based on this information, and in conversation with David Spath, this document was prepared as a basic outline for conceptual models of treated water quality. The CALFED Water Quality Program is asking DHS District Engineers to review the document for accuracy (for the plants in their respective districts). We are not requesting that additional treatment plants be added.

SACRAMENTO River (Upper)
Source Water: High quality, low variability
Conveyance to Plants: Direct from river to plant (intake only)
Plants:

City of Sacramento	3410020-002	Fairbairn Treatment Plant (American River)
	Plant:	Conventional
	Particulate Removal:	pre-pH adjustment, coagulation, flocculation, sedimentation, rapid sand filtration, rapid mix, rapid mix for nitrate removal
	Disinfection:	pre-and post-gaseous chlorination
	Other:	post- pH adjustment, lime-soda ash addition, PAC
	Distribution:	Booster disinfection in distribution system
Carmichael Water District	3410004-023	Bajamont SWTP - Treated (American River)
		Ranney collector
	Plant:	Membrane filtration
	Disinfection:	post-gaseous chlorination
	Distribution:	Booster disinfection in distribution system
City of Redding	4510005-029	Sacramento River @ Foothill WTP-Treated
	Plant:	Conventional (Treatment plant is approved to operate in in-line filtration mode during the summer months.)
	Particulate Removal:	coagulation, flocculation, sedimentation, rapid sand filtration
	Disinfection:	pre- and post-gaseous chlorination
	Other:	None
	Distribution:	No booster disinfection in distribution system

Yuba County Water District	5810006-002	Treatment Plant - Treated (Feather River?)
	Plant:	Conventional
	Particulate Removal:	rapid sand filtration
	Disinfection:	post-gaseous chlorination
	Distribution:	Booster disinfection in distribution system?

SACRAMENTO River (Upper)

Source Water: Medium-high quality (more anthropogenic discharges), low variability
Conveyance to Plants: Direct from river to plant (intake only)
Plants:

City of West Sacramento	5710003-002	Sacramento River - Treated
	Plant:	Conventional
	Particulate Removal:	rapid sand filtration
	Disinfection:	Chlorine gas
	Distribution:	Booster disinfection in distribution system
City of Sacramento	3410020-008	Sac R WTP - Treated (Lab Tap #12)
	Plant:	Conventional
	Particulate Removal:	pre-pH adjustment, coagulation, flocculation, sedimentation, rapid sand filtration, rapid mix, rapid mix for nitrate removal
	Disinfection:	pre-and post-gaseous chlorination
	Other:	post- pH adjustment, lime-soda ash addition, Diffused Aeration
	Distribution	Booster disinfection in distribution system

SAN JOAQUIN River (Upper) & Tributaries

Tributary Source Water: High quality (more anthropogenic discharges), low variability. WQ issues in local reservoirs
Conveyance to Plants: Aqueducts from Sierra reservoirs to plants or local reservoirs
Plants:

East Bay MUD	0110005-005	Orinda Water Treatment Plant
	Plant:	Direct Filtration
	Particulate Removal:	Coagulation, multi-media filtration.
	Disinfection:	chloramines
	Distribution	No booster disinfection in distribution system
	0110005-004	Lafayette Water Treatment Plant
	Plant:	Direct Filtration
	Particulate Removal:	Coagulation, multi-media filtration.
	Disinfection:	chloramines

	Distribution	No booster disinfection in distribution system
	0110005-012	Walnut Creek Water Treatment Plant
	Plant:	Direct Filtration
	Particulate Removal:	Coagulation, multi-media filtration.
	Disinfection:	chloramines
	Distribution	No booster disinfection in distribution system
	0110005-009	El Sobrante Water Treatment Plant
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation,multi-media filtration.
	Disinfection:	chloramines
	Distribution	No booster disinfection in distribution system
	0110005-011	Upper San Leandro Water Treatment Plant
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation,multi-media filtration.
	Disinfection:	chloramines
	Distribution	No booster disinfection in distribution system
	0110005-013	San Pablo Water Treatment Plant
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation,multi-media filtration.
	Disinfection:	chloramines
	Distribution	No booster disinfection in distribution system
Conveyance to Plants: Sierra Reservoir – local reservoir – canal system		
Modesto Irrigation District	5010038-002	Modesto Reservoir - Treated
	Plant:	Conventional
	Particulate Removal:	coagulation, flocculation, sedimentation, rapid sand filtration, rapid mix, rapid mix for nitrate removal
	Disinfection:	pre-ozonation, post-hypochlorination
	Other:	post-pH adjustment
	Distribution:	Booster disinfection in distribution system?
Conveyance to Plants: Large Sierra Reservoir – intake to treatment plant (?)		
Stockton East Water District	3910006-002	Treatment Plant - Final Treated-SA5 (Calaveras River)
	Plant:	Conventional
	Particulate Removal:	GAC, sedimentation, rapid sand filtration, rapid mix, rapid mix for nitrate removal
	Disinfection:	post-gaseous chlorination
	Other:	post-pH adjustment, GAC
	Distribution:	Booster disinfection in distribution system?

Clovis, City of	1010003-067	Clovis SWTP – Treated (Kings River)
	Plant:	Two Actiflo clarifiers and pressure membranes
	Disinfection:	post-hypochlorination
	Other:	post-pH adjustment
	Distribution:	Booster disinfection in distribution system?
Fresno, City of	1010007-607	Fresno SWTF – Treated (Kings River)
	Plant:	Conventional
	Particulate Removal:	pre-pH adjustment, coagulation, rapid mixing, two Actiflo clarifiers, and 6 GAC gravity filters
	Disinfection:	pre-ozonation, post-hypochlorination
	Other:	post-pH adjustment
	Distribution:	Booster disinfection in distribution system?
Cal Water NE Bakersfield	1510003-252	Kern River Water
	Plant:	Conventional sedimentation and membrane filtration.
	Distribution:	Booster disinfection in distribution system?
Conveyance to Plants: Direct from river to plant (intake only)		
Calaveras County WD	510005-002 510005-006	Bear Creek – Treated Mokelumne River - Treated
	Plant:	Conventional
	Particulate Removal:	coagulation, flocculation, sedimentation, filtration, rapid mix, rapid mix for nitrate removal
	Disinfection:	pre- and post-hypochlorination
	Distribution:	Booster disinfection in distribution system?

NORTH DELTA

Source Water: Medium quality (more anthropogenic discharges), high variability
Conveyance to Plants: River – Aqueduct – (local reservoir/watersheds) – plant

City of Fairfield	4810003-006	North Bay Regional WTP – Treated (NBA and Putah South Canal)
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, dual media gravity deep-bed filtration
	Disinfection:	pre-ozonation, post-hypochlorination and post-ozonation
	Distribution:	No booster disinfection in distribution system
	4810003-007	Waterman WTP-Finished Water
	Plant:	Conventional
	Particulate Removal	Coagulation, flocculation, sedimentation, dual media gravity filtration
	Disinfection:	pre-ozonation, post-hypochlorination and post-ozonation
	Distribution:	Booster disinfection in distribution system
City of Benicia	4810001-001	Benicia WTP – Treated (NBA and **PSC**)
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, rapid sand filtration

	Disinfection:	Pre- and post- Hypochlorination
	Other:	Permanganate
	Distribution:	Booster disinfection in distribution system?
City of Vallejo	4810007-002	Fleming Hill WTP - Treated (NBA Sept-Dec, Berryessa Jan-Mar) [42 MGD]
	Plant:	Conventional
	Particulate Removal:	Coagulation, Flocculation, Sedimentation, Multi-media Filtration
	Disinfection:	Post-gaseous chlorination
	Distribution:	No booster disinfection in distribution system
	4810007-011	Travis WTP – Treated
	Plant:	Conventional
	Particulate Removal:	Coagulation, Flocculation, Sedimentation, Multi-media Filtration
	Disinfection:	Post-gaseous chlorination
	Distribution:	No booster disinfection in distribution system
American Canyon, City of	2810005-004	Treatment Plant_American Canyon – Treated (NBA)
	Plant:	2 processes with matching flows system, older conventional and new membrane
	Particulate Removal:	Conventional: coagulation, flocculation, sedimentation, rapid sand filtration
	Disinfection:	Post-liquid chlorination
	Other:	Post pH adjustment
	Distribution:	No booster disinfection in distribution system

CENTRAL/SOUTH DELTA

Source Water: Delta: Medium-Low quality (more anthropogenic discharges, seawater intrusion), high variability

Conveyance to Plants: Delta – Contra Costa Canal/Los Vaqueros Pipeline – (Los Vaqueros Reservoir) – (local reservoir/watershed) – (blending) -plant

Contra Costa Water District	710003-003	Canal/Mallard-Sampled at Bollman-Treated (Delta – Old River/Rock Slough intakes/LV) [75 MGD]
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, rapid sand filtration, rapid mix, rapid mix for nitrate removal (mixed media GAC filtration)
	Disinfection:	Chloramines, Post-hypochlorination (intermediate ozonation)
	Other:	Permanganate, post-pH adjustment
	Distribution:	Booster disinfection in distribution system
Randall-Bold WTA	710010-002	Randall-Bold Water Treatment Plant [40 MGD]
	Plant:	Direct Filtration 2007 conversion to conventional filtration (new sedimentation basins will be placed in operation during

		Summer)
	Particulate Removal:	Coagulation, flocculation, rapid sand filtration, rapid mix, rapid mix for nitrate removal (mixed media GAC filtration)
	Disinfection:	Chloramines, pre- and Post-ozonation, post-gaseous chlorination
	Other:	post-pH adjustment
	Distribution:	No booster disinfection in distribution system
City of Antioch	710001-001	Contra Costa Canal/Muni Res-Antioch WTP (100% Delta)
	Plant:	Conventional
	Particulate Removal:	Coagulation, sedimentation, dual media gravity
	Disinfection:	Chloramines
	Other:	post-pH adjustment
	Distribution:	No booster disinfection in distribution system

CENTRAL/SOUTH DELTA

Source Water: Delta: Medium-Low quality (more anthropogenic discharges, seawater intrusion), high variability

Conveyance to Plants: Delta – Delta Mendota Canal - plant

Tracy, City of	3910011-008	Treatment Plant Effluent (Delta, groundwater)
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, rapid sand filtration, rapid mix, rapid mix for nitrate removal
	Disinfection:	Pre-and post-gaseous chlorination
	Other:	Permanganate, PAC
	Distribution:	Booster disinfection in distribution system?

SOUTH BAY AQUEDUCT

Source Water: Delta: Medium-Low quality (more anthropogenic discharges, seawater intrusion), high variability

Conveyance to Plants: Delta – Clifton Court Forebay – South Bay Aqueduct- (local reservoir) – plant; also Delta Mendota Canal – San Luis Reservoir – plant

Zone 7 Water Agency	110010-001	Del Valle CWE-Treated Water (Lake Del Valle)
	Plant:	Conventional
	Particulate Removal:	Coagulation, sedimentation, slow sand filtration
	Disinfection:	chloramines
	Other:	post-pH adjustment
	Distribution:	No booster disinfection in distribution system
	110010-008	Patterson Pass CWE-Treated Water (small reservoir)
	Plant:	Parallel Convential/ UF membrane
	Particulate Removal:	Conventional: Coagulation, sedimentation, slow sand filtration/ Membrane ultrafiltration

	Disinfection:	chloramines
	Other:	post-pH adjustment
	Distribution:	No booster disinfection in distribution system
Alameda County Water District	110001-040	Water Treatment Plant #2 – Treated, close to 100% Delta (Lake Del Valle, SBA)
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, slow sand filtration
	Disinfection:	Pre-hypochlorination, pre-ozonation, chloramines
	Distribution:	No booster disinfection in distribution system
	0110001-015	Mission San Jose WTP (Lake Del Valle, SBA)
	Plant:	Ultrafiltration
	Particulate Removal:	Coagulation, Ultrafiltration
	Disinfection:	Pre-ozonate & post chloramination
	Distribution:	Booster disinfection in distribution system? No
Santa Clara Valley Water District	4310027-005	Penitencia WTP [42 MGD] 90% Delta
	Plant:	Conventional
	Particulate Removal:	sedimentation, filtration (biologically active GAC)
	Disinfection:	Intermediate ozone (chlorine primary, chloramines residual)
	Distribution:	Booster disinfection in distribution system? No
	4310027-011	Santa Teresa WTP (100 MGD) 90% Delta
	Plant:	Conventional
	Particulate Removal:	sedimentation, filtration (biologically active GAC)
	Disinfection:	Intermediate ozone (chlorine primary, chloramines residual)
	Distribution:	No booster disinfection in distribution system
	4310027-007	Rinconada WTP (80 MGD) 90% Delta
	Plant:	Conventional
	Particulate Removal:	upflow clarifiers, filtration
	Disinfection:	chlorine primary, chloramines residual (switching to intermediate ozone in 2011 or later)
	Distribution:	No booster disinfection in distribution system
Hollister/ Sunnyslope Water Treatment Authority	3510007-001	Lessalt Treatment Plant (San Luis Reservoir – San Felipe Division pipeline - Hollister conduit) 100% delta (San Luis Reservoir) water
	Plant:	Membrane
	Particulate Removal:	Microfiltration

	Disinfection:	Post-chlorination
	Other:	pH adjustment (caustic soda) for corrosion control
	Distribution:	No booster disinfection in distribution system
CSA 31 - Stonegate	3500006-002	Stonegate WTP– 100% San Luis Reservoir water
	Plant:	conventional (Water Tech packaged plant)
	Particulate Removal:	Coagulation, flocculation (alum & polymer)
	Disinfection:	Post chlorination hyprochloride; no distribution system booster
	Distribution:	No booster disinfection in distribution system

CALIFORNIA AQUEDUCT - SAN LUIS REACH, O'NEILL FOREBAY TO CHECK 21

Source Water: Delta: Medium-Low quality (more anthropogenic discharges, seawater intrusion), medium variability (attenuation in San Luis Reservoir, additional wq issues associated with location of withdrawal from aqueduct)

Conveyance to Plants: Delta – Clifton Court Forebay –Ca Aqueduct - San Luis Reservoir – Ca Aqueduct – (Aqueduct turnout) – Plant

Dos Palos-City	2410002-003	Dos Palos WTP - Treated
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, GAC gravity filtration
	Disinfection:	chloramines
	Distribution:	No booster disinfection in distribution system
Coalinga-City	1010004-002	Plant Effluent [12 MGD] -100% SWP through Coalinga Canal
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtered (dual media filtration), rapid mix,
	Disinfection:	Post-gaseous chlorination (chloramines)
	Other:	Inhibitor, Orthophosphate
	Distribution:	Booster disinfection in distribution system?
Huron, City of	1010044-002	Huron Plant No. 2 Effluent - Treated
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, rapid sand filtration, rapid mix,
	Disinfection:	pre-gaseous chlorination
	Distribution:	Booster disinfection in distribution system?
Avenal, City of	1610002-007	Treatment Plant No. 2 – Treated [3.1 MGD] – 100% SWP
	Plant:	Conventional with gravity filtration
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtered, rapid mix,
	Disinfection:	post-gaseous chlorination
	Distribution:	Booster disinfection in distribution system?
	1610002-008	Treatment Plant No. 1 - Treated [2.2 MGD] – 100% SWP
	Plant:	Conventional with updraft clarifiers and pressure filtration
	Particulate	Coagulation, flocculation, sedimentation, pressure sand

	Removal:	filtration
	Disinfection:	post-gaseous chlorination
	Distribution:	Booster disinfection in distribution system?

CALIFORNIA AQUEDUCT - SAN JOAQUIN FIELD DIVISION, CHECK 21 TO CHECK 39

Source Water: Delta: Medium-Low quality (more anthropogenic discharges, seawater intrusion), medium variability (attenuation in San Luis Reservoir, additional wq issues associated with location of withdrawal from aqueduct)

Conveyance to Plants: Delta – Clifton Court Forebay –Ca Aqueduct - San Luis Reservoir – Ca Aqueduct – (Aqueduct turnout) – Plant [also SWP water exchanged for Kern River, water banking, CVP/Friant-Kern Canal]

Kern County Water Agency	1510040-010	Henry C. Garnett Water Purification Plant – 45 MGD
	Plant:	Conventional (gravity multi-media filtration)
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtered, rapid mix, rapid mix use for nitrate blending
	Disinfection:	Pre- and post-gaseous chlorination
	Other:	Post-pH adjustment, (potassium permanganate. PAC, orthophosphate)
	Distribution:	Booster disinfection in distribution system?

CALIFORNIA AQUEDUCT – COASTAL BRANCH

Source Water: Delta: Medium- quality (more anthropogenic discharges, seawater intrusion), medium variability (attenuation in San Luis Reservoir and with blending of other sources, additional wq issues associated with location of withdrawal from aqueduct)

Conveyance to Plants: Delta – Clifton Court Forebay –Ca Aqueduct - San Luis Reservoir – Ca Aqueduct – Coastal Branch – (local watersheds/reservoirs) - Plant

Central Coast Water Authority	4210030-002	State Water Project – Treated (Polonio Pass WTP, 43 MGD – 100% SWP)
	Plant:	Conventional
	Particulate Removal:	(enhanced) Coagulation, flocculation, sedimentation, filtered (GAC), rapid mix
	Disinfection:	Pre- and post-gaseous chlorination, (chloramine residuals)
	Distribution:	Booster disinfection in distribution system?

CALIFORNIA AQUEDUCT – EAST BRANCH - CHECK 42 TO CHECK 66

Source Water: Delta: Medium- quality (more anthropogenic discharges, seawater intrusion), medium variability (attenuation in San Luis Reservoir and with blending of other sources, additional wq issues associated with location of withdrawal from aqueduct)

Conveyance to Plants: Delta – Clifton Court Forebay –Ca Aqueduct - San Luis Reservoir – Ca Aqueduct – East Branch – (local gw) - Plant

Antelope Valley E Kern Wtr Agy	1510053-020	Water Treatment Plant - Treated
	Plant:	Conventional
	Particulate Removal:	Rapid sand filtration
	Disinfection:	Pre- and post-gaseous chlorination
	Distribution:	Booster disinfection in distribution system?
	1910045-001	Quartz Hill WTP - Clear Well - Treated
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtration
	Disinfection:	Post-liquid chlorination
	Other:	Inhibitor, Orthophosphate
	Distribution:	No booster disinfection in distribution system
	1910045-004	Acton Plant - Treated Effluent
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtration
	Disinfection:	Post-liquid chlorination
	Distribution:	No booster disinfection in distribution system
	1910045-006	Eastside Plant - Treated Effluent
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtration
	Disinfection:	Post-liquid chlorination
	Distribution:	No booster disinfection in distribution system
Palmdale Water Dist.	1910102-030	Filter Plant - Effluent
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtered
	Disinfection:	Post chlorination (sodium hypochlorite)
	Distribution:	Booster disinfection in distribution system

CALIFORNIA AQUEDUCT – EAST BRANCH - SILVERWOOD LAKE

Source Water: Delta: Medium- quality (more anthropogenic discharges, seawater intrusion), medium variability (attenuation in San Luis Reservoir and with blending of other sources, additional wq issues associated with location of withdrawal from aqueduct)

Conveyance to Plants: Delta – Clifton Court Forebay –Ca Aqueduct - San Luis Reservoir – Ca Aqueduct – East Branch – Silverwood Lake - Plant

Metropolitan Water Dist. of So. Cal.	1910087-013	Mills Plant Effluent - Treated (100% SWP, emergency supply from Colorado River, 160 MGD)
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtered
	Disinfection:	Chloramines (ozone primary, chlorine backup and chloramines as secondary disinfectant?)
	Distribution:	No booster disinfection in distribution system
Crestline Lake Arrowhead Water Agency	3610114-002	Lake Silverwood WTP [5 MGD] -100% Lake Silverwood (SWP + local runoff)
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation (upflow clarifier), GAC, filtered (multi-media pressure filters)
	Disinfection:	(MIOX, free chlorine residual)
	Distribution:	Booster disinfection in distribution system

CALIFORNIA AQUEDUCT – EAST BRANCH - DIAMOND VALLEY LAKE, LAKE PERRIS

Source Water: Delta: Medium- quality (more anthropogenic discharges, seawater intrusion), medium variability (attenuation in San Luis Reservoir and with blending of other sources, additional wq issues associated with discharges into aqueduct and residence times of aqueduct, reservoirs)

Conveyance to Plants: Delta – Clifton Court Forebay –Ca Aqueduct - San Luis Reservoir – Ca Aqueduct – East Branch – Diamond Valley Lake/Lake Perris - Plant

Metropolitan Water Dist. of So. Cal.	1910087-003	Diemer Plant Effluent - Treated
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtered
	Disinfection:	Chloramines (chlorine primary and chloramines as secondary disinfectant)
	Distribution:	No Booster disinfection in distribution system
	1910087-017	Skinner Plant Effluent #1 - Treated
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtered
	Disinfection:	Chloramines (chlorine primary and chloramines as secondary disinfectant)
	Distribution:	No Booster disinfection in distribution system
	1910087-020	Weymouth Plant Effluent - Treated
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtered
	Disinfection:	Chloramines (chlorine primary and chloramines as secondary

		disinfectant)
	Distribution:	No Booster disinfection in distribution system

CALIFORNIA AQUEDUCT – WEST BRANCH - CASTAIC LAKE

Source Water: Delta: Medium- quality (more anthropogenic discharges, seawater intrusion), medium variability (attenuation in San Luis Reservoir and with blending of other sources, additional wq issues associated with discharges into aqueduct and residence times of aqueduct, reservoirs)

Conveyance to Plants: Delta – Clifton Court Forebay –Ca Aqueduct - San Luis Reservoir – Ca Aqueduct – West Branch – Castaic Lake - Plant

Metropolitan Water Dist. of So. Cal.	1910087-005	Jensen Plant Effluent - Treated
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtered
	Disinfection:	Chloramines (ozone primary, chlorine backup and chloramines as secondary disinfectant)
	Distribution:	No Booster disinfection in distribution system
Castaic Lake Water Agency	1910048-002	Earl Schmidt WTP Effluent - Treated
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtered, rapid mix
	Disinfection:	Pre-ozonation and post chloramination
	Distribution:	No booster chlorination
	1910048-003	Rio Vista WTP Effluent - Treated
	Plant:	Conventional
	Particulate Removal:	Coagulation, flocculation, sedimentation, filtered, rapid mix
	Disinfection:	pre-ozonation and post chloramination
	Distribution:	No booster chlorination

Assistance Received from the Following California Department of Public Health Engineers:
Stefan Cajina, P.E
Carl L. Carlucci, P.E.
Richard Haberman P.E.
Eric Lacy, P.E.
Sean McCarthy, P.E.
Catherine Ma, P.E.
Terry Macaulay, P.E.
Michael J. McNamara, P.E.
Jeff O'Keefe, P.E.
Kurt Souza, P.E.
Jan R. Sweigert, P.E.
Paul Williams, P.E.

CALFED Water Quality Program – Final Assessment
Basic Treatment Questionnaire January 30, 2007

Background:

The CALFED Water Quality Program committed to developing a final program assessment in the CALFED Program 10-Year Action Plan, released in early 2006. The initial program assessment, completed in July 2005, focused on assessing the results of funded projects and progress toward specific ROD goals. This final program assessment will take a systemic look at drinking water quality and the Delta and attempt to describe the status of our knowledge, including watershed sources and timing, drinking water treatment, and potential improvement actions. In parallel with this project, the program is also developing a performance measure system and working closely with the Central Valley Drinking Water Policy project. The U.S. Bureau of Reclamation has retained the services of URS (with subconsultant Brown and Caldwell) to support development of the final program assessment. The evaluation of tap water and potential tap water improvement actions will focus on an analysis of drinking water treatment in California, a more in-depth assessment of drinking water treatment, and reviewing the benefit of the CALFED funded drinking water treatment studies.

Request:

The CALFED Water Quality Program is trying to compile fundamental information on the use of the Delta as a drinking water source. The California Department of Health Services has provided information from its databases on treatment process and treated water quality, but some information is either out of date or simply not captured. Some of this updated information is being gathered through DHS District Engineers. For the remaining information, the CALFED Water Quality Program is requesting assistance directly from utility representatives. This should not take a substantial amount of time, and does not require extensive detail. The information would be used to develop/inform criteria for the selection of 5 to 10 representative treatment plants, for which conceptual models will be developed detailing water quality from source through treatment plant. To a limited degree, the data will also support evaluation of drinking water treatment within the CALFED solution area.

PLEASE RETURN BY March 9, 2007 to Sam Harader at sharader@calwater.ca.gov, (916) 445-5466.

Questionnaire

(Based on entire utility/agency/district, unless it is easier to answer for specific treatment plants):

Utility Name:

Does utility resale water?

If so, approximately what percentage?

Does utility wholesale water?

If so, approximately what percentage?

What communities/resalers receive the water?

(Based on individual treatment plants):

Treatment plant :

Rated capacity of plant:

What percentage of Delta water is used, on average, per year?

0-10% 10-25% 25-50% 50-80% 80-100%

Does the plant use other surface water sources?

Does the plant use ground water sources?

Are there times when there is no Delta water being treated?

What are the major drivers of use of Delta water?

Water Quality

Economics

Infrastructure limitations

Supply needs

If your source is 100% Delta water, do you have a back up source?

What is your primary disinfectant (disinfectants used within treatment plant to achieve log removal requirements?

What is the residual disinfectant in your distribution system?

Would you be willing to review DHS data for accuracy?

Would you be willing to provide an ArcView (GIS) shape file of your service area (to be used in 8.5” x 11” maps of state or large portions of state)?

Are you interested in reviewing interim products of the CALFED Final Assessment? (If so, please include your contact information)

		Alkalinity (Total) as CaCO3							Total Organic Carbon (TOC)							Bromodichlormethane (THM)							Carbon Tetrachloride						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
Upper Sacramento basin or tributary to Sacramento R - high quality source																													
City of Sacramento	Amer R WTP - Treated (Lab Tap #08)	25.96	26	31	19	45	6/30/88	8/14/06								1.93	1.7	2.8	0.87	5	1/27/03	8/14/06	0	0	0	0	5	1/27/03	8/14/06
Carmichael Water District	Bajamont SWTP - Treated	30.52	30.9	38	22	21	11/19/03	4/20/06	0.843	0.8	1.3	0.6	19	11/19/03	4/20/06	1	1	1.7	0	24	11/19/03	7/27/06	<0.5	<0.5	<0.5	<0.5	4	6/16/05	7/27/06
City of Redding	Sacramento River @ Foothill WTP-Treated	45.62	48.9	57	30	6	3/4/85	1/15/93	1.262	0.79	8.3	0	11	2/1/02	11/8/04	2	2	4.7	0	5	2/3/88	1/12/93	0.16667	0	<0.5	0	3	2/3/88	9/28/89
Yuba County Water District	Treatment Plant - Treated	22.68	22	28	19	9	3/7/84	3/6/06								0.48	0.25	1.4	0	6	3/27/90	8/29/06	0	0	0	0	3	3/27/90	6/22/04
Lower Sacramento basin - still high quality but downstream of ag and urban land uses																													
City of West Sacramento	Sacramento River - Treated	58.41	58	74	47	14	8/23/88	7/12/06	1.184	1.1	2.9	0.7	57	4/8/02	11/8/06	2.35	2.8	4.2	0	13	8/23/88	8/7/06	<0.4	<0.5	<0.5	0	5	11/13/92	8/7/06
City of Sacramento	Sac R WTP - Treated (Lab Tap #12)	50.66	51.5	69	26	38	6/30/88	8/14/06								4.6	4.6	5.7	3.5	2	4/21/03	8/14/06	0	0	0	0	2	4/21/03	8/14/06
Upper San Joaquin basin or tributary to San Joaquin R. - high quality source																													
East Bay MUD	Lafayette WTP-Mokelumne Aqueduct - Trtd	19.6	19	27	15	67	1/11/86	10/5/06								2.02	1.9	4.8	1.08	20	8/10/94	8/3/00	<0.422962	<0.5	<0.5	0	27	5/17/95	7/12/06
	Orinda TP-Mokelumne Aqueduct Water-Trtd	25.65	23.5	53	17	86	1/11/86	10/6/06								2.09	2	5.1	0.59	31	8/10/94	12/4/00	<0.500952	<0.5	<1	<0.14	63	2/15/95	7/12/06
	Sobrante WTP-San Pablo Water - Treated	74.93	72	120	38	70	1/11/86	11/7/06								12.8	13.5	23	0.62	48	8/10/94	12/4/00	<0.500821	<0.5	<1	<0.14	73	2/15/95	7/12/06
	San Pablo WTP	74.31	68	98	60	32	2/15/95	11/14/06								9.72	9.45	14	6.9	16	2/15/95	4/15/97	0.5	0.5	0.5	0.5	26	2/15/95	10/17/06
	Upper San Leandro WTP-USL Water-Treated	114.1	120	140	76	58	9/1/88	10/5/06								18.7	19	30	1.56	22	8/10/94	8/3/00	<0.409629	<0.5	<0.5	0	27	2/15/95	7/12/06
	Walnut Creek WTP-Mokelumne Aqueduct-Trtd	20.08	19	38	15	76	1/11/86	11/9/06								3.87	2.5	13	1.55	8	8/10/94	9/19/00	<0.421666	<0.5	<1	<0.14	12	2/15/95	7/12/06
Modesto Irrigation District	Modesto Reservoir - Treated								1.2				1	11/7/06															
Stockton East Water District	Treatment Plant - Final Treated-SA5	57.8	52.5	96	30	10	6/8/89	6/13/06								3.19	3.2	11	0	29	12/20/88	9/22/06	0	0	0	0	2	5/8/89	7/5/89
C.C.W.D., West Point	West Point WTP - Effluent	24.63	26	32	13	16	5/14/91	4/12/06	1.3				1	4/13/05		2.35	1.95	3.9	1.6	4	3/29/00	9/15/04	0	0	0	0	2	3/29/00	3/21/01
	Bear Creek - Treated	25				1	4/13/05		1.3				1	4/13/05															
	Mokelumne River - Treated															2.8				1	11/12/03								
Clovis, City of	Clovis SWTP - Treated	10				1	9/28/05																						
Fresno, City of	Fresno SWTF - Treated	36.25	34.5	75	20	16	10/26/04	8/1/06	0.829	0.9	2	0	27	7/26/04	11/2/06														
North Delta																													
City of Fairfield	North Bay Regional WTP - Treated	115.8	119	158	65	33	12/2/91	10/10/06	1.567	1.48	3.26	0.92	15	1/9/02	10/10/06	2.41	1.6	19	0	27	10/12/91	10/10/06	<0.173076	0	<0.5	0	26	10/12/91	10/10/06
	Waterman WTP-Finished Water	148.4	150	177	131	43	10/1/87	10/10/06	1.639	1.6	2.72	1.12	15	4/11/02	10/10/06	3.06	1.8	11	0	34	10/1/87	10/10/06	<0.25	<0.25	<0.5	0	22	2/8/93	10/10/06
City of Benicia	Benicia WTP - Treated	93.83	91.5	120	80	6	9/14/89	12/7/05	2.536	1.8	14	<0.2	55	3/21/02	11/7/06	11.9	11	30	0	27	1/22/02	1/26/04	0				1	7/9/02	
City of Vallejo	Fleming Hill WTP - Treated	118.4	125	134	79	7	12/17/92	10/16/06								8.3				1	12/17/92		0				1	12/17/92	
	Travis WTP - Treated	109				1	9/29/94																						
American Canyon, City of	Treatment Plant_American Canyon - Treated								3.332	3	12	0	66	1/22/02	11/1/06														
Central/South Delta																													
Contra Costa Water District	Canal/Mallard-Sampled at Bollman-Treated	65.51	64	102	41	276	2/24/87	11/21/06								6.82	6.65	19	0	128	6/29/89	10/17/06	<0.495145	<0.5	<1	0	103	6/29/89	10/9/02
Randall-Bold Water Treatment Plant	Randall Bold WTP - Treated	73.98	71	107	40	51	11/5/02	11/21/06	2.733	2.9	3	2.3	3	10/4/04	11/16/06	2.29	<0.5	19	0	15	1/9/02	10/17/06	0	0	0	0	4	1/9/02	10/9/02

		Alkalinity (Total) as CaCO3							Total Organic Carbon (TOC)							Bromodichlormethane (THM)							Carbon Tetrachloride						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
City of Antioch	Contra Costa Canal/Muni Res-Antioch WTP	71.57	69.5	130	48	30	1/29/88	3/22/06																					
Delta Mendota Canal																													
Tracy, City of	Treatment Plant Effluent	54.75	57	94	21	25	12/19/89	7/31/06	2.204	2.1	4.16	0.89	53	3/20/02	10/2/06	11.1	11.5	23	0	30	6/21/89	7/31/06	0.21667	0	1.1	0	12	6/21/89	7/31/06
South Bay Aqueduct																													
Zone 7 Water Agency	Del Valle CWE-Treated Water	79.98	74	146	38	54	1/13/87	10/11/06	1.782	1.6	3.4	0.78	47	7/16/02	10/11/06	13.3	13	20	7	17	7/13/88	9/13/06	0	0	0	0	17	7/13/88	9/13/06
	Patterson Pass CWE-Treated Water	69.81	72	118	24	86	4/14/87	10/11/06	1.718	1.57	3.73	1	56	2/21/01	10/11/06	13.9	13	26	6.1	37	7/13/88	9/13/06	0	0	0	0	30	7/13/88	9/13/06
Alameda County Water District	Water Treatment Plant #2 - Treated	93.18	88	164	42	28	8/22/95	6/21/06	1.585	1.59	1.9	1.27	2	6/21/05	7/5/05	1.43	1.3	3.5	0	20	6/14/95	6/21/06	<0.083333	0	<0.5	0	18	6/14/95	6/21/05
	Mission San Jose WTP	88.41	90	146	36	27	5/22/86	6/21/06	1.92	1.92	2.27	1.57	2	6/21/05	7/5/05	15.9	16.5	29	0	26	12/30/87	6/21/06	<0.068181	0	<0.5	0	22	3/31/88	6/21/06
Santa Clara Valley Water District	Penitencia WTP	66	66	113	29	31	8/12/87	11/14/06	1.871	1.9	2.6	0.82	15	2/25/03	11/14/06	15.6	15	30.7	0	45	7/1/87	11/14/06	<0.027027	0	<0.5	0	37	7/1/87	11/14/06
California Aqueduct - O'Neill Forebay and San Luis Reservoir																													
Santa Clara Valley Water District	Santa Teresa WTP	83.97	78.5	142	62	30	3/31/92	11/14/06	2.212	2.14	3	1.6	17	11/12/02	11/14/06	18.2	18	34.4	7	46	2/23/89	11/14/06	<0.0125	0	<0.5	0	40	10/16/89	11/14/06
	Rinconada WTP	76.51	77	123	49	35	8/12/87	11/14/06	1.974	1.93	2.55	1.4	17	11/12/02	11/14/06	14.8	13	43	7.73	51	7/1/87	8/8/06	<0.011627	0	<0.5	0	43	7/1/87	8/8/06
California Aqueduct - San Luis Reach, O'Neill Forebay to Check 21																													
Dos Palos-City	Dos Palos WTP - Treated	69.09	70.4	95	35	33	9/28/90	11/2/06	2.414	2.3	4	1.6	29	4/15/04	11/2/06	2.1	2.1	2.4	1.8	2	10/17/91	7/9/92							
Coalinga-City	Plant Effluent	56.76	60	100	30	45	1/5/01	11/9/06	2.453	2.2	5.2	1.4	70	5/4/01	11/9/06	18.2	18	31	9.3	13	11/8/96	9/1/06	0.27333	0	1.4	0	12	11/8/96	9/1/06
Huron, City of	Huron Plant No. 2 Effluent - Treated	59.07	56	92	45	11	8/2/05	10/5/06	3.381	2.3	14	1	25	3/30/04	11/2/06	35.9				1	8/23/05								
Avenal, City of	Treatment Plant No. 2 - Treated								2.474	2.25	5.9	1.04	42	12/13/00	12/7/05														
	Treatment Plant No. 1 - Treated								2.167	2.11	4.2	0.9	35	7/18/01	12/7/05														
California Aqueduct - San Joaquin Field Division, Check 21 to Check 39																													
Kern County Water Agency	ID4 Treated - T1 (Henry Garnett WTF)	53.02	53.7	98	19	177	3/10/90	10/3/06	1.925	1.94	2.44	1.14	12	9/6/05	10/3/06	7.36	5.65	25.8	1.3	86	3/20/90	8/30/02	0.31818	<0.5	<0.5	0	44	3/20/90	10/16/06
Coastal Branch																													
Central Coast Water Authority	State Water Project - Treated (Polonio Pass WTP)	72.07	76	86	0	26	1/1/02	7/24/06	2.24	2.2	3.7	1	31	5/1/02	8/7/06	11.9	13	17	4.8	13	2/19/02	3/15/06	<0.1	0	<0.5	0	5	3/26/02	3/15/06
East Branch - Check 42 to Check 66																													
Antelope Valley E Kern Wtr Agy	Water Treatment Plant - Treated	61.08	57	80	40	17	12/29/87	12/7/05	2.046	1.88	4.4	1.32	58	1/16/02	10/11/06	2.1	0	6.3	0	3	10/19/89	12/3/03	0	0	0	0	3	10/19/89	12/3/03
	Quartz Hill WTP - Clear Well - Treated	59.14	57.3	90	37	14	12/21/93	12/7/05	2.011	1.89	3.59	0.19	56	1/16/02	10/11/06	4.35	4.35	8.7	0	2	12/3/03	12/13/04	0	0	0	0	2	12/3/03	12/13/04
	Acton Plant - Treated Effluent	63.6	67	69	57	5	2/4/03	10/11/06	2.098	2.08	4	1.43	56	1/16/02	10/11/06	11.8				1	12/3/03		0				1	12/3/03	
	Eastside Plant - Treated Effluent	58.28	52.6	96	35	11	12/4/96	12/7/05	2.122	1.96	4.15	1.38	57	1/30/02	10/11/06	7.5				1	12/3/03		0				1	12/3/03	
Palmdale Water Dist.	Filter Plant - Effluent	85.64	86	90	80	11	1/21/02	1/4/06	2.167	2.09	3.08	1.7	14	1/14/02	10/17/03	13.5	6.8	64	4.2	9	1/16/02	1/4/06	<0.222222	0	<0.5	0	9	1/16/02	1/4/06
East Branch - Silverwood Lake																													
Metropolitan Water Dist. of So. Cal.	Mills Plant Effluent - Treated	69.01	68	93	48	67	10/31/86	11/1/06	2.308	2.16	3.84	1.58	47	2/28/02	12/30/05	4				1	9/6/05		<0.052631	0	<0.5	0	19	3/5/02	10/3/06
CLAWA	Lake Silverwood WTP	68.4	64.4	102	51	7	1/15/90	7/13/92	3.9	3.7	4.4	3.6	3	2/22/02	4/18/02	2.7	2.7	5.4	0	2	6/11/90	6/23/03	0	0	0	0	1	6/11/90	6/11/90
East Branch - Diamond Valley Lake, Lake Perris																													
Metropolitan Water Dist. of So. Cal.	Diemer Plant Effluent - Treated	94.42	92	126	71	67	10/31/86	10/31/06	2.312	2.25	3.12	1.72	46	2/28/02	12/30/05	12				1	9/12/05		<0.055555	0	<0.5	0	18	3/5/02	10/3/06

		Alkalinity (Total) as CaCO3							Total Organic Carbon (TOC)							Bromodichlormethane (THM)							Carbon Tetrachloride						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
Metropolitan Water Dist. of So. Cal.	Skinner Plant Effluent #1 - Treated	114.1	112	127	105	11	10/31/86	7/31/94																					
Metropolitan Water Dist. of So. Cal.	Weymouth Plant Effluent - Treated	93.99	94	126	63	67	10/31/86	10/31/06	2.327	2.24	3.25	1.74	47	2/28/02	12/30/05	17				1	9/6/05		<0.052631	0	<0.5	0	19	3/5/02	10/19/06
Metropolitan Water Dist. of So. Cal.	Skinner Reservoir Effluent - Treated	107.8	109	124	80	57	2/28/02	10/31/06	2.512	2.54	3.1	2.07	46	2/28/02	12/30/05	23				1	9/6/05		<0.052631	0	<0.5	0	19	3/5/02	11/6/06
West Branch - Castaic Lake																													
Metropolitan Water Dist. of So. Cal.	Jensen Plant Effluent - Treated	86.98	87	111	79	66	10/31/86	10/31/06	2.337	2.22	3	1.91	47	2/28/02	12/30/05	12				1	9/6/05		<0.052631	0	<0.5	0	19	3/5/02	10/3/06
Castaic Lake Water Agency	Earl Schmidt WTP Effluent - Treated	86	86	90	80	5	3/28/91	10/20/97								0				1	10/17/89		0				1	10/17/89	
	Rio Vista WTP Effluent - Treated	86				1	10/6/97																						

		Bromoform (THM)							Dibromochloromethane (THM)							Chloroform (THM)							Total Dissolved Solids						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
Upper Sacramento basin or tributary to Sacramento R - high quality source																													
City of Sacramento	Amer R WTP - Treated (Lab Tap #08)	0	0	0	0	5	1/27/03	8/14/06	0	0	0	0	5	1/27/03	8/14/06	32	29	39	29	5	1/27/03	8/14/06	57.58	57	74	45	48	6/30/88	8/14/06
Carmichael Water District	Bajamont SWTP - Treated	<0.5	<0.5	<1	0	24	11/19/03	7/27/06	<0.4791	<0.5	<1	0	24	11/19/03	7/27/06	6.1	4.8	15	<1	24	11/19/03	7/27/06							
City of Redding	Sacramento River @ Foothill WTP-Treated	0.1	0	<0.5	0	5	2/3/88	1/12/93	0.202	0	0.51	0	5	2/3/88	1/12/93	12	18	24	0	5	2/3/88	1/12/93	67	69	95	31	6	3/4/85	1/15/93
Yuba County Water District	Treatment Plant - Treated	<0.16666	0	<0.5	0	6	3/27/90	8/29/06	<0.1666	0	<0.5	0	6	3/27/90	8/29/06	6.6	2.56	20	0	6	3/27/90	8/29/06	40.11	46	50	15	9	3/7/84	5/6/03
Lower Sacramento basin - still high quality but downstream of ag and urban land uses																													
City of West Sacramento	Sacramento River - Treated	<0.27272	0	<1	0	11	12/6/90	8/7/06	<0.3	0	<1	0	11	12/6/90	8/7/06	13	9.4	27	0	13	8/23/88	8/7/06	108.2	110	130	80	13	8/23/88	7/12/06
City of Sacramento	Sac R WTP - Treated (Lab Tap #12)	0	0	0	0	2	4/21/03	8/14/06	0	0	0	0	2	4/21/03	8/14/06	29	28.5	31	26	2	4/21/03	8/14/06	104.1	105	149	1	39	6/30/88	8/14/06
Upper San Joaquin basin or tributary to San Joaquin R. - high quality source																													
East Bay MUD	Lafayette WTP-Mokelumne Aqueduct - Trtd	<0.3665	<0.5	<0.5	0	20	8/10/94	8/3/00	<0.372	<0.5	<0.5	0	20	8/10/94	8/3/00	62	67.5	88	32	20	8/10/94	8/3/00	40.88	41	57	<25	17	1/11/86	7/12/06
	Orinda TP-Mokelumne Aqueduct Water-Trtd	<0.48161	<0.5	<1	<0.03	31	8/10/94	12/4/00	<0.4845	<0.5	<1	<0.06	31	8/10/94	12/4/00	51	48	80	28	31	8/10/94	12/4/00	53.95	51	88	38	20	1/11/86	7/12/06
	Sobrante WTP-San Pablo Water - Treated	<0.49354	<0.5	1	<0.03	48	8/10/94	12/4/00	3.3633	3.35	7.2	<0.06	48	8/10/94	12/4/00	43	47	84	1.2	48	8/10/94	12/4/00	135.7	130	220	73	19	1/11/86	7/12/06
	San Pablo WTP	<0.5	<0.5	<0.5	0.5	16	2/15/95	4/15/97	0.9375	0.94	1.2	0.66	16	2/15/95	4/15/97	41	39.5	59	27	16	2/15/95	4/15/97	153.3	145	180	140	12	2/15/95	10/17/06
	Upper San Leandro WTP-USL Water-Treated	<0.36818	<0.5	<0.5	0	22	8/10/94	8/3/00	3.7209	4	7.4	<0.06	22	8/10/94	8/3/00	65	64	97	19	22	8/10/94	8/3/00	192.1	200	240	130	16	9/1/88	7/12/06
	Walnut Creek WTP-Mokelumne Aqueduct-Trtd	<0.30375	<0.1	<1	<0.03	8	8/10/94	9/19/00	1.1063	0.38	6.41	0.06	8	8/10/94	9/19/00	56	60.5	81	24	8	8/10/94	9/19/00	44.78	45	58	32	18	1/11/86	7/12/06
Modesto Irrigation District	Modesto Reservoir - Treated																												
Stockton East Water District	Treatment Plant - Final Treated-SA5	<0.70666	<0.5	7.7	0	30	8/7/85	9/22/06	<0.56	<0.5	1.9	0	30	8/7/85	9/22/06	21	20.6	54	0	30	8/7/85	9/22/06							
C.C.W.D., West Point	West Point WTP - Effluent	0.35	0	1.4	0	4	3/29/00	9/15/04	0.1375	0	0.55	0	4	3/29/00	9/15/04	20	17	36	11	4	3/29/00	9/15/04	73.13	71	160	46	16	5/14/91	4/12/06
	Bear Creek - Treated																						49				1	4/13/05	
	Mokelumne River - Treated	0				1	11/12/03		0				1	11/12/03		85				1	11/12/03								
Clovis, City of	Clovis SWTP - Treated																						15				1	9/28/05	
Fresno, City of	Fresno SWTF - Treated																						65	65	73	57	2	10/26/04	5/2/05
North Delta																													
City of Fairfield	North Bay Regional WTP - Treated	<0.61071	<0.5	2.6	0	28	10/12/91	10/10/06	2.4321	1.85	14	0	28	10/12/91	10/10/06	2.7	0.9	26	0	27	10/12/91	10/10/06	221.7	215	300	150	33	12/2/91	10/10/06
	Waterman WTP-Finished Water	<0.30937	0	2.4	0	32	10/1/87	10/10/06	1.6541	1.4	5.2	0	34	10/1/87	10/10/06	7.3	2.1	64	0	34	10/1/87	10/10/06	217.9	210	360	130	44	12/31/86	10/10/06
City of Benicia	Benicia WTP - Treated	0.28815	0	1	0	27	1/22/02	1/26/04	3.1926	2.1	11	0	27	1/22/02	1/26/04	33	34	52	0	27	1/22/02	1/26/04	193.5	190	260	150	8	7/24/86	12/7/05
City of Vallejo	Fleming Hill WTP - Treated	0				1	12/17/92		0.92				1	12/17/92		36				1	12/17/92		175.1	190	250	66	7	12/17/92	10/16/06
	Travis WTP - Treated																						230				1	9/29/94	
American Canyon, City of	Treatment Plant_American Canyon - Treated																												
Central/South Delta																													
Contra Costa Water District	Canal/Mallard-Sampled at Bollman-Treated	7.1782	3.13	47	0	128	6/29/89	10/17/06	8.8613	8.6	21.9	0	128	6/29/89	10/17/06	4.5	3.75	16	0	128	6/29/89	10/17/06	246.4	230	524	110	184	2/24/87	2/18/03
Randall-Bold Water Treatment Plant	Randall Bold WTP - Treated	0.85333	<0.5	5.9	0	15	1/9/02	10/17/06	2.0533	<0.5	18	0	15	1/9/02	10/17/06	1.5	<0.5	9.7	0	15	1/9/02	10/17/06							

		Bromoform (THM)							Dibromochloromethane (THM)							Chloroform (THM)							Total Dissolved Solids						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
City of Antioch	Contra Costa Canal/Muni Res-Antioch WTP																						294.1	280	639	140	33	1/30/87	3/22/06
Delta Mendota Canal																													
Tracy, City of	Treatment Plant Effluent	3.92	1.55	18	0	30	6/21/89	7/31/06	10.99	9.75	32	0	30	6/21/89	7/31/06	7.4	7	16	0	30	6/21/89	7/31/06	285.4	280	470	160	10	12/19/89	7/31/06
South Bay Aqueduct																													
Zone 7 Water Agency	Del Valle CWE-Treated Water	6.24706	1.8	34	0	17	7/13/88	9/13/06	11.641	8.1	57	0	17	7/13/88	9/13/06	20	15	52	2	17	7/13/88	9/13/06	254.1	252	443	114	53	1/13/87	10/11/06
	Patterson Pass CWE-Treated Water	7.11944	1.9	33	0	36	7/13/88	9/13/06	15.076	9.6	50	1.5	37	7/13/88	9/13/06	16	15	40	1.8	37	7/13/88	9/13/06	256.6	248	432	111	86	4/14/87	10/11/06
Alameda County Water District	Water Treatment Plant #2 - Treated	1.03	0.75	3.9	0	20	6/14/95	7/5/05	1.9205	1.85	5.1	0	20	6/14/95	6/21/06	2.9	1.2	40	0	20	6/14/95	6/21/06	255	245	394	96	20	8/22/95	6/21/06
	Mission San Jose WTP	8.288	1.5	45.9	0	25	3/31/88	6/21/06	14.277	9.85	43	0	26	12/30/87	6/21/06	18	20.5	52	0	26	12/30/87	6/21/06	268.6	249	402	74	18	5/22/86	6/21/06
Santa Clara Valley Water District	Penitencia WTP	4.72727	1	32	0	44	7/1/87	11/14/06	12.931	8.9	47	0	45	7/1/87	11/14/06	17	16.9	33	0	45	7/1/87	11/14/06	248.6	230	459	114	31	8/12/87	11/14/06
California Aqueduct - O'Neill Forebay and San Luis Reservoir																													
Santa Clara Valley Water District	Santa Teresa WTP	7.31444	5.7	28	0	45	2/23/89	11/14/06	19.534	18.2	41	1.5	46	2/23/89	11/14/06	11	9.56	31	2	46	2/23/89	11/14/06	282.9	281	380	220	29	3/31/92	11/14/06
	Rinconada WTP	7.1544	5.18	31.6	0	50	7/1/87	8/8/06	18.915	17.1	52	0	51	7/1/87	11/14/06	10	7.6	45	2.7	51	7/1/87	11/14/06	278.3	273	411	148	35	8/12/87	11/14/06
California Aqueduct - San Luis Reach, O'Neill Forebay to Check 21																													
Dos Palos-City	Dos Palos WTP - Treated	4.8				1	10/17/91		2.8	2.8	3.8	1.8	2	10/17/91	7/9/92	1.2	1.15	1.3	1	2	10/17/91	7/9/92	133	133	230	36	2	9/28/90	9/1/05
Coalinga-City	Plant Effluent	4.66231	2.4	18	0	13	11/8/96	9/1/06	13.431	11	35	4.2	13	11/8/96	9/1/06	13	12	28	2.9	13	11/8/96	9/1/06	328	320	380	260	5	1/19/01	1/21/05
Huron, City of	Huron Plant No. 2 Effluent - Treated	2.31				1	8/23/05		22.4				1	8/23/05		48				1	8/23/05								
Avenal, City of	Treatment Plant No. 2 - Treated																												
	Treatment Plant No. 1 - Treated																												
California Aqueduct - San Joaquin Field Division, Check 21 to Check 39																													
Kern County Water Agency	ID4 Treated - T1 (Henry Garnett WTF)	2.18547	<0.5	32.8	0	86	3/20/90	8/30/02	4.6616	<0.5	46.8	0	86	3/20/90	10/5/99	33	35.7	91	0.5	86	3/20/90	8/30/02	131.2	103	465	40	176	3/10/90	10/3/06
Coastal Branch																													
Central Coast Water Authority	State Water Project - Treated (Polonio Pass WTP)	3.83077	3.2	10	0.8	13	2/19/02	3/15/06	10.769	10	18	5.1	13	2/19/02	3/15/06	8.2	9.2	14	2	13	2/19/02	3/15/06	244	245	280	206	4	3/26/02	7/24/06
East Branch - Check 42 to Check 66																													
Antelope Valley E Kern Wtr Agy	Water Treatment Plant - Treated	6	0	18	0	3	10/19/89	12/3/03	6.6333	0	19.9	0	3	10/19/89	12/3/03	0.4	0	1.2	0	3	10/19/89	12/3/03	299.3	304	440	160	14	12/29/87	12/7/05
	Quartz Hill WTP - Clear Well - Treated	7.65	7.65	15.3	0	2	12/3/03	12/13/04	12.6	12.6	25.2	0	2	12/3/03	12/13/04	0.8	0.8	1.6	0	2	12/3/03	12/13/04	292.1	293	435	160	14	12/21/93	12/7/05
	Acton Plant - Treated Effluent	23.9				1	12/3/03		34.3				1	12/3/03		2.2				1	12/3/03		301.5	300	320	287	4	2/4/03	10/11/06
	Eastside Plant - Treated Effluent	15.3				1	12/3/03		23.1				1	12/3/03		1.2				1	12/3/03		289.4	304	390	160	10	12/4/96	12/7/05
Palmdale Water Dist.	Filter Plant - Effluent	4.61111	4.7	9.1	0	9	1/16/02	1/4/06	19.7	11	89	8.6	9	1/16/02	1/4/06	5.7	2.4	26	2	9	1/16/02	1/4/06	324	320	380	290	5	1/21/02	1/4/06
East Branch - Silverwood Lake																													
Metropolitan Water Dist. of So. Cal.	Mills Plant Effluent - Treated	1.9				1	9/6/05		5.5				1	9/6/05		1.9				1	9/6/05		282	287	422	146	67	10/31/86	11/1/06
CLAWA	Lake Silverwood WTP	0.8	0.8	1.6	0	2	6/11/90	6/23/03	3.3	3.3	6.6	0	2	6/11/90	6/23/03	3.2	3.15	6.3	0	2	6/11/90	6/23/03	342.8	338	408	270	7	1/15/90	7/13/92
East Branch - Diamond Valley Lake, Lake Perris																													
Metropolitan Water Dist. of So. Cal.	Diemer Plant Effluent - Treated	1.5				1	9/12/05		9.6				1	9/12/05		8.2				1	9/12/05		462.8	463	656	290	67	10/31/86	10/31/06

		Bromoform (THM)							Dibromochloromethane (THM)							Chloroform (THM)							Total Dissolved Solids						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
Metropolitan Water Dist. of So. Cal.	Skinner Plant Effluent #1 - Treated																						534.9	490	710	452	11	10/31/86	7/31/94
Metropolitan Water Dist. of So. Cal.	Weymouth Plant Effluent - Treated	1.3				1	9/6/05		11				1	9/6/05		15				1	9/6/05		457.1	465	653	293	66	10/31/86	10/31/06
Metropolitan Water Dist. of So. Cal.	Skinner Reservoir Effluent - Treated	2.1				1	9/6/05		17				1	9/6/05		20				1	9/6/05		509.2	510	609	397	57	2/28/02	10/31/06
West Branch - Castaic Lake																													
Metropolitan Water Dist. of So. Cal.	Jensen Plant Effluent - Treated	2.2				1	9/6/05		12				1	9/6/05		6				1	9/6/05		311.4	309	462	249	66	10/31/86	10/31/06
Castaic Lake Water Agency	Earl Schmidt WTP Effluent - Treated	0				1	10/17/89		0				1	10/17/89		0				1	10/17/89		344	330	390	300	5	3/28/91	10/20/97
	Rio Vista WTP Effluent - Treated																						310				1	10/6/97	

		Dichloroacetic Acid (DCAA)							Dibromomethane							Turbidity, Laboratory							Total Trihalomethanes						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
Upper Sacramento basin or tributary to Sacramento R - high quality source																													
City of Sacramento	Amer R WTP - Treated (Lab Tap #08)															0.083	0.1	0.17	0.05	48	6/30/88	8/14/06	33.56	32	42	30	5	1/27/03	8/14/06
Carmichael Water District	Bajamont SWTP - Treated	3.6	3.3	6.7	2.2	20	11/19/03	7/13/06	<0.5	<0.5	<0.5	<0.5	4	6/16/05	7/27/06								6.838	6.4	16	<0.5	24	11/19/03	7/27/06
City of Redding	Sacramento River @ Foothill WTP-Treated															0.32	0.35	0.65	<0.1	5	3/4/85	1/15/93	15.21	19	36	0	7	2/3/88	1/26/94
Yuba County Water District	Treatment Plant - Treated	3.9	4.1	5.7	1.8	3	2/21/06	8/29/06								0.15	0.1	0.25	<0.1	3	6/23/92	6/14/94	7.027	2.8	21	0	6	3/27/90	8/29/06
Lower Sacramento basin - still high quality but downstream of ag and urban land uses																													
City of West Sacramento	Sacramento River - Treated	2	2.1	3.8	0	4	5/14/03	5/14/03								0.296	0.18	1.1	0.04	14	8/23/88	7/12/06	13.17	11	25	0	11	12/6/90	8/7/06
City of Sacramento	Sac R WTP - Treated (Lab Tap #12)															0.1	0.1	0.38	0.05	37	6/30/88	8/14/06	34.35	34	37	32	2	4/21/03	8/14/06
Upper San Joaquin basin or tributary to San Joaquin R. - high quality source																													
East Bay MUD	Lafayette WTP-Mokelumne Aqueduct - Trtd															0.261	0.1	1.4	0.02	11	4/17/96	7/12/06	16.33	0	49	0	3	8/10/94	3/6/96
	Orinda TP-Mokelumne Aqueduct Water-Trtd															0.122	0.1	0.54	<0.02	13	2/15/95	7/12/06	52				1	8/10/94	
	Sobrante WTP-San Pablo Water - Treated															0.236	0.11	1.6	0.05	12	2/15/95	7/12/05	33				1	8/10/94	
	San Pablo WTP															0.1	0.1	0.16	0.04	12	2/15/95	10/17/06	<0.01	0	0	0.01	2	2/15/95	2/15/95
	Upper San Leandro WTP-USL Water-Treated															0.181	0.1	1	0.03	11	2/15/95	7/12/06	20.33	0	61	0	3	8/10/94	3/6/96
	Walnut Creek WTP-Mokelumne Aqueduct-Trtd															0.094	0.1	0.16	0	11	2/15/95	7/12/06	62				1	8/10/94	8/10/94
Modesto Irrigation District	Modesto Reservoir - Treated																												
Stockton East Water District	Treatment Plant - Final Treated-SA5															1.083	0.3	4.8	0	9	6/8/89	6/13/06	24.67	24	66	0	28	3/24/89	9/22/06
C.C.W.D., West Point	West Point WTP - Effluent	8.8	8.8	8.9	8.6	2	9/10/03	9/15/04								1.143	0.21	15	<0.1	16	5/14/91	4/12/06	23.3	21	38	13.2	4	3/29/00	9/15/04
	Bear Creek - Treated															0.31				1	4/13/05								
	Mokelumne River - Treated	37				1	11/12/03																87				1	11/12/03	
Clovis, City of	Clovis SWTP - Treated															0.1				1	9/28/05								
Fresno, City of	Fresno SWTF - Treated															0.15	0.15	0.2	<0.1	2	10/26/04	5/2/05							
North Delta																													
City of Fairfield	North Bay Regional WTP - Treated															0.06	0.05	0.17	0.03	33	12/2/91	10/10/06	7.78	4.9	61	0	25	3/23/92	10/10/06
	Waterman WTP-Finished Water															0.135	0.07	0.9	0.03	43	12/31/86	10/10/06	11.76	5.7	76	0	34	10/1/87	10/10/06
City of Benicia	Benicia WTP - Treated	11	11	29	0	29	1/22/02	2/18/04								0.555	0.58	1.1	0	6	10/5/92	12/7/05	49.19	52	93	0	31	1/22/02	1/26/04
City of Vallejo	Fleming Hill WTP - Treated															0.064	0.05	0.14	0.02	7	12/17/92	10/16/06	45				1	12/17/92	
	Travis WTP - Treated															0.04				1	9/29/94								
American Canyon, City of	Treatment Plant_American Canyon - Treated																												
Central/South Delta																													
Contra Costa Water District	Canal/Mallard-Sampled at Bollman-Treated	1.7	1.4	3.6	<1	16	4/9/02	10/17/06								0.072	0.07	0.16	0.03	74	2/24/87	11/21/06	27.23	25	75	0	128	6/29/89	10/17/06
Randall-Bold Water Treatment Plant	Randall Bold WTP - Treated	1.6	1.2	3	<1	12	1/20/04	10/17/06								0.194	0.06	3.8	0.03	46	11/5/02	11/21/06	5.847	0.5	53	0	15	1/9/02	10/17/06

		Dichloroacetic Acid (DCAA)							Dibromomethane							Turbidity, Laboratory							Total Trihalomethanes						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
City of Antioch	Contra Costa Canal/Muni Res-Antioch WTP															0.14	0.14	0.4	0	21	7/31/92	3/22/06							
Delta Mendota Canal																													
Tracy, City of	Treatment Plant Effluent															0.33	0.1	1.2	0.07	9	6/21/89	7/31/06	31.58	33	78	0	30	6/21/89	7/31/06
South Bay Aqueduct																													
Zone 7 Water Agency	Del Valle CWE-Treated Water															0.423	0.07	18.3	0.04	54	1/13/87	10/11/06	46.63	42	78	29	16	7/13/88	9/13/06
	Patterson Pass CWE-Treated Water															0.084	0.08	0.38	0	86	4/14/87	10/11/06	50.06	47	88	17	35	7/13/88	9/13/06
Alameda County Water District	Water Treatment Plant #2 - Treated	4	2.6	14	1.2	9	1/22/02	4/12/05								0.101	0.09	0.17	0.05	20	8/22/95	6/21/06	7.185	5.3	42	0	20	6/14/95	6/21/06
	Mission San Jose WTP															0.127	0.09	0.42	0.06	19	5/22/86	6/21/06	53.83	50	103	0	24	3/31/88	6/21/06
Santa Clara Valley Water District	Penitencia WTP															0.06	0.06	0.2	0.03	30	8/12/87	11/14/06	48.13	45	99	0	43	7/1/87	2/7/06
California Aqueduct - O'Neill Forebay and San Luis Reservoir																													
Santa Clara Valley Water District	Santa Teresa WTP															0.155	0.05	3	0.03	29	3/31/92	11/14/06	55.75	52	92	26	44	10/16/89	2/7/06
	Rinconada WTP															0.12	0.06	2	0.04	34	8/12/87	11/14/06	47.56	43	116	0.5	49	7/1/87	2/7/06
California Aqueduct - San Luis Reach, O'Neill Forebay to Check 21																													
Dos Palos-City	Dos Palos WTP - Treated															1.53	1.53	2.8	0.26	2	9/28/90	9/1/05	8.45	8.5	12	4.6	2	10/17/91	7/9/92
Coalinga-City	Plant Effluent	5				1	5/14/04									0.804	0.12	3.4	<0.1	5	1/19/01	1/21/05	49.08	47	74	29	13	11/8/96	9/1/06
Huron, City of	Huron Plant No. 2 Effluent - Treated	15	18	24	6.6	5	8/23/05	7/6/06															109				1	8/23/05	
Avenal, City of	Treatment Plant No. 2 - Treated																												
	Treatment Plant No. 1 - Treated																												
California Aqueduct - San Joaquin Field Division, Check 21 to Check 39																													
Kern County Water Agency	ID4 Treated - T1 (Henry Garnett WTF)															0.073	0.05	3.69	0	177	3/10/90	10/3/06	46.5	47	108	3.1	86	3/20/90	8/30/02
Coastal Branch																													
Central Coast Water Authority	State Water Project - Treated (Polonio Pass WTP)	3.5	3.3	7.4	0	8	5/13/02	12/6/04								0.072	0.06	0.3	0.04	22	1/1/02	7/24/06	34.75	35	49	20	13	2/19/02	3/15/06
East Branch - Check 42 to Check 66																													
Antelope Valley E Kern Wtr Agy	Water Treatment Plant - Treated															0.043	0.05	0.08	0.02	8	12/29/87	12/7/05	15.13	0	45	0	3	10/19/89	12/3/03
	Quartz Hill WTP - Clear Well - Treated															0.048	0.05	0.1	0.02	6	10/31/00	12/7/05	25.4	25	51	0	2	12/3/03	12/13/04
	Acton Plant - Treated Effluent															0.035	0.04	0.05	0.02	4	10/2/02	10/11/06	72.2				1	12/3/03	
	Eastside Plant - Treated Effluent															0.033	0.03	0.05	0.02	6	10/31/00	12/7/05	47.1	47	47	47.1	1	12/3/03	12/3/03
Palmdale Water Dist.	Filter Plant - Effluent															<0.115	0.08	<0.2	0.049	11	1/21/02	1/4/06	23.34	27	38	0	9	1/16/02	1/7/04
East Branch - Silverwood Lake																													
Metropolitan Water Dist. of So. Cal.	Mills Plant Effluent - Treated															0.058	0.05	0.11	0.03	67	10/31/86	11/1/06							
CLAWA	Lake Silverwood WTP																						9.95	10	20	0	2	6/11/90	6/23/03
East Branch - Diamond Valley Lake, Lake Perris																													
Metropolitan Water Dist. of So. Cal.	Diemer Plant Effluent - Treated															0.059	0.05	0.16	0.04	67	10/31/86	10/31/06							

		Dichloroacetic Acid (DCAA)							Dibromomethane						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
Metropolitan Water Dist. of So. Cal.	Skinner Plant Effluent #1 - Treated														
Metropolitan Water Dist. of So. Cal.	Weymouth Plant Effluent - Treated								<0.0526	0	<0.5	0	19	3/5/02	10/19/06
Metropolitan Water Dist. of So. Cal.	Skinner Reservoir Effluent - Treated								<0.0526	0	<0.5	0	19	3/5/02	11/6/06
West Branch - Castaic Lake															
Metropolitan Water Dist. of So. Cal.	Jensen Plant Effluent - Treated								<0.0526	0	<0.5	0	19	3/5/02	10/3/06
Castaic Lake Water Agency	Earl Schmidt WTP Effluent - Treated														
	Rio Vista WTP Effluent - Treated														

		Turbidity, Laboratory							Total Trihalomethanes						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
Metropolitan Water Dist. of So. Cal.	Skinner Plant Effluent #1 - Treated	0.095	0.09	0.13	0.07	11	10/31/86	7/31/94							
Metropolitan Water Dist. of So. Cal.	Weymouth Plant Effluent - Treated	0.068	0.06	0.17	0.05	67	10/31/86	10/31/06							
Metropolitan Water Dist. of So. Cal.	Skinner Reservoir Effluent - Treated	0.062	0.06	0.08	0.05	57	2/28/02	10/31/06							
West Branch - Castaic Lake															
Metropolitan Water Dist. of So. Cal.	Jensen Plant Effluent - Treated	0.056	0.05	0.13	0.04	66	10/31/86	10/31/06							
Castaic Lake Water Agency	Earl Schmidt WTP Effluent - Treated	0.07				1	10/20/97		0				1	10/17/89	
	Rio Vista WTP Effluent - Treated	0.07				1	10/6/97								

		Bromide							Dibromoacetic Acid (DBAA)							Trichloroacetic Acid (TCAA)							Bromochloromethane						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
Upper Sacramento basin or tributary to Sacramento R - high quality source																													
City of Sacramento	Amer R WTP - Treated (Lab Tap #08)																						0	0	0	0	5	1/27/03	8/14/06
Carmichael Water District	Bajamont SWTP - Treated								<0.9	<1	<1	0	20	11/19/03	7/13/06	3.215	2.8	6.6	1.8	20	11/19/03	7/13/06	<0.5	<0.5	<0.5	<0.5	4	6/16/05	7/27/06
City of Redding	Sacramento River @ Foothill WTP-Treated																						0	0	0	0	2	1/24/89	9/28/89
Yuba County Water District	Treatment Plant - Treated								0	0	0	0	3	2/21/06	8/29/06	5.667	5.4	6.3	5.3	3	2/21/06	8/29/06	0	0	0	0	3	3/27/90	6/22/04
Lower Sacramento basin - still high quality but downstream of ag and urban land uses																													
City of West Sacramento	Sacramento River - Treated								0	0	0	0	4	5/14/03	5/14/03	9.85	10	12	6.8	4	5/14/03	5/14/03	<0.4	<0.5	<0.5	0	5	11/13/92	8/7/06
City of Sacramento	Sac R WTP - Treated (Lab Tap #12)																						0	0	0	0	2	4/21/03	8/14/06
Upper San Joaquin basin or tributary to San Joaquin R. - high quality source																													
East Bay MUD	Lafayette WTP-Mokelumne Aqueduct - Trtd	<1.455	<0.05	<10	0	7	1/11/86	12/13/95															<0.96210	<0.5	11	0	19	5/17/95	8/3/00
	Orinda TP-Mokelumne Aqueduct Water-Trtd	<1.13	<0.01	<10	0	9	1/11/86	2/15/95															<0.864	<0.5	11	0.14	30	2/15/95	12/4/00
	Sobrante WTP-San Pablo Water - Treated	<0.02	<0.01	<0.05	0	9	1/11/86	2/15/95															<0.68340	<0.5	8.7	<0.14	47	2/15/95	12/4/00
	San Pablo WTP																												
	Upper San Leandro WTP-USL Water-Treated	<0.02	<0.01	<0.05	0	7	2/26/92	2/15/95															<1.16952	<0.5	17	0	21	2/15/95	8/3/00
	Walnut Creek WTP-Mokelumne Aqueduct-Trtd	<1.265	<0.01	<10	0	8	2/26/92	2/15/95															<1.74571	<0.5	9.8	<0.14	7	2/15/95	9/19/00
Modesto Irrigation District	Modesto Reservoir - Treated																												
Stockton East Water District	Treatment Plant - Final Treated-SA5								0.5263	<1	<1	0	19	3/11/02	9/22/06	6.3	4.9	16	2.9	19	3/11/02	9/22/06	0	0	0	0	2	5/8/89	7/5/89
C.C.W.D., West Point	West Point WTP - Effluent								0	0	0	0	2	9/10/03	9/15/04	12	12	13	11	2	9/10/03	9/15/04	0	0	0	0	2	3/29/00	3/21/01
	Bear Creek - Treated																												
	Mokelumne River - Treated								0				1	11/12/03		45				1	11/12/03								
Clovis, City of	Clovis SWTP - Treated																												
Fresno, City of	Fresno SWTF - Treated																												
North Delta																													
City of Fairfield	North Bay Regional WTP - Treated	0.078	0.023	0.44	0	32	10/14/92	10/10/06															<0.17307	0	<0.5	0	26	10/12/91	10/10/06
	Waterman WTP-Finished Water	0.114	0.015	0.55	0	31	10/14/92	10/10/06															<0.25	<0.25	<0.5	0	22	2/8/93	10/10/06
City of Benicia	Benicia WTP - Treated	0.049				1	7/9/02		<0.2586	0	1.3	0	29	1/22/02	2/18/04	8.89	8.3	19	0	29	1/22/02	2/18/04	0				1	7/9/02	
City of Vallejo	Fleming Hill WTP - Treated	<0.095	<0.025	0.23	0	5	12/17/92	10/18/04															0				1	12/17/92	
	Travis WTP - Treated	<0.2				1	9/29/94																						
American Canyon, City of	Treatment Plant_American Canyon - Treated																												
Central/South Delta																													
Contra Costa Water District	Canal/Mallard-Sampled at Bollman-Treated	0.097	0	0.5	0	205	7/15/92	7/19/06	1.9688	1.7	3.1	<1	16	4/9/02	10/17/06	1.288	<1	4	<1	16	4/9/02	10/17/06	<0.49504	<0.5	<1	0	101	6/29/89	10/9/02
Randall-Bold Water Treatment Plant	Randall Bold WTP - Treated	0.189	0.2	0.6	<0.1	28	7/8/03	11/16/06	1.4583	1.4	2.3	<1	12	1/20/04	10/17/06	1.117	<1	2.3	<1	12	1/20/04	10/17/06	0	0	0	0	4	1/9/02	10/9/02

		Bromide							Dibromoacetic Acid (DBAA)							Trichloroacetic Acid (TCAA)							Bromochloromethane						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
City of Antioch	Contra Costa Canal/Muni Res-Antioch WTP																												
Delta Mendota Canal																													
Tracy, City of	Treatment Plant Effluent																						<0.125	0	<0.5	0	12	6/21/89	7/31/06
South Bay Aqueduct																													
Zone 7 Water Agency	Del Valle CWE-Treated Water	0.062	<0.05	0.27	0	46	7/16/02	10/11/06															0	0	0	0	17	7/13/88	9/13/06
	Patterson Pass CWE-Treated Water	0.09	0.07	0.32	0	79	11/8/94	10/11/06															0	0	0	0	30	7/13/88	9/13/06
Alameda County Water District	Water Treatment Plant #2 - Treated	0.043	0.043	0.047	0	2	6/21/05	7/5/05	1.4	1.6	2.6	0	9	1/22/02	4/12/05	1.456	0	9.7	0	9	1/22/02	4/12/05	<0.08333	0	<0.5	0	18	6/14/95	6/21/06
	Mission San Jose WTP																												
Santa Clara Valley Water District	Penitencia WTP	<0.076	<0.05	0.61	0	27	7/1/87	11/14/06																					
California Aqueduct - O'Neill Forebay and San Luis Reservoir																													
Santa Clara Valley Water District	Santa Teresa WTP	0.068	0.06	0.16	0	30	3/31/92	11/14/06																					
	Rinconada WTP	0.097	0.05	0.69	0	31	7/1/87	11/14/06																					
California Aqueduct - San Luis Reach, O'Neill Forebay to Check 21																													
Dos Palos-City	Dos Palos WTP - Treated																												
Coalinga-City	Plant Effluent								4				1	5/14/04		6.8				1	5/14/04		0	0	0	0	12	11/8/96	9/1/06
Huron, City of	Huron Plant No. 2 Effluent - Treated								12.54	5	31	0	5	8/23/05	7/6/06	16.48	18	33	4.1	5	8/23/05	7/6/06							
Avenal, City of	Treatment Plant No. 2 - Treated																												
	Treatment Plant No. 1 - Treated																												
California Aqueduct - San Joaquin Field Division, Check 21 to Check 39																													
Kern County Water Agency	ID4 Treated - T1 (Henry Garnett WTF)	<0.251	<0.1	<0.5	0	31	5/1/95	10/3/06															<0.24242	0	<0.5	0	33	3/20/90	10/16/06
Coastal Branch																													
Central Coast Water Authority	State Water Project - Treated (Polonio Pass WTP)								3.275	3.4	5.5	1.7	8	5/13/02	12/6/04	2.638	2.1	5.7	0	8	5/13/02	12/6/04							
East Branch - Check 42 to Check 66																													
Antelope Valley E Kern Wtr Agy	Water Treatment Plant - Treated																												
	Quartz Hill WTP - Clear Well - Treated																						0	0	0	0	2	12/3/03	12/13/04
	Acton Plant - Treated Effluent																						0				1		
	Eastside Plant - Treated Effluent																						0				1		
Palmdale Water Dist.	Filter Plant - Effluent	10.02	10.02	20	0	2	10/14/02	10/21/02															<0.22222	0	<0.5	0	9	1/16/02	1/4/06
East Branch - Silverwood Lake																													
Metropolitan Water Dist. of So. Cal.	Mills Plant Effluent - Treated																						<0.05263	0	<0.5	0	19	3/5/02	10/3/06
CLAWA	Lake Silverwood WTP																												
East Branch - Diamond Valley Lake, Lake Perris																													
Metropolitan Water Dist. of So. Cal.	Diemer Plant Effluent - Treated	0.12				1	9/30/05																0.05556	0	0.5	0	18	3/5/02	10/3/06

		Bromide							Dibromoacetic Acid (DBAA)							Trichloroacetic Acid (TCAA)							Bromochloromethane						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
Metropolitan Water Dist. of So. Cal.	Skinner Plant Effluent #1 - Treated																												
Metropolitan Water Dist. of So. Cal.	Weymouth Plant Effluent - Treated																						<0.05263	0	<0.5	0	19	3/5/02	10/19/06
Metropolitan Water Dist. of So. Cal.	Skinner Reservoir Effluent - Treated																						<0.05263	0	<0.5	0	19	3/5/02	11/6/06
West Branch - Castaic Lake																													
Metropolitan Water Dist. of So. Cal.	Jensen Plant Effluent - Treated																						<0.05263	0	<0.5	0	19	3/5/02	10/3/06
Castaic Lake Water Agency	Earl Schmidt WTP Effluent - Treated	0.1				1	10/20/97																0				1	10/17/89	
	Rio Vista WTP Effluent - Treated	0.11				1	10/6/97																						

		Bromate							Bromochloroacetic Acid (BCAA)							Monobromoacetic Acid (MBAA)							Monochloroacetic Acid (MCAA)						
System Name	**Facility**	mean	median	max	min	count	start	finish	mean	median	max	min	count	start	finish	mean	median	max	min	count	start	finish	mean	median	max	min	count	start	finish
Upper Sacramento basin or tributary to Sacramento R - high quality source																													
City of Sacramento	Amer R WTP - Treated (Lab Tap #08)																												
Carmichael Water District	Bajamont SWTP - Treated															<0.9	<1	<1	0	20	11/19/03	7/13/06	<1.8	<2	<2	0	20	11/19/03	7/13/06
City of Redding	Sacramento River @ Foothill WTP-Treated																												
Yuba County Water District	Treatment Plant - Treated															0	0	0	0	3	2/21/06	8/29/06	0	0	0	0	3	2/21/06	8/29/06
Lower Sacramento basin - still high quality but downstream of ag and urban land uses																													
City of West Sacramento	Sacramento River - Treated															0	0	0	0	4	5/14/03	5/14/03	0	0	0	0	4	5/14/03	5/14/03
City of Sacramento	Sac R WTP - Treated (Lab Tap #12)																												
Upper San Joaquin basin or tributary to San Joaquin R. - high quality source																													
East Bay MUD	Lafayette WTP-Mokelumne Aqueduct - Trtd	<0.005				1	8/10/94																						
	Orinda TP-Mokelumne Aqueduct Water-Trtd	<0.005				1	8/10/94																						
	Sobrante WTP-San Pablo Water - Treated	<0.0016	0	<0.005	0	3	8/10/94	9/20/01																					
	San Pablo WTP																												
	Upper San Leandro WTP-USL Water-Treated	0.0075	0.008	0.015	0	4	8/10/94	10/25/01																					
	Walnut Creek WTP-Mokelumne Aqueduct-Trtd	<0.005				1	8/10/94																						
Modesto Irrigation District	Modesto Reservoir - Treated																												
Stockton East Water District	Treatment Plant - Final Treated-SA5															<0.5263	<1	<1	0	19	3/11/02	9/22/06	<1.052	<2	<2	0	19	3/11/02	9/22/06
C.C.W.D., West Point	West Point WTP - Effluent															0.55	0.55	1.1	0	2	9/10/03	9/15/04	2.9	2.9	3.7	2.1	2	9/10/03	9/15/04
	Bear Creek - Treated																												
	Mokelumne River - Treated	0				1	8/3/05									0				1	11/12/03		8				1	11/12/03	
Clovis, City of	Clovis SWTP - Treated																												
Fresno, City of	Fresno SWTF - Treated	0.3718	0	10	0	27	7/26/04	11/2/06																					
North Delta																													
City of Fairfield	North Bay Regional WTP - Treated	<0.12104	0	<5	0	42	1/9/02	10/10/06																					
	Waterman WTP-Finished Water	<0.23964	0	<5	0	42	1/9/02	10/10/06																					
City of Benicia	Benicia WTP - Treated								2.2	2.1	5.1	0	5	1/22/02	1/22/02	<0.1724	0	<1	0	29	1/22/02	2/18/04	0.669	0	2.6	0	29	1/22/02	2/18/04
City of Vallejo	Fleming Hill WTP - Treated	<0.28083	<0.005	<5	0	18	2/13/02	8/17/06																					
	Travis WTP - Treated	<0.00833	<0.005	<0.015	<0.005	3	5/15/02	5/17/06																					
American Canyon, City of	Treatment Plant_American Canyon - Treated																												
Central/South Delta																													
Contra Costa Water District	Canal/Mallard-Sampled at Bollman-Treated	<0.97035	<0.005	9.9	<0.001	62	6/13/00	11/14/06	1.8	1.9	2.4	<1	4	4/9/02	4/22/03	<1.2937	<1	2.9	<1	16	4/9/02	10/17/06	<1.868	<2	2.7	<1	16	4/9/02	10/17/06
Randall-Bold Water Treatment Plant	Randall Bold WTP - Treated	1.0527	0.006	9.2	0.002	38	11/12/02	11/16/06								1.5167	<1	6.8	<1	12	1/20/04	10/17/06	2.15	<2	3.6	<2	12	1/20/04	10/17/06

		Bromate							Bromochloroacetic Acid (BCAA)							Monobromoacetic Acid (MBAA)							Monochloroacetic Acid (MCAA)						
System Name	**Facility**	mean	median	max	min	count	start	finish	mean	median	max	min	count	start	finish	mean	median	max	min	count	start	finish	mean	median	max	min	count	start	finish
City of Antioch	Contra Costa Canal/Muni Res-Antioch WTP																												
Delta Mendota Canal																													
Tracy, City of	Treatment Plant Effluent																												
South Bay Aqueduct																													
Zone 7 Water Agency	Del Valle CWE-Treated Water																												
	Patterson Pass CWE-Treated Water																												
Alameda County Water District	Water Treatment Plant #2 - Treated															<0.2222	0	<1	0	9	1/22/02	4/12/05	<0.444	0	<2	0	9	1/22/02	4/12/05
	Mission San Jose WTP																												
Santa Clara Valley Water District	Penitencia WTP	<0.00011	0	<0.001	0	9	8/27/02	11/14/06	4.4	1.8	12	0	9	5/14/02	2/7/06	0.11	0	1.1	0	10	5/14/02	11/14/06	0.56	0	2.3	0	10	5/14/02	11/14/06
California Aqueduct - O'Neill Forebay and San Luis Reservoir																													
Santa Clara Valley Water District	Santa Teresa WTP	<0.09227	0	<1	0	11	2/13/01	11/14/06	6.6	7	13	0	14	2/14/02	2/7/06	0.0667	0	1	0	15	2/14/02	11/14/06	0.347	0	1.9	0	15	2/14/02	11/14/06
	Rinconada WTP	<0.09227	0	<1	0	11	2/13/01	11/14/06	7.4	7.8	12	0	15	2/14/02	2/7/06	0.525	0	3	0	16	2/14/02	11/14/06	0.688	0	3.7	0	16	2/14/02	11/14/06
California Aqueduct - San Luis Reach, O'Neill Forebay to Check 21																													
Dos Palos-City	Dos Palos WTP - Treated																												
Coalinga-City	Plant Effluent															0				1	5/14/04		0				1	5/14/04	
Huron, City of	Huron Plant No. 2 Effluent - Treated															0.6	0	1.8	0	5	8/23/05	7/6/06	1.08	0	3.2	0	5	8/23/05	7/6/06
Avenal, City of	Treatment Plant No. 2 - Treated																												
	Treatment Plant No. 1 - Treated																												
California Aqueduct - San Joaquin Field Division, Check 21 to Check 39																													
Kern County Water Agency	ID4 Treated - T1 (Henry Garnett WTF)																												
Coastal Branch																													
Central Coast Water Authority	State Water Project - Treated (Polonio Pass WTP)								3.8	3.8	4.4	3.2	2	11/18/02	2/10/03	<0.375	0	<1	0	8	5/13/02	12/6/04	<0.75	0	<2	0	8	5/13/02	12/6/04
East Branch - Check 42 to Check 66																													
Antelope Valley E Kern Wtr Agy	Water Treatment Plant - Treated																												
	Quartz Hill WTP - Clear Well - Treated																												
	Acton Plant - Treated Effluent																												
	Eastside Plant - Treated Effluent																												
Palmdale Water Dist.	Filter Plant - Effluent																												
East Branch - Silverwood Lake																													
Metropolitan Water Dist. of So. Cal.	Mills Plant Effluent - Treated																												
CLAWA	Lake Silverwood WTP																												
East Branch - Diamond Valley Lake, Lake Perris																													
Metropolitan Water Dist. of So. Cal.	Diemer Plant Effluent - Treated																												

		Bromate							Bromochloroacetic Acid (BCAA)							Monobromoacetic Acid (MBAA)							Monochloroacetic Acid (MCAA)						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
Metropolitan Water Dist. of So. Cal.	Skinner Plant Effluent #1 - Treated																												
Metropolitan Water Dist. of So. Cal.	Weymouth Plant Effluent - Treated																												
Metropolitan Water Dist. of So. Cal.	Skinner Reservoir Effluent - Treated																												
West Branch - Castaic Lake																													
Metropolitan Water Dist. of So. Cal.	Jensen Plant Effluent - Treated																												
Castaic Lake Water Agency	Earl Schmidt WTP Effluent - Treated																												
	Rio Vista WTP Effluent - Treated	0.009	0.005	0.026	0.005	8	7/15/04	9/14/05																					

		Haloacetic Acids (5) (HAA5)							DCPA (Total Di & Mono Acid Degradates)							Color							Odor Threshold @ 60 C						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
Upper Sacramento basin or tributary to Sacramento R - high quality source																													
City of Sacramento	Amer R WTP - Treated (Lab Tap #08)																												
Carmichael Water District	Bajamont SWTP - Treated	6.91	6.15	13	4.3	20	11/19/03	7/13/06																					
City of Redding	Sacramento River @ Foothill WTP-Treated																												
Yuba County Water District	Treatment Plant - Treated	7.15	8.3	12	0	4	6/22/04	8/29/06																					
Lower Sacramento basin - still high quality but downstream of ag and urban land uses																													
City of West Sacramento	Sacramento River - Treated								<0.0666	0	<0.2	0	3	3/4/02	7/30/03														
City of Sacramento	Sac R WTP - Treated (Lab Tap #12)																												
Upper San Joaquin basin or tributary to San Joaquin R. - high quality source																													
East Bay MUD	Lafayette WTP-Mokelumne Aqueduct - Trtd																												
	Orinda TP-Mokelumne Aqueduct Water-Trtd																												
	Sobrante WTP-San Pablo Water - Treated																												
	San Pablo WTP																												
	Upper San Leandro WTP-USL Water-Treated																												
	Walnut Creek WTP-Mokelumne Aqueduct-Trtd																												
Modesto Irrigation District	Modesto Reservoir - Treated																												
Stockton East Water District	Treatment Plant - Final Treated-SA5	10.8	7.55	24	6.5	8	6/14/04	3/16/06																					
C.C.W.D., West Point	West Point WTP - Effluent	22				1	9/15/04																						
	Bear Creek - Treated																												
	Mokelumne River - Treated																												
Clovis, City of	Clovis SWTP - Treated																												
Fresno, City of	Fresno SWTF - Treated																												
North Delta																													
City of Fairfield	North Bay Regional WTP - Treated																												
	Waterman WTP-Finished Water																												
City of Benicia	Benicia WTP - Treated	16.1	16	32	0	19	4/14/03	2/18/04																					
City of Vallejo	Fleming Hill WTP - Treated																												
	Travis WTP - Treated																												
American Canyon, City of	Treatment Plant_American Canyon - Treated																												
Central/South Delta																													
Contra Costa Water District	Canal/Mallard-Sampled at Bollman-Treated	5.25	4.3	10.6	1.4	12	1/20/04	10/17/06	0	0	0	0	4	1/9/02	10/9/02														
Randall-Bold Water Treatment Plant	Randall Bold WTP - Treated	3.83	1.9	13.6	<1	12	1/20/04	10/17/06	0	0	0	0	4	1/9/02	10/9/02														

		Haloacetic Acids (5) (HAA5)							DCPA (Total Di & Mono Acid Degradates)							Color							Odor Threshold @ 60 C						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
City of Antioch	Contra Costa Canal/Muni Res-Antioch WTP																												
Delta Mendota Canal																													
Tracy, City of	Treatment Plant Effluent								0	0	0	0	3	5/23/02	11/18/02														
South Bay Aqueduct																													
Zone 7 Water Agency	Del Valle CWE-Treated Water								0				1	7/16/02															
	Patterson Pass CWE-Treated Water								0				1	7/16/02															
Alameda County Water District	Water Treatment Plant #2 - Treated	3.65	3.65	4.7	2.6	2	3/29/05	4/12/05	<0.6	<1	<1	0	5	8/28/02	6/21/06														
	Mission San Jose WTP															0	0	0	0	18	5/22/86	6/21/06	0.2	0	1	0	18	5/22/86	6/21/06
Santa Clara Valley Water District	Penitencia WTP	17.2	11.1	35.1	6	9	6/3/03	11/14/06								<2.387096	<2.5	<2.5	<1	31	8/12/87	11/14/06	0.9	1	1.4	0	16	8/12/87	2/7/06
California Aqueduct - O'Neill Forebay and San Luis Reservoir																													
Santa Clara Valley Water District	Santa Teresa WTP	18.9	16.7	33.6	4.6	11	6/3/03	11/14/06								<2.482758	<2.5	<2.5	<2	29	3/31/92	11/14/06	1	1	2	0	13	10/20/92	2/7/06
	Rinconada WTP	21.8	20.3	33.9	13.9	11	6/3/03	11/14/06								<2.4	<2.5	<2.5	<1	35	8/12/87	11/14/06	0.9	1	1	0	17	8/12/87	2/7/06
California Aqueduct - San Luis Reach, O'Neill Forebay to Check 21																													
Dos Palos-City	Dos Palos WTP - Treated																												
Coalinga-City	Plant Effluent	16				1	5/14/04																						
Huron, City of	Huron Plant No. 2 Effluent - Treated	45.8	44	65	34	5	8/23/05	7/6/06																					
Avenal, City of	Treatment Plant No. 2 - Treated																												
	Treatment Plant No. 1 - Treated																												
California Aqueduct - San Joaquin Field Division, Check 21 to Check 39																													
Kern County Water Agency	ID4 Treated - T1 (Henry Garnett WTF)																												
Coastal Branch																													
Central Coast Water Authority	State Water Project - Treated (Polonio Pass WTP)	9.15	9.15	9.2	9.1	2	8/30/04	12/6/04	<1				1	3/15/06															
East Branch - Check 42 to Check 66																													
Antelope Valley E Kern Wtr Agy	Water Treatment Plant - Treated															<4.5	<5	<5	1	8	12/29/87	12/7/05	<0.8	<1	<1	0	8	12/29/87	12/7/05
	Quartz Hill WTP - Clear Well - Treated																												
	Acton Plant - Treated Effluent																												
	Eastside Plant - Treated Effluent																												
Palmdale Water Dist.	Filter Plant - Effluent																												
East Branch - Silverwood Lake																													
Metropolitan Water Dist. of So. Cal.	Mills Plant Effluent - Treated																												
CLAWA	Lake Silverwood WTP																												
East Branch - Diamond Valley Lake, Lake Perris																													
Metropolitan Water Dist. of So. Cal.	Diemer Plant Effluent - Treated																												

		Haloacetic Acids (5) (HAA5)							DCPA (Total Di & Mono Acid Degradates)							Color							Odor Threshold @ 60 C						
System Name	**Facility**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**	**mean**	**median**	**max**	**min**	**count**	**start**	**finish**
Metropolitan Water Dist. of So. Cal.	Skinner Plant Effluent #1 - Treated																												
Metropolitan Water Dist. of So. Cal.	Weymouth Plant Effluent - Treated																												
Metropolitan Water Dist. of So. Cal.	Skinner Reservoir Effluent - Treated																												
West Branch - Castaic Lake																													
Metropolitan Water Dist. of So. Cal.	Jensen Plant Effluent - Treated																												
Castaic Lake Water Agency	Earl Schmidt WTP Effluent - Treated																												
	Rio Vista WTP Effluent - Treated																												

Figure 11	
W1	City of Fresno Enterprise Canal Raw
Figure 12	
W1	City of Sacramento Amer R WTP - Intake - Raw (Lab Tap #01)
W2	Carmichael Water District Bajamont Junction Structure Landis 1,2,3
W3	City of Redding Sacramento River @ Foothill WTP-Intake - Raw
W4	City of West Sacramento Sacramento River - Intake - Raw
W5	City of Sacramento Sac R WTP - Intake - Raw (Lab Tap #12)
W6	Modesto Irrigation District Modesto Reservoir - Raw
W7	City of Fresno Enterprise Canal Raw
Figure 13	
W1	City of Sacramento Amer R WTP - Intake - Raw (Lab Tap #01)
W2	Carmichael Water District Bajamont Junction Structure Landis 1,2,3
W3	City of Redding Sacramento River @ Foothill WTP-Intake - Raw
W4	City of West Sacramento Sacramento River - Intake - Raw
W5	City of Sacramento Sac R WTP - Intake - Raw (Lab Tap #12)
W6	Modesto Irrigation District Bear Creek - Raw
W7	C.C.W.D., West Point Mokelumne River - Raw
W8	City of Clovis Enterprise Canal Raw
W9	City of Fresno Enterprise Canal Raw
Figure 14	
W1	City of Sacramento Amer R WTP - Intake - Raw (Lab Tap #01)
W2	Carmichael Water District Bajamont Junction Structure Landis 1,2,3
W3	City of Redding Sacramento River @ Foothill WTP-Intake - Raw
W4	Yuba County Water District Forbestown Ditch Intake (XCLD)
W5	City of West Sacramento Sacramento River - Intake - Raw
W6	City of Sacramento Sac R WTP - Intake - Raw (Lab Tap #12)
W7	Modesto Irrigation District Modesto Reservoir - Raw
W8	Modesto Irrigation District Bear Creek - Raw
W9	City of Clovis Enterprise Canal Raw
W10	City of Fresno Enterprise Canal Raw
Figure 15	
W1	City of Sacramento Amer R WTP - Intake - Raw (Lab Tap #01)
W2	Carmichael Water District Bajamont Junction Structure Landis 1,2,3
W3	City of Redding Sacramento River @ Foothill WTP-Intake - Raw
W4	Yuba County Water District Forbestown Ditch Intake (XCLD)
W5	City of West Sacramento Sacramento River - Intake - Raw
W6	City of Sacramento Sac R WTP - Intake - Raw (Lab Tap #12)
W7	C.C.W.D., West Point Bear Creek - Raw
W8	C.C.W.D., West Point Mokelumne River - Raw
W9	City of Clovis Enterprise Canal Raw
W10	City of Fresno Enterprise Canal Raw
Figure 16	
L1	EBMUD Lafayette Res Standby
L2	EBMUD San Pablo Reservoir Intake Raw
L3	EBMUD Upper San Leandro Reservoir - Raw
Figure 17	
L1	EBMUD Lafayette Res Standby
L2	EMBUD San Pablo Reservoir Intake Raw
L3	EBMUD Upper San Leandro Reservoir - Raw

Figure 18	
L1	EBMUD Lafayette Res Standby
L2	EMBUD San Pablo Reservoir Intake Raw
L3	EBMUD Upper San Leandro Reservoir - Raw
Figure 19	
L1	EBMUD Lafayette Res Standby
L2	EBMUD San Pablo Reservoir Intake Raw
L3	EBMUD Upper San Leandro Reservoir - Raw
Figure 20 (Figure 6.11)	
W1	City of Sacramento Amer R WTP - Treated (Lab Tap #08)
W2	Carmichael Water District Bajamont SWTP - Treated
W3	City of Redding Sacramento River @ Foothill WTP-Treated
W4	Yuba County Water District Treatment Plant - Treated
W5	City of West Sacramento Sacramento River - Treated
W6	City of Sacramento Sac R WTP - Treated (Lab Tap #12)
W7	East Bay MUD Lafayette WTP-Mokelumne Aqueduct - Trtd
W8	East Bay MUD Orinda TP-Mokelumne Aqueduct Water-Trtd
W9	Stockton East Water District Treatment Plant - Final Treated-SA5
W10	C.C.W.D., West Point West Point WTP - Effluent
W11	C.C.W.D., West Point Mokelumne River - Treated
W12	East Bay MUD Walnut Creek WTP-Mokelumne Aqueduct-Trtd
Figure 21 (Figure 6.12)	
W1	Carmichael Water District Bajamont SWTP - Treated
W2	Yuba County Water District Treatment Plant - Treated
W3	Stockton East Water District Treatment Plant - Final Treated-SA5
W4	C.C.W.D., West Point West Point WTP - Effluent
Figure 22 (Figure 6.13)	
W1	East Bay MUD Lafayette WTP-Mokelumne Aqueduct - Trtd
W2	East Bay MUD Orinda TP-Mokelumne Aqueduct Water-Trtd
W3	East Bay MUD Walnut Creek WTP-Mokelumne Aqueduct-Trtd
W4	C.C.W.D., West Point Mokelumne River - Treated
W5	Fresno, City of Fresno SWTF - Treated
Figure 23	
W1	City of Sacramento Amer R WTP - Treated (Lab Tap #08)
W2	City of Redding Sacramento River @ Foothill WTP-Treated
W3	Yuba County Water District Treatment Plant - Treated
W4	City of West Sacramento Sacramento River - Treated
W5	City of Sacramento Sac R WTP - Treated (Lab Tap #12)
W6	East Bay MUD Lafayette WTP-Mokelumne Aqueduct - Trtd
W7	East Bay MUD Orinda TP-Mokelumne Aqueduct Water-Trtd
W8	Stockton East Water District Treatment Plant - Final Treated-SA5
W9	C.C.W.D., West Point West Point WTP - Effluent
W10	C.C.W.D., West Point Bear Creek - Treated
W11	Clovis, City of Clovis SWTP - Treated
W12	Fresno, City of Fresno SWTF - Treated
W13	East Bay MUD Walnut Creek WTP-Mokelumne Aqueduct-Trtd

Figure 24	
W1	City of Sacramento Amer R WTP - Treated (Lab Tap #08)
W2	City of Redding Sacramento River @ Foothill WTP-Treated
W3	Yuba County Water District Treatment Plant - Treated
W4	City of West Sacramento Sacramento River - Treated
W5	City of Sacramento Sac R WTP - Treated (Lab Tap #12)
W6	East Bay MUD Lafayette WTP-Mokelumne Aqueduct - Trtd
W7	East Bay MUD Orinda TP-Mokelumne Aqueduct Water-Trtd
W8	Stockton East Water District Treatment Plant - Final Treated-SA5
W9	C.C.W.D., West Point West Point WTP - Effluent
W10	C.C.W.D., West Point Bear Creek - Treated
W11	Clovis, City of Clovis SWTP - Treated
W12	Fresno, City of Fresno SWTF - Treated
W13	East Bay MUD Walnut Creek WTP-Mokelumne Aqueduct-Trtd
Figure 25	
L1	East Bay MUD Sobrante WTP-San Pablo Water - Treated
L2	East Bay MUD San Pablo WTP
L3	East Bay MUD Upper San Leandro WTP-USL Water-Treated
Figure 26	
L1	East Bay MUD Sobrante WTP-San Pablo Water - Treated
L2	East Bay MUD San Pablo WTP
L3	East Bay MUD Upper San Leandro WTP-USL Water-Treated
Figure 27	
L1	East Bay MUD Sobrante WTP-San Pablo Water - Treated
L2	East Bay MUD Upper San Leandro WTP-USL Water-Treated
Figure 28	
L1	East Bay MUD Sobrante WTP-San Pablo Water - Treated
L2	East Bay MUD San Pablo WTP
L3	East Bay MUD Upper San Leandro WTP-USL Water-Treated
Figure 29	
L1	East Bay MUD Sobrante WTP-San Pablo Water - Treated
L2	East Bay MUD San Pablo WTP
L3	East Bay MUD Upper San Leandro WTP-USL Water-Treated
Figure 30	
N1	City of Fairfield Waterman WTP-Putah S Raw NBA
N2	City of Vallejo Fleming Hill WTP - Raw
N3	City of American Canyon NBR WTP - NBA Raw
Figure 31	
N1	City of Farifield Waterman WTP-Putah S Raw NBA
N2	City of Benicia Putah S Canal - Terminal Reservoir Raw
N3	City of American Canyon NBR WTP - NBA Raw
Figure 32	
N1	City of Farifield Waterman WTP-Putah S Raw NBA
N2	City of Benicia Putah S Canal - Terminal Reservoir Raw
N3	City of Vallejo Fleming Hill WTP - Raw
N4	City of American Canyon NBR WTP - NBA Raw

Figure 33	
N1	City of Farifield Waterman WTP-Putah S Raw NBA
N2	City of Benicia Putah S Canal - Terminal Reservoir Raw
N3	City of Vallejo Fleming Hill WTP - Raw
N4	City of American Canyon NBR WTP - NBA Raw
Figure 34	
N1	City of Fairfield Waterman WTP-Putah S Raw North Bay Aqueduct
N2	City of Benicia NBA Raw @ Benicia WTP
N3	City of Vallejo Fleming Hill WTP - Raw
N4	City of American Canyon NBR WTP - NBA Raw
Figure 35 (Figure 6.15)	
N1	City of Fairfield North Bay Regional WTP - Treated
N2	City of Fairfield Waterman WTP-Finished Water
N3	City of Benicia Benicia WTP - Treated
N4	City of Vallejo Fleming Hill WTP - Treated
Figure 36 (Figure 6.16)	
N1	City of Benicia Benicia WTP - Treated
Figure 37 (Figure 6.17)	
N1	City of Fairfield North Bay Regional WTP - Treated
N2	City of Fairfield Waterman WTP-Finished Water
N3	City of Vallejo Fleming Hill WTP - Treated
N4	City of Vallejo Travis WTP - Treated
Figure 38	
N1	City of Fairfield North Bay Regional WTP - Treated
N2	City of Fairfield Waterman WTP-Finished Water
N3	City of Benicia Benicia WTP - Treated
N4	City of Vallejo Fleming Hill WTP - Treated
N5	City of Vallejo Travis WTP - Treated
Figure 39	
N1	City of Fairfield North Bay Regional WTP - Treated
N2	City of Fairfield Waterman WTP-Finished Water
N3	City of Benicia Benicia WTP - Treated
N4	City of Vallejo Fleming Hill WTP - Treated
N5	City of Vallejo Travis WTP - Treated
Figure 40	
N1	City of Fairfield North Bay Regional WTP - Treated
N2	City of Fairfield Waterman WTP-Finished Water
N3	City of Benicia Benicia WTP - Treated
N4	American Canyon, City of Treatment Plant_American Canyon - Treated
Figure 41	
D1	Canal/Mallard-Sampled at Bollman
D2	Contra Costa Canal raw
D3	Contra Costa Canal/Muni Res-Antioch WTP
D4	Zone 7 Water Agency Del Valle CWE-Raw Inlet
D5	Zone 7 Water Agency Patterson Pass CWE-Raw Water Res
D6	Santa Clara Valley Water District Penitencia WTP influent
Figure 42	
D1	Randall-Bold Water Treatment Plant Contra Costa Canal raw
D2	City of Antioch Contra Costa Canal/Muni Res-Antioch WTP
D3	Zone 7 Water Agency Del Valle CWE-Raw Inlet SBA
D4	Zone 7 Water Agency Patterson Pass CWE-Raw Water Res
D5	Santa Clara Valley Water District Penitencia WTP influent

Figure 43	
D1	Canal/Mallard-Sampled at Bollman
D2	Contra Costa Canal raw
D3	Contra Costa Canal/Muni Res-Antioch WTP
D4	Zone 7 Water Agency Del Valle CWE-Raw Inlet
D5	Zone 7 Water Agency Patterson Pass CWE-Raw Water Res
D6	Santa Clara Valley Water District Penitencia WTP influent
Figure 44	
D1	Contra Costa Water District Canal/Mallard-Sampled at Bollman
D2	Randall-Bold WTP Contra Costa Canal raw
D3	City of Antioch Contra Costa Canal/Muni Res-Antioch WTP
D4	Zone 7 Water Agency Del Valle CWE-Raw Inlet
D5	Zone 7 Water Agency Patterson Pass CWE-Raw Water Res
D6	Santa Clara Valley Water District Penitencia WTP influent
Figure 45	
D1	Zone 7 WA Del Valle CWE-Raw Inlet SBA
D2	Zone 7 WA Patterson Pass -Raw Water Res
D3	SCVWD Penitencia WTP influent
Figure 46 (Figure 6.19)	
D1	Contra Costa Water District Canal/Mallard-Sampled at Bollman-Treated
D2	Randall-Bold Water Treatment Plant Randall Bold WTP - Treated
D3	Tracy, City of Treatment Plant Effluent
D4	Zone 7 Water Agency Del Valle CWE-Treated Water
D5	Zone 7 Water Agency Patterson Pass CWE-Treated Water
D6	Alameda County Water District Water Treatment Plant #2 - Treated
D7	Alameda County Water District Mission San Jose WTP
D8	Santa Clara Valley Water District Penitencia WTP
Figure 47 (Figure 6.20)	
D1	Contra Costa Water District Canal/Mallard-Sampled at Bollman-Treated
D2	Randall-Bold Water Treatment Plant Randall Bold WTP - Treated
D3	Alameda County Water District Water Treatment Plant #2 - Treated
D4	Santa Clara Valley Water District Penitencia WTP
Figure 48 (Figure 6.21)	
D1	Contra Costa Water District Canal/Mallard-Sampled at Bollman-Treated
D2	Randall-Bold Water Treatment Plant Randall Bold WTP - Treated
D3	Santa Clara Valley Water District Penitencia WTP
Figure 49	
D1	Contra Costa Water District Canal/Mallard-Sampled at Bollman-Treated
D2	Randall-Bold Water Treatment Plant Randall Bold WTP - Treated
D3	City of Antioch Contra Costa Canal/Muni Res-Antioch WTP
D4	Tracy, City of Treatment Plant Effluent
D5	Zone 7 Water Agency Del Valle CWE-Treated Water
D6	Zone 7 Water Agency Patterson Pass CWE-Treated Water
D7	Alameda County Water District Water Treatment Plant #2 - Treated
D8	Alameda County Water District Mission San Jose WTP
D9	Santa Clara Valley Water District Penitencia WTP
Figure 50	
D1	Randall-Bold Water Treatment Plant Randall Bold WTP - Treated
D2	Tracy, City of Treatment Plant Effluent
D3	Zone 7 Water Agency Del Valle CWE-Treated Water
D4	Zone 7 Water Agency Patterson Pass CWE-Treated Water
D5	Alameda County Water District Water Treatment Plant #2 - Treated
D6	Alameda County Water District Mission San Jose WTP
D7	Santa Clara Valley Water District Penitencia WTP

Figure 51	
D1	Contra Costa Water District Canal/Mallard-Sampled at Bollman-Treated
D2	City of Antioch Contra Costa Canal/Muni Res-Antioch WTP
D3	Tracy, City of Treatment Plant Effluent
D4	Zone 7 Water Agency Del Valle CWE-Treated Water
D5	Zone 7 Water Agency Patterson Pass CWE-Treated Water
D6	Alameda County Water District Water Treatment Plant #2 - Treated
D7	Alameda County Water District Mission San Jose WTP
D8	Santa Clara Valley Water District Penitencia WTP
Figure 52	
C1	Santa Clara Valley Water District Santa Teresa WTP
C2	Santa Clara Valley Water District Rinconada WTP
C3	Palmdale Water District SWP California Aqueduct Raw
C4	Metropolitan Water Dist. of So. Cal. Skinner Reservoir Influent - Raw
C5	Metropolitan Water Dist. of So. Cal. Jensen Plant Influent
Figure 53	
C1	City of Dos Palos California Aqueduct intake raw
C2	City of Coalinga California Aqueduct raw
C3	City of Huron California Aqueduct raw
C4	City of Avenal California Aqueduct raw
C5	Central Coast Water Authority State Water Project - Raw
C6	Antelope Valley E Kern Water Agency Quartz Hill WTP - Raw
C7	Antelope Valley E Kern Water Agency Acton Plant - Influent
C8	Antelope Valley E Kern Water Agency Eastside Plant - Influent
C9	Palmdale Water Dist. SWP California Aqueduct Raw
C10	Metropolitan Water Dist. Of So. Cal. Skinner Reservoir Influent - Raw
C11	Metropolitan Water of So. Cal. Jensen Plant Influent
Figure 54	
C1	Santa Clara Valley Water District Santa Teresa WTP
C2	Santa Clara Valley Water District Rinconada WTP
C3	City of Dos Palos California Aqueduct intake raw
C4	City of Coalinga California Aqueduct raw
C5	City of Huron California Aqueduct raw
C6	City of Avenal California Aqueduct raw
C7	Kern County Water Agency ID-4 Raw Aqt & KWB Blend
C8	Central Coast Water Authority State Water Project - Raw
C9	Antelope Valley E Kern Wtr Agy Water Treatment Plant - Raw
C10	Antelope Valley E Kern Wtr Agy Quartz Hill WTP - Raw
C11	Antelope Valley E Kern Wtr Agy Acton Plant - Influent
C12	Antelope Valley E Kern Wtr Agy Eastside Plant - Influent
C13	Palmdale Water District SWP California Aqueduct Raw
C14	Metropolitan Water Dist. of So. Cal. Skinner Reservoir Influent - Raw
C15	Metropolitan Water Dist. of So. Cal. Jensen Plant Influent

Figure 55	
C1	Santa Clara Valley Water District Santa Teresa WTP
C2	Santa Clara Valley Water District Rinconada WTP
C3	City of Dos Palos California Aqueduct intake raw
C4	City of Coalinga California Aqueduct raw
C5	City of Huron California Aqueduct raw
C6	City of Avenal California Aqueduct raw
C7	Kern County Water Agency ID-4 Raw Aqt & KWB Blend
C8	Central Coast Water Authority State Water Project - Raw
C9	Antelope Valley E Kern Water Agency Water Treatment Plant - Raw
C10	Antelope Valley E Kern Water Agency Quartz Hill WTP - Raw
C11	Antelope Valley E Kern Water Agency Acton Plant - Influent
C12	Antelope Valley E Kern Water Agency Eastside Plant - Influent
C13	Palmdale Water Dist. SWP California Aqueduct Raw
C14	Metropolitan Water Dist. of So. Cal. Skinner Reservoir Influent - Raw
C15	Metropolitan Water Dist. of So. Cal. Jensen Plant Influent

Figure 56	
C1	City of Avenal California Aqueduct raw
C2	Kern County Water Agency ID-4 Raw Aqt & KWB Blend
C3	Central Coast Water Authority State Water Project - Raw
C4	Antelope Valley E Kern Water Agency Water Treatment Plant - Raw
C5	Antelope Valley E Kern Water Agency Quartz Hill WTP - Raw
C6	Antelope Valley E Kern Water Agency Acton Plant - Influent
C7	Antelope Valley E Kern Water Agency Eastside Plant - Influent
C8	Palmdale Water Dist. SWP California Aqueduct Raw
C9	Metropolitan Water Dist. Of So. Cal. Skinner Reservoir Influent - Raw
C10	Metropolitan Water Dist. Of So. Cal. Jensen Plant Influent

Figure 57 (Figure 6.23)	
C1	Santa Clara Valley Water District Santa Teresa WTP
C2	Santa Clara Valley Water District Rinconada WTP
C3	Dos Palos-City Dos Palos WTP - Treated
C4	Coalinga-City Plant Effluent
C5	Huron, City of Huron Plant No. 2 Effluent - Treated
C6	Kern County Water Agency ID4 Treated - T1
C7	Central Coast Water Authority State Water Project - Treated
C8	Antelope Valley E Kern Wtr Agy WTP - Treated
C9	Antelope Valley E Kern Wtr Agy Quartz Hill WTP - Clear Well - Treated
C10	Antelope Valley E Kern Wtr Agy Acton Plant - Treated Effluent
C11	Antelope Valley E Kern Wtr Agy Eastside Plant - Treated Effluent
C12	Palmdale Water Dist. Filter Plant - Effluent
C13	CLAWA Lake Silverwood WTP
C14	Castaic Lake Water Agency Earl Schmidt WTP Effluent - Treated

Figure 58 (Figure 6.24)	
C1	Santa Clara Valley Water District Santa Teresa WTP
C2	Santa Clara Valley Water District Rinconada WTP
C3	Coalinga-City Plant Effluent
C4	Huron, City of Huron Plant No. 2 Effluent - Treated
C5	Central Coast Water Authority State Water Project - Treated

Figure 59 (Figure 6.25)	
C1	Santa Clara Valley Water District Santa Teresa WTP
C2	Santa Clara Valley Water District Rinconada WTP
C3	Castaic Lake Water Agency Rio Vista WTP Effluent - Treated

Figure 60	
C1	Santa Clara Valley Water District Santa Teresa WTP
C2	Santa Clara Valley Water District Rinconada WTP
C3	Dos Palos-City Dos Palos WTP - Treated
C4	Coalinga-City Plant Effluent
C5	Kern County Water Agency ID4 Treated - T1
C6	Central Coast Water Authority State Water Project - Treated
C7	Antelope Valley E Kern Wtr Agy WTP - Treated
C8	Antelope Valley E Kern Wtr Agy Quartz Hill WTP - Clear Well - Treated
C9	Antelope Valley E Kern Wtr Agy Acton Plant - Treated Effluent
C10	Antelope Valley E Kern Wtr Agy Eastside Plant - Treated Effluent
C11	Palmdale Water Dist. Filter Plant - Effluent
C12	Metropolitan Water Dist. of So. Cal. Mills Plant Effluent - Treated
C13	Metropolitan Water Dist. of So. Cal. Diemer Plant Effluent - Treated
C14	Metropolitan Water Dist. of So. Cal. Skinner Plant Effluent #1 - Treated
C15	Metropolitan Water Dist. of So. Cal. Weymouth Plant Effluent - Treated
C16	Metropolitan Water Dist. of So. Cal. Skinner Reservoir Effluent - Treated
C17	Metropolitan Water Dist. of So. Cal. Jensen Plant Effluent - Treated
C18	Castaic Lake Water Agency Earl Schmidt WTP Effluent - Treated
C19	Castaic Lake Water Agency Rio Vista WTP Effluent - Treated

Figure 61	
C1	Santa Clara Valley Water District Santa Teresa WTP
C2	Santa Clara Valley Water District Rinconada WTP
C3	Dos Palos-City Dos Palos WTP - Treated
C4	Coalinga-City Plant Effluent
C5	Huron, City of Huron Plant No. 2 Effluent - Treated
C6	Avenal, City of Treatment Plant No. 2 - Treated
C7	Avenal, City of Treatment Plant No. 1 - Treated
C8	Kern County Water Agency ID4 Treated - T1
C9	Central Coast Water Authority State Water Project - Treated
C10	Antelope Valley E Kern Wtr Agy WTP - Treated
C11	Antelope Valley E Kern Wtr Agy Quartz Hill WTP - Clear Well - Treated
C12	Antelope Valley E Kern Wtr Agy Acton Plant - Treated Effluent
C13	Antelope Valley E Kern Wtr Agy Eastside Plant - Treated Effluent
C14	Palmdale Water Dist. Filter Plant - Effluent
C15	Metropolitan Water Dist. of So. Cal. Mills Plant Effluent - Treated
C16	CLAWA Lake Silverwood WTP
C17	Metropolitan Water Dist. of So. Cal. Diemer Plant Effluent - Treated
C18	Metropolitan Water Dist. of So. Cal. Weymouth Plant Effluent - Treated
C19	Metropolitan Water Dist. of So. Cal. Skinner Reservoir Effluent - Treated
C20	Metropolitan Water Dist. of So. Cal. Jensen Plant Effluent - Treated

Figure 62	
C1	Santa Clara Valley Water District Santa Teresa WTP
C2	Santa Clara Valley Water District Rinconada WTP
C3	Dos Palos-City Dos Palos WTP - Treated
C4	Coalinga-City Plant Effluent
C5	Kern County Water Agency ID4 Treated - T1
C6	Central Coast Water Authority State Water Project - Treated
C7	Antelope Valley E Kern Wtr Agy WTP - Treated
C8	Antelope Valley E Kern Wtr Agy Quartz Hill WTP - Clear Well - Treated
C9	Antelope Valley E Kern Wtr Agy Acton Plant - Treated Effluent
C10	Antelope Valley E Kern Wtr Agy Eastside Plant - Treated Effluent
C11	Palmdale Water Dist. Filter Plant - Effluent
C12	Metropolitan Water Dist. of So. Cal. Mills Plant Effluent - Treated
C13	CLAWA Lake Silverwood WTP
C14	Metropolitan Water Dist. of So. Cal. Diemer Plant Effluent - Treated
C15	Metropolitan Water Dist. of So. Cal. Skinner Reservoir Effluent #1- Treated
C16	Metropolitan Water Dist. of So. Cal. Weymouth Plant Effluent - Treated
C17	Metropolitan Water Dist. of So. Cal. Skinner Reservoir Effluent - Treated
C18	Metropolitan Water Dist. of So. Cal. Jensen Plant Effluent - Treated
C19	Castaic Lake Water Agency Earl Schmidt WTP Effluent - Treated
C20	Castaic Lake Water Agency Rio Vista WTP Effluent - Treated
Figure 63 (Figure 6.7)	
N1	City of Fairfield Waterman WTP-Finished Water
D1	Zone 7 Water Agency Del Valle CWE-Treated Water
D2	Zone 7 Water Agency Patterson Pass CWE-Treated Water
C1	Santa Clara Valley Water District Penitencia WTP
C2	Coalinga-City Plant Effluent
C3	Central Coast Water Authority State Water Project - Treated
Figure 64	
L1	East Bay MUD San Pablo WTP
L2	East Bay MUD Upper San Leandro WTP-USL Water-Treated
N1	City of Fairfield Waterman WTP-Finished Water
D1	Santa Clara Valley Water District Santa Teresa WTP
D2	Santa Clara Valley Water District Rinconada WTP
Figure 65	
W1	Carmichael Water District Bajamont SWTP - Treated
D1	Santa Clara Valley Water District Penitencia WTP
C1	Huron, City of Huron Plant No. 2 Effluent - Treated

Appendix E:
CALFED Drinking Water Quality Study
for the Stage 1 Final Assessment

CALFED Drinking Water Quality Study for the Stage 1 Final Assessment

Prepared by:

URS and BROWN AND CALDWELL

Prepared for

CALFED BAY-DELTA PROGRAM

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

September, 2007

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

ACWD	Alameda County Water District
AVEK	Antelope Valley East Kern
CDPH	California Department of Public Health
CLWA	Castaic Lake Water Authority
CCWD	Contra Costa Water District
CT	contact time
CVP	Central Valley Project
DBP	disinfection by-products
D/DBPR	Disinfectants and Disinfection By-Products Rule
DMC	Delta-Mendota Canal
DOC	dissolved organic carbon
DV	Del Valle
DWR	California Department of Water Resources
EC	electrical conductivity
ELPH	equivalent level of public health protection
GAC	granular activated carbon
HAAs	halo acetic-acids
HAA5	five regulated halo acetic-acid species
MCLs	maximum contaminant levels
MIB	2-methylisoborneol
MP	milepost
NBA	North Bay Aqueduct
NTU	Nephelometric Turbidity Units
O&M	operations and maintenance
PAC	powdered activated carbon
PACl	poly-aluminum chloride
ROD	CALFED Record of Decision
SWP	State Water Project
SBA	South Bay Aqueduct
T&O	taste and odor
TDS	total dissolved solids
TOC	total organic carbon
THMs	tri-halomethanes
TTHMs	total tri-halomethanes (four regulated THMs)
WQP	CALFED Water Quality Program
WTPs	water treatment plants
USEPA	United States Environmental Protection Agency
UV	ultraviolet radiation

DELTA DRINKING WATER QUALITY STUDY

EXECUTIVE SUMMARY

As part of the CALFED Water Quality Program (WQP) Stage 1 Final Assessment, this study made a systematic examination of drinking water quality through a detailed analysis of water quality as it changes from the Delta intakes through water treatment plants (WTPs) that use Delta water. This evaluation was conducted to support the State of Science and the CALFED Stage 1 Report, and to aid the WQP in developing a better understanding of progress towards the CALFED Record of Decision (ROD) goal of achieving an "equivalent level of public health protection (ELPH) using a cost effective combination of alternative source waters, source control, and treatment technologies." Water quality is driven by a number of factors, such as supply, economics, and customer expectations, many of which are beyond the scope of the WQP or its state and federal implementing agencies. The WQP is seeking to understand its role in treated water quality, build a water quality strategy, prioritize actions, and develop quantitative performance measures for improvements in source (specifically Delta) water quality. The conclusions and recommendations presented here inform the WQP's plans for Stage II actions to improve drinking water quality and support the Delta Vision.

Selecting and implementing the actions that will make key improvements requires an understanding of the connections between source water quality protection and public health protection, and recognition of the importance of maintaining the Delta as a drinking water source. To meet a critical need for integrated information, this study examined water quality at each step of the "system:" Delta intakes, storage, conveyance, and treatment, and analyzed the potential linkages among system elements. The overarching goals of this effort were to provide a scientific evaluation, expand upon the information obtained during the Initial Assessment, and reexamine beliefs and assumptions on Delta drinking water quality. This study helps to furnish the context for the ELPH goal by outlining key water quality drivers in the system. This study found that several parts of the system may present opportunities for the WQP to help agencies treating water from the Delta. A key recommendation of this study is that the WQP should pursue actions for reducing both the variability in water quality at the Delta intakes and episodic high constituent concentrations, and should develop strategies for storage and conveyance to dampen variability between the intakes and the WTPs.

The study team included researchers working directly with CALFED implementing agencies: the California Department of Health Services (CDHS), Department of Water Resources (DWR), and United States Bureau of Reclamation, as well as agencies treating drinking water from the Delta and its primary tributaries.

Approach

This study focuses on an analysis of water quality as it affects ten case study WTPs that reflect a range of Delta water quality and WTP characteristics. The representatives of these WTPs furnished "real world" insight regarding the quality of Delta source water and its treatment for potable use by providing data and qualitative information regarding their water sources, facilities, methods, challenges, and desired improvements, The study team took the following steps.

1. Developed a conceptual model framework, depicting Delta source water quality and its effects on drinking water treatment.
2. Developed hypotheses that describe: Delta water quality and relationships between source water quality and treated water quality; effects within conveyance and storage facilities; and other issues of interest to the WQP.

3. Determined the range of treatment technologies and water quality characteristics within the CALFED solution area and areas within the tributaries to the Delta, and selected ten WTPs for study participation.
4. Used the model framework and the hypotheses to develop an outline of the information desired for each of the participating WTPs.
5. Met with representatives of the participating WTPs to collect data and qualitative information.
6. Reviewed the *California State Water Project (SWP) Watershed Sanitary Survey 2006 Update* (State Contractors Authority 2007)*,* for WTPs on the SWP. Used the DWR data library and Contra Costa Water District water resources staff to obtain intake and conveyance water quality data for these WTPs.
7. Developed a database containing water quality data representing locations in the Delta, through conveyance, and into WTP intakes throughout California.
8. Analyzed the water quality data developed in Step 7.
9. Developed a conceptual model that depicts water quality from the plant's source through its treatment process for each participating WTP.
10. Tested the hypotheses and reported on the results.
11. Developed conclusions and recommendations for quantitative drinking water quality performance measures.
12. Made recommendations for Stage II of the CALFED WQP.

Study Regions and Water Treatment Plants

This study covered five regions, identified based on the location of their WTP intakes: the Upper Watershed, North Bay Aqueduct, Central/South Delta, South Bay Aqueduct, and California Aqueduct. For 54 representative WTPs (that either use Delta water as a source or are within the upstream tributaries in the Central Valley), CDHS provided data including general treatment parameters, raw water quality data, and treated water quality. An analysis of this data and information guided the selection of ten WTPs for the detailed study. Based on a number of factors, including location, distribution of filtration and disinfection technologies, and treatment plant size, the team narrowed the list to the WTPs shown in Table ES-1.

Hypothesis Testing Results

Hypothesis testing clarified study objectives, challenged the current understanding regarding Delta water treatment, identified data/information gaps, and led to recommendations for the WQP Stage II. Hypotheses were categorized by system component: source, conveyance and storage, and treatment, as listed below.

Source Hypotheses

This study considered both the difference between tributary and Delta water quality and differences among the Delta intakes.

1. **CALFED ROD Targets -** *Upper Watershed raw water quality consistently and reliably meets the ROD Delta intake targets of average concentrations of 3 mg/L total organic carbon (TOC) and 50 µg/L bromide, but the Delta intakes do not.*

   The water quality data supports this hypothesis. The study data showed that Sacramento River water consistently and reliably meets the ROD intake targets and the water at the Delta intakes evaluated for this study does not.

Table ES-1. Case Study WTPs

Region	WTP	Intake Locations/Source	Filtration Technology	Disinfection
Upper Watershed	City of Redding Foothill WTP	Sacramento River	Conventional Media Filtration	Pre-Chlorine
	City of Sacramento Sacramento River WTP	Sacramento River	Conventional Media Filtration	Pre-Chlorine
NBA	City of American Canyon WTP	Barker Slough	Conventional Media and Membrane Filtration	Post-Chlorine
Central/South Delta	Contra Costa Water District Bollman WTP	Rock Slough Old River Mallard Slough	Conventional Media Filtration	Pre-Ozone
	City of Antioch WTP	Rock Slough Old River San Joaquin River	Conventional Media Filtration	Pre-Chlorine
South Bay Aqueduct	Zone 7 Water Agency Patterson Pass WTP	H.O. Banks Pumping Plant Lake Del Valle	Conventional Media and Membrane Filtration	Pre-and Post-Chlorine
	Alameda County Water District WTP # 2	H.O. Banks Pumping Plant Lake Del Valle	Conventional Media Filtration	Pre-Ozone
California Aqueduct	City of Coalinga WTP	H.O. Banks Pumping Plant Bill Jones (Tracy) Pumping Plant	Conventional Media Filtration	Post-Chlorine
	Castaic Lake Water Authority Earl Schmidt Filtration Plant	H.O. Banks Pumping Plant Bill Jones (Tracy) Pumping Plant	Conventional Media Filtration	Pre-Ozone
	Antelope Valley East Kern Quartz Hill WTP	H.O. Banks Pumping Plant Bill Jones (Tracy) Pumping Plant	Conventional Media Filtration	Post-Chlorine

2. **Treatment of Source Waters with Higher TOC, Bromide, and Turbidity** - *Better raw water quality allows treatment plants to more cost effectively, reliably, and consistently meet water quality regulations (comparing Upper Watershed versus Delta).*

3. **Treatment of Source Waters with Higher TOC, Bromide, and Turbidity** - *Water quality at each Delta intake is different and therefore has unique water quality challenges related to treatment.*

   The water quality data, chemical addition data, and qualitative information supplied by WTPs support Hypotheses 2. The study team compared chemical addition to TOC concentrations and turbidity levels to evaluate the "cost to treat" as it relates to water quality for the Upper Watershed and Delta WTPs. Qualitative information obtained from the WTPs supports Hypothesis 3. Because conveyance and storage within the study regions also affect treatment, the hypothesis was evaluated by intake and region rather than intake alone. Regional differences in water quality do affect treatment and other operations.

4. **Blending with Alternative Supplies** - *Changes in the quality of Delta water prompt WTPs to switch to or blend Delta water with other water and effectively reduce the reliability of the Delta as a drinking water supply.*

   Data obtained during this study neither fully supports nor refutes this hypothesis. To fully evaluate this hypothesis, additional data and operational information from WTPs that blend supplies is required.

Conveyance and Storage Hypotheses

Water in California is often transported great distances and stored in reservoirs or lakes prior to reaching a treatment plant. The study evaluated the role of conveyance and storage for a number of water quality constituents.

1. **Attenuation of Water Quality** - *Long residence times within conveyance and storage facilities result in changes to water quality constituents such as TOC/DOC, bromide, nutrients, algae, turbidity, and pathogens. For more conservative constituents (e.g., bromide and TDS or EC), longer conveyance and storage residence times attenuate the variability seen at Delta intakes. For highly reactive constituents (e.g., nutrients and algae), longer residence times in storage change the water quality characteristics.*

   The study data supports the hypothesis that long residence times in storage change TOC/DOC, bromide, and turbidity, but does not support this hypothesis for conveyance. Additional data is necessary to evaluate this hypothesis with respect to nutrients, algae, and pathogens.

2. **Algae and Taste and Odor (T&O)** - *All plants receiving Delta water have T&O issues associated with Delta water, but the nature and extent of their T&O problems are dependent on intake location and their conveyance and storage infrastructure.*

   The T&O information collected for this study does not support this hypothesis. Not all WTPs that treat Delta water receive T&O complaints. In addition, problems associated with algae growth in the Delta and in conveyance structures is not limited to T&O but includes operational challenges.

3. **Delta Variability -** *Treatment plants receiving water directly from the Delta (e.g., via the SBA) have costs and operational challenges beyond those of plants that receive Delta water with longer residence times in storage and conveyance that provide a buffering capacity.*

   This hypothesis concerned the water quality and operational challenges of only the treatment plants receiving Delta water, and did not include the Upper Watershed WTPs. The data and qualitative information collected for this study neither supports nor refutes this hypothesis. This was due to data and analysis limitations; the water quality data was insufficient to compare the changes in variability and water quality that are due to residence times in conveyance for the two aqueducts.

Treatment Hypotheses

A study goal was to begin quantifying how Delta water quality influences the ability of treatment plants to meet regulations and local objectives. Treatment hypotheses addressed disinfection and filtration.

1. **Disinfection By-product (DBP) Formation** - *Higher raw water TOC concentrations due to source water quality, conveyance, and local watershed inputs lead to increased DBP formation.*

   The data obtained for this study neither fully supports nor refutes these hypotheses. This is due to both data limitations and the complexity of the relationship in DBP precursor removal and formation during treatment.

2. **DBP Formation** - *Plants employing alternative disinfectant technologies:*
   i. *Have lower DBP concentrations and/or meet maximum contaminant levels (MCLs) more reliably;*
   ii. *Achieve higher log removals; and*
   iii. *Are better prepared to meet future regulations (e.g. lower DBP MCLs).*

The data supports hypotheses (i) and (iii), WTPs that have implemented ozone disinfection achieve lower MCLs and are better prepared to meet future regulations. Hypothesis (ii) was not tested because all the WTPs achieve sufficient log removals while achieving DBP concentrations below the MCLs.

3. **Effectiveness of Conventional Filtration** - *Current conventional filtration processes in use in California provide sufficient filtration/removal of organic carbon in Delta water.*

   The data and qualitative information obtained in this study support this hypothesis. WTPs practicing conventional treatment are able to meet TOC percent removal regulations and DBP MCLs. However, optimization of pre-treatment remains challenging and treating sometimes comes at a high cost.

4. **Effectiveness of Membrane Filtration -** *Compared with conventional filtration, membrane filtration achieves as good or better finished water quality (pathogens, TOC, and turbidity).*

   Data neither refuted nor supported this hypothesis due to data limitations. To fully test the suitability of membrane treatment on Delta water, an analysis of side by side raw water, post pre-treatment, filtrate data and more comprehensive operation data is necessary.

Study Conclusions

Source

- Many of the water quality challenges experienced at the case study WTPs originate with Delta intake water quality. Delta intake water has TOC, turbidity, and bromide concentrations that are higher and more variable, and that require more extensive treatment than the Upper Watershed (WTPs on the Sacramento River in this study) raw water sources.
- Water at the Upper Watershed WTPs in this study comes closer to meeting the ROD intake targets than water from the Delta. Water at the Upper Watershed WTP intakes consistently meets ROD bromide and TOC intake targets while the water at the Delta intakes does not. The differences in source water quality affect treatment and operation in the case study WTPs. Achieving water quality at the Delta intakes that is similar to Sacramento River water quality, through conveyance and/or source improvement projects, would significantly increase the ability of WTPs to meet treated water quality objectives less expensively and more reliability.

Conveyance and Storage

- Algae growth in the Delta and along conveyance and storage structures for some WTPs results in operational upsets, presents challenges with respect to pre-treatment optimization and T&O, and is not fully addressed by current mitigation methods. Algae mitigation is a growing concern due to increased limitations on copper sulfate use.
- Storage times between Delta intakes and WTP intakes can attenuate high concentrations of undesirable constituents and buffer the variability of water quality from the Delta, but must be carefully maintained and/or managed to avoid degradation of water quality.

Treatment

- Treatment issues associated with TOC concentrations in the Delta are compounded by low and variable alkalinity, which makes achieving optimal TOC removal and optimizing pre-treatment difficult.
- While treatment plants are able to meet TOC percent removal regulatory requirements, they are not always able to meet the agency/WTP TOC removal objectives to minimize DBP formation.
- The treatment challenges associated with Delta water quality depend on which Delta intake a WTP uses, and upon the conveyance used. Specific regional problems include high TOC in the NBA; algae growth

and resultant changes in water quality along the SBA; and continual changes in source water quality, with corresponding changes in WTP intake water quality that affect treatment differently in each region.

- Most WTPs treating Delta water are able to consistently meet DBP MCLs; however, DBPs continue to be a challenge when WTPs treat raw water having high TOC concentrations. TOC removal and the optimization of disinfection processes are also challenging when treating Delta water.
- For WTPs that have switched to ozone, limiting bromate formation remains a challenge; however, most of the study WTP operators prefer to use ozone for T&O benefits and THM/HAA minimization.

New Findings

In addition to confirming may of the historic beliefs and assumptions on Delta drinking water, this study developed new information regarding the treatment of Delta water and offered new perspectives, as follows.

- The cost difference between treating Delta water and treating Upper Watershed water can be roughly quantified and evaluated by comparing pre-treatment chemical concentrations associated with WTP intake TOC and turbidity concentrations.
- Challenges posed by algae growth are becoming more complicated, as a result of more prevalent year-round growth, which causes operational challenges beyond T&O issues. Regulatory restrictions on mitigation measures (i.e., copper sulfate usage) are exacerbating the problem.
- This study further clarified the issues and complexity associated with balancing TOC removal and DBP minimization.

Further Clarification of the ELPH Concept

The conceptual models developed for this study were based upon the ELPH construct to better describe linkages within the system and areas to improve water quality within the ELPH concept. These conceptual models present a visualization of boundary conditions and constraints, and they help to determine where water quality can be changed within the system when water quality targets can not be met at the source. By encompassing the whole system, the conceptual models can support decision-making regarding the appropriate locations within the system where investments can achieve the most economical water quality improvements and meet ELPH objectives. Finally, the conceptual models aided in developing recommendations for performance measures, which can be applied to various system locations to evaluate progress towards meeting ELPH objectives.

Performance Measure Recommendations

Based on the data and information obtained during this study, performance measures or evaluation of water quality improvements should be assessed for two tiers of parameters.

Tier 1 Parameters are direct indicators of WTP source water improvement. These key drinking water quality parameters are measured at the Delta intakes, through conveyance and storage, and at the WTP intakes at a daily or higher frequency. These parameters can be used to investigate improvement or degradation of water quality, changes in variability, and changes to episodic high concentrations at the Delta source. Because these parameters are also measured within conveyance and at the WTPs, they are good measures for evaluating changes in water quality through the system.

- ***TOC***
- ***EC/TDS/Chloride***
- ***Turbidity***

Tier 2 Parameters are indicators of drinking water quality improvement but would not necessarily be direct measures of Delta source water quality improvements. These parameters are not measured as frequently and are influenced significantly by water quality management strategies within conveyance, storage, and drinking water treatment. Measurement of these parameters for performance measures must be done at the WTPs.

- ***Pathogens and Pathogen Indicators***
- ***DBP***
- ***T&O issues associated with Algae Blooms***

While the WQP might not set specific targets for these Tier 2 parameters, it should continue to take steps to minimize pathogens, reduce DBP concentrations, and address algae growth to the extent possible.

The WQP should produce an annual report on drinking water quality as indicated by the performance measures. As discussed above, Tier 1 parameters would be used to measure changes in water quality through the system, and Tier 2 would measure changes in drinking water quality at the WTPs. The evaluation would assess whether changes in the variability of water quality and changes in constituent concentrations occur.

This study also included development of an "ideal" set of performance measures. The description of this ideal set of performance measures includes water quality parameters to be measured, monitoring frequency, and monitoring locations. This ideal set represents the performance measures that would be needed to fully describe changes in water quality through the system and determine progress towards meeting ELPH when source targets are not met. These ideal performance measures were developed without consideration of the cost to complete the monitoring and analysis, but to outline an long-term objective.

Recommendations for WQP Stage II

The results of this study suggest that, to assist in improving drinking water quality, the WQP should pursue actions for reducing both the variability in water quality at the Delta intakes and the episodic high constituent concentrations, and develop strategies for storage and conveyance to dampen variability between the intakes and the WTPs. The study team recommendations for WQP Stage II actions are presented below.

Source

- Continue improving and/or maintaining Delta intake water quality. Particularly to variability for TOC, bromide, and turbidity.
- Continue to investigate projects (such as the Through-Delta facility or an isolated facility) that could permit more direct access to Upper Watershed water for those WTPs currently treating Delta water.
- Fund research to develop alternatives to copper sulfate for algae mitigation at Clifton Court Forebay.
- Approach drinking water quality and treatment challenges at a regional level to develop more site-specific solutions that meet local needs.

Conveyance and Storage

- Fund research to develop alternatives to copper sulfate for algae mitigation in conveyance and reservoirs.
- Investigate/support enclosing sections of conveyance channels that have significant algae growth.
- Investigate storage options for WTPs that currently do not have storage.
- Investigate alternatives to limit water quality degradation in Barker Slough or proceed with projects to re-locate the NBA intake.

Treatment

- To increase the level and availability of knowledge and experience with organic carbon removal, conduct detailed assessments of WTPs that achieve good organic carbon removal while treating water that is difficult to coagulate and that is high in organic carbon. Provide this information to Delta WTPs.
- Evaluate the trade-offs between membrane treatment and conventional treatment with the help of agencies that currently operate both. This evaluation should consider the membrane technology used, influent water quality, and membrane and media filtrate.
- Provide direct outreach to disadvantaged communities with small WTPs that use Delta water to identify specific opportunities to improve drinking water quality at the level of these small WTPs statewide.

1. INTRODUCTION

1.1 Introduction

As part of the CALFED Water Quality Program (WQP) Stage 1 Final Assessment, a study of drinking water in California was undertaken by the WQP with assistance from the United States Bureau of Reclamation (Reclamation), California Department of Public Health (CDPH), a small working group of the CALFED Water Quality Subcommittee, and their consultants, Brown and Caldwell. The study team conducted a systematic examination of drinking water quality through a study of water quality as it changes from the Delta intakes through the water treatment plants (WTPs) that use Delta water. This evaluation was conducted to aid the WQP in developing a better understanding of the CALFED Record of Decision (ROD) objective of achieving an "equivalent level of public health protection (ELPH) using a cost effective combination of alternative source waters, source control, and treatment technologies" and determining how best to implement this. The ELPH objective recognizes the connections between source water quality protection and public health protection, the importance of multiple barriers, and retaining the Delta as a drinking water source. The Water Quality Subcommittee (previously the Drinking Water Subcommittee) assisted the WQP in developing a visual representation of ELPH, referred to as the "ELPH" diagram (Appendix A). The individual elements of ELPH have not been described fully, and areas in which the WQP can assist in meeting the ELPH goal have not been fully defined. The results from this study expand the ELPH framework by looking at drinking water quality at each step of the water supply and treatment "system:" Delta intakes, storage and conveyance, and treatment. This study will also support future decisions on the Through-Delta Facility or other similar projects.

This effort built upon lessons learned from the qualitative survey prepared for the Initial Assessment, *Issues with Delta Drinking Water Treatment* (Brown and Caldwell, 2005), which evaluated specific drinking water quality constituents of concern through the system in order to aid the WQP in confirming its objectives and in identifying implementation actions. This report presents the information gathered to help inform the WQP regarding Stage 2 implementation, the end of Stage 1 decision on conveyance, and the development of quantitative performance measures for the program. This study was conducted by a team working directly with the CALFED implementing agencies: the CDPH, Department of Water Resources (DWR), and Reclamation, as well as agencies treating drinking water from the Delta and its primary tributaries. While the study team identified a number of information gaps during this study, this report serves as a template for evaluation of other WTPs and further quantification of water quality through the system, and to better understand drinking water quality in the ELPH context.

1.2 Objectives and Outcomes

The overarching goals of this effort were to provide a scientific evaluation, expand upon the information obtained during the Initial Assessment, and reexamine beliefs and assumptions on Delta drinking water quality. Specific study objectives included:

- Capture the range of (and quantify) existing conditions;
- Determine relationships between Delta source water quality and finished water quality;
- Identify the key indicators of source water degradation on finished water quality;
- Quantify the issues and challenges associated with treating Delta water;

- Identify options for addressing water quality and treatment challenges; and
- Identify where in the system improvements are best focused.
- Help refine the concept of ELPH and determine how to achieve it.

The outcomes that are expected to follow from this study include:

- Provide feedback to implementing agencies and to the legislature; and
- Guide future funding and identification of future resource allocation, including Stage 2 CALFED actions.

The project objectives, desired outcomes, and approach (below) of this study were developed in coordination with WQP staff, CDPH, Reclamation, and a small working group of the CALFED Water Quality Subcommittee.

1.3 Study Approach

This study focuses on an analysis of water quality as it affects ten case study WTPs, which were asked to participate by the WQP and two of its implementing agencies, Reclamation and CDPH. By providing data and qualitative information regarding their water sources, facilities, methods, challenges, and desired improvements, the representatives of these WTPs furnished "real world" insight regarding the quality of Delta source water and its treatment for potable use. The study team conducted this study by taking the following steps.

1. Developed a conceptual model framework, depicting Delta source water quality and its effects on drinking water treatment.
2. Based on current knowledge of drinking water in California, developed hypotheses that describe: Delta water quality tendencies; relationships between Delta water quality and treated water quality; effects that certain facilities or treatment methods have on water quality; and other areas of interest for the WQP.
3. Determined the range of treatment technologies and water quality characteristics within the CALFED solution area and areas within the tributaries to the Delta, and selected ten WTPs for participation in the study.
4. Using the model framework and the hypotheses, developed an outline of the information desired for each of the participating WTPs.
5. Met with representatives of the participating WTPs to collect the desired data and the supporting qualitative information.
6. For WTPs on the State Water Project (SWP), reviewed the *California SWP Watershed Sanitary Survey 2006 Update*. Used the DWR data library and Contra Costa Water District water resources staff to obtain intake and conveyance water quality data for these WTPs.
7. Developed a database containing water quality data representing locations in the Delta, through conveyance, and into WTP intakes throughout California.
8. Analyzed the water quality data from the source water intakes to the WTPs (through conveyance and storage).
9. For each participating WTP, developed a conceptual model that depicts water quality from the plant's source through its treatment process.
10. Applied conceptual models to further refine ELPH.
11. Tested the hypotheses and reported on the results.
12. Developed conclusions and recommendations for quantitative drinking water quality performance measures.

13. Made recommendations for Stage II of the WQP.

The water quality constituents that were evaluated during this study included: organic carbon (total organic carbon [TOC])/disinfection by-products (DBP), bromide, total dissolved solids (TDS), nutrients and algae, and pathogens. These water quality constituents are the same constituents of concern identified previously by other efforts, including the Central Valley Drinking Water Policy development.[1] These constituents were also selected because they provide a linkage between source water improvements and impacts on drinking water quality and are parameters for which quantitative drinking water quality performance measures could be developed. This report also considers turbidity levels, because they are critical to the operation of WTPs and resultant drinking water quality.

1.4 Report Contents

Section 2 includes an overview of drinking water treatment and the WTPs included in this study. Also contained in Section 2 are the hypotheses to be tested as part of this study. Section 3 presents water quality data representing Delta intake locations, upper watershed intake locations, locations from the Delta intakes through conveyance and storage, and finished drinking water for each WTP. Section 4 presents information obtained from WTP representatives and describes the conceptual models developed for each of the WTPs. Section 5 evaluates the study hypotheses. Section 6 presents the study conclusions, recommendations regarding the development of quantitative drinking water quality performance measures, and recommendations for WQP Stage II. See the Table of Contents for the list of materials in the appendices, which contain supplemental figures, data, meeting summaries, and additional detail regarding the study approach.

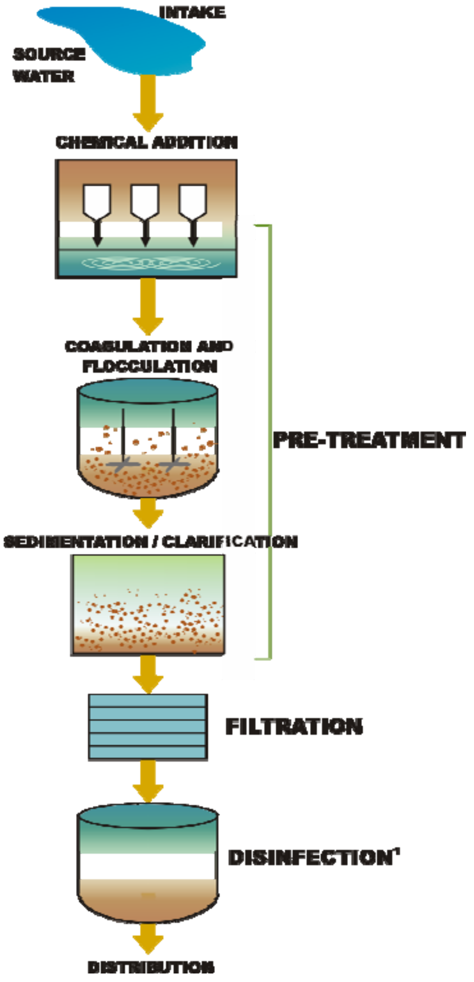
---

[1] Available at http://www.swrcb.ca.gov/rwqcb5/available_documents/dw-policy/index.html

2. OVERVIEW OF DRINKING WATER TREATMENT AND STUDY HYPOTHESES

This section presents an overview of drinking water treatment (Section 2.1) to provide background relevant to the selection of WTPs and to support the information about drinking water quality at the individual WTPs, as presented in Section 4.0. This section also describes the study WTPs and the source water/conveyance regions of the selected WTPs (Section 2.2), and presents the hypotheses evaluated during this study (Section 2.3).

2.1 Overview of Drinking Water Treatment



[1] *Disinfection can be applied at any location in the treatment process and at multiple locations.*

The primary function of drinking water treatment is to provide healthy and safe drinking water to consumers. Treatment's secondary function is to provide good aesthetic quality (for both human consumption and for household and industrial use). The manner in which this is done depends on a number of factors, including source water quality and economics. This section provides an overview of methods used to treat Delta water. The discussion is divided into three subsections (pre-treatment, filtration, and disinfection), which also represent the organizational structure of the treatment descriptions in the WTP conceptual models, and covers distribution in a fourth sub-section. Terms used in the conceptual models are described here.

2.1.1 Pre-Treatment

"Pre-treatment," as defined for this study includes coagulation/flocculation and sedimentation/ clarification. When pre-treatment occurs prior to filtration, the whole treatment process is considered "conventional treatment." Non-conventional treatment processes, such as direct filtration, omit the sedimentation/clarification process and consist only of coagulation/ flocculation followed directly by filtration.

Processes using membrane filtration can include coagulation/flocculation and sometimes, sedimentation/clarification. A number of variations exist within pretreatment that change effectiveness or constituents targeted; the driving factors for these variations are usually economics and water quality. The coagulation/flocculation process employs chemical coagulants and rapid mixing (or flash mixing) to bind non-settleable solids into larger, settleable solids, to aid and accelerate the sedimentation/clarification and filtration processes (during which the solids are removed from the water). Chemical coagulants commonly used in California include ferric chloride ($FeCl_3$), aluminum sulfate (alum), aluminum chloride, and poly-aluminum chloride (PACl). In addition, polymers or other synthetic chemicals are sometimes used at this stage, or just prior to filtration, to enhance the removal of solids that are difficult to filter out. Some treatment plants practice enhanced coagulation to produce the greatest possible reduction of TOC. To do this, plant operators adjust coagulant doses and pH and sometimes add an oxidant (such as chlorine, ozone, or potassium permanganate). Powdered activated carbon (PAC) is sometimes included as part of chemical addition, to absorb compounds that cause taste and odor (T&O). The PAC is removed in the sedimentation/clarification process. While PAC is effective at eliminating T&O in finished water, it is expensive, challenging to handle and use, and only treats specific organic contaminants effectively.

The sedimentation process traditionally uses gravity to remove larger suspended particles; water moves slowly through a large tank, allowing heavier particles to settle to the bottom. Some agencies increase the effective surface area of their sedimentation tank by installing tube settlers or plate settlers to increase the settling time. Several agencies have reported that upflow clarifiers, also called solids-contact clarifiers, achieve good suspended solids removal and alleviate T&O problems, by combining coagulation, flocculation, and sedimentation in a single tank. While upflow clarifiers can reduce operations costs, they also require adjustments in response to incoming water quality to achieve effective solids removal.

2.1.2 Filtration

Filtration removes the remaining suspended particles by passing the water through a gradation of fine grained media (media filtration) or polymer membranes (membrane filtration).

Media Filtration

Media filters are composed of different types and gradations of materials. The type and size of the media is dictated by the filter type, operation method, and the source water quality. Filters may include only one medium (mono-medium filters) or two to three types of media (multi-media filters). Media commonly used in California include sand and anthracite. Filters sometimes include granular activated carbon (GAC) because of its high capacity to adsorb organic compounds. GAC is typically more expensive and requires more frequent replacement than other media. Gravity filtration, which is the most common type of media filtration operation used in California, uses gravity to move water vertically through the filter media. A modification to gravity media filtration allows microorganisms to grow on the media to aid in organic carbon removal. This modification is typically done with GAC media, and is referred to as Biological Activated Carbon. Some Pressure filtration systems employ pressure either to accelerate a vertical filtering process or to force horizontal flow through the filter media.

Membrane Filtration

During membrane filtration with typical microfilters, very small particles (smaller than 0.1 to 1 µm) pass through a synthetic membrane and larger particles (over 1 µm) are retained on the feed side. For a particle to pass through the membrane, its size must be smaller than the pore size of the membrane. Microfiltration (using pore sizes 0.1 to 1 µm) will remove many bacteria and protozoan because most bacteria and protozoan oocysts (*Giardia* and *Cryptosporidium*) are larger than 1 µm (protozoan oocysts are also usually larger). Ultrafiltration or nanofiltration is required to remove viruses, which are usually smaller than 0.1 µm.

Membrane systems are typically highly automated and require less operator attention than other systems, and they typically meet regulatory turbidity levels in finished water effectively and consistently. Microfiltration typically does not remove the portion of total organic carbon that passes through a 0.45 μm filter, which can be a significant amount of dissolved organic carbon (DOC). Nanonfiltration is sometimes used if removal of DOC is desired. Membrane filtration is an emerging technology that California agencies treating Delta water have started to implement on a limited basis.

2.1.3 Disinfection

Disinfection using chemicals may occur at any point in the treatment train, and often, WTPs include chemical disinfection at more than one step. Chemical disinfection can serve multiple purposes in addition to inactivating (killing) pathogenic microorganisms. Chemical disinfection can resolve T&O issues, enhance the removal of organic carbon (enhanced coagulation), and treat some problematic organics. Disinfectant residuals must be maintained in the distribution system to prevent microbial regrowth.

The two critical measures of disinfection are:

- Disinfectant concentration (expressed in units of mg/L), and
- Residence time – the amount of time the oxidant remains in contact with the water (expressed in minutes).

The product of the oxidant concentration and the time the water is exposed to a specified oxidant concentration results in microorganism inactivation or disinfection of microorganisms. Microorganism inactivation or removal is generally referred to as "log removal," where one log is 90 percent removal, two logs is 99 percent removal, and so on. The United States Environmental Protection Agency (USEPA) specifies the "contact time (CT – mg/L*)" necessary for each chemical disinfectant required for specific microorganism log removal. Chemical disinfection to meet required log removal requirements is commonly referred to as primary disinfection. In addition to disinfection, for which a specified CT must be achieved for a desired log removal, the USEPA regulates disinfection through "removal credits" based on physical removal of microorganisms during coagulation/sedimentation and filtration (both membrane and media filtration). Disinfection prior to filtration is typically referred to as "pre-disinfection" and disinfection after filtration is called "post-disinfection."

The USEPA also regulates DBPs in treated drinking water through the Disinfection and Disinfection Byproducts Rule (D/DBPR). Bromide and organic carbon are DBP precursors, because during disinfection, they interact with chlorine to form tri-halomethanes (THMs) and halo-acetic acids (HAAs). Ozone also interacts with bromide to form bromate. Maximum contaminant levels were set to regulate four THM species at 80 μg/L (referred to as total THMs [TTHMs]) and five HAAs species at 60 μg/L (referred to as HAA5). In 2006, the USEPA promulgated the Stage 2 D/DBPR which will require additional monitoring for DBPs through distribution systems. With these regulatory changes, agencies that currently struggle to meet DBP Maximum Contaminant Levels (MCLs) will have to increase the removal of DBP precursors and optimize disinfection. Pre-treatment and filtration are critical steps in removing organic carbon to limit DBP formation. Several approaches for reducing DBP formation exist, including point-of-disinfectant application, alternative disinfectants, precursor removal strategies (which can include pre-oxidation), source shifting and blending, and disinfection process modifications.

The selection of a disinfectant often requires evaluating tradeoffs and balancing effective disinfection with the minimization of DBP formation. Ozone might be used, for example, because it does not produce THMs or HAAs. Ozone does, however, produce bromate, the formation of which can be reduced by pH suppression. Removal of bromide during treatment to prevent the formation of bromate is primarily limited to processes such as ion-exchange and is not commonly practiced.

Commonly used disinfectants are described below.

- ***Free chlorine*** in its gaseous form or hypochlorous acid (sodium hypochlorite, a.k.a. bleach) in its liquid form is the most commonly used disinfectant for drinking water treatment. The use of free chlorine results in the highest concentrations of THMs and HAAs when compared to other oxidants.
- ***Chloramines*** are formed by a mixture of chlorine and ammonia that is also referred to as "combined chlorine." Chloramines produce lower concentrations of DBPs than chlorine but, among chemical disinfectants, chloramines are the least effective in inactivating microorganisms. Chloramines are commonly used to maintain a residual in the distribution system because they produce lower DBP concentrations. However, due to high CT requirements to achieve log removal, chloramines are not commonly used as a primary disinfectant. In a distribution system, chloramines can result in increased nitrates, which form indirectly from the breakdown of ammonia and are a regulated drinking water constituent.
- ***Chlorine dioxide*** is an effective disinfectant for water treatment; it produces lower concentrations of THMs and HAAs than other disinfectants. Adding chlorine dioxide to water can also produce chlorite, another regulated DBP. Due to concerns regarding chlorite formation, few treatment plants in California have implemented chlorine dioxide as a primary disinfectant.
- ***Ozone*** is a highly effective, but short-lived, disinfectant produced onsite by combining gaseous oxygen from air or liquid oxygen with a high electrical voltage. Disinfection using ozone does not produce a sustainable residual in the treated water, so another disinfectant is added (usually chloramines) prior to distribution. Ozone is also effective at treating noxious T&O and reducing color in water. The use of ozone in WTPs in California is becoming more widespread.
- ***Physical Disinfection*** processes include both ultraviolet radiation (UV) and membranes (discussed under filtration) which inactivate and remove microorganisms, respectively. With physical disinfection processes, a disinfectant such as chlorine or chloramines must be added prior to distribution. The primary advantage of physical disinfection processes is that currently there are no identified or regulated DBPs associated with them.

  Ultraviolet radiation disrupts various cellular organic components, causing cellular changes that are fatal to microorganisms. UV disinfection is an emerging technology that has been implemented at WTPs on a limited basis in the United States. Previous studies have indicated that UV disinfection can effectively inactivate some microorganisms, particularly *Cryptosporidium*, without producing DBPs. UV is less effective than chemical disinfectants (chlorine and ozone) at disinfecting viruses. Contra Costa Water District and the Metropolitan Water District of Southern California completed WQP-funded demonstration-scale studies on UV disinfection of Delta water.

2.1.4 Distribution

The purpose of a water distribution system is to deliver an adequate water supply at sufficient pressures while maintaining water quality. Disinfectants may be added just prior to distribution, because disinfectant concentrations must be maintained throughout potable water distribution systems to prevent microbial regrowth. Because of this requirement, a concern for many treatment facilities is the formation of DBPs in the distribution system. Future regulations (Stage 2 D/DBPR) require additional monitoring for DBPs in the distribution system. Ineffective operation of a water treatment plant may result in contaminants of concern being discharged into the distribution system and ultimately, delivered to end users. Distribution system water quality was not examined as part of this initial study.

The disinfectant used in the distribution system can be different from or the same as the primary disinfectant. Frequently, when chlorine is applied after filtration there is no additional disinfectant added prior to the distribution system. The chlorine applied at this point serves as both the primary and residual disinfectant.

Some treatment plants apply chlorine as the primary disinfectant and then add ammonia prior to the distribution system so that chloramines (combined chlorine) are present through the distribution system.

2.2 Study Regions and WTPs

This study included five separate regions, identified based on the location of their source water intakes: the Upper Watershed, North Bay Aqueduct, Central/South Delta, South Bay Aqueduct, and California Aqueduct. Below are descriptions of these regions and the WTPs selected within each region. WTPs in the Upper Watershed (the watershed to the Delta) were included in this study as baseline WTPs for comparison to WTPs receiving Delta water. The Upper Watershed WTPs were also included to examine the treatment of water that is of higher quality than Delta water, to support decisions on the Through-Delta Facility and other similar projects. Because only one WTP, the City of Tracy, receives Delta water from the Central Valley Project's (CVP's) Delta Mendota Canal (DMC), the DMC was not included as a region for this study.

In coordination with the Central Valley Drinking Water Policy Workgroup and the CDPH, WQP staff identified 54 WTPs that either use Delta water as a source or are within the upstream tributaries in the Central Valley. CDPH then provided some of its collected data to the WQP in order to develop a database of general treatment parameters, raw water quality data, and treated water quality data for the 54 WTPs. The general treatment parameters were then confirmed or corrected by CDPH District Engineers, and additional WTP characteristics were collected through a survey of utilities (60% response rate). This limited data set was analyzed to determine the range of treatment technologies and water quality characteristics within the CALFED solution area and areas within the tributaries to the Delta. Results from the database analysis informed the selection of ten WTPs for the study. Appendix B presents the technical memorandum *Approach to the Detailed Study of Delta Drinking Water Quality* (Brown and Caldwell April 2007), which includes the results used to select the WTPs. The technical memorandum *Identifying Water Treatment Plants using Delta water as a Major Source* (CALFED WQP, July 2007) documents in greater detail the development of the WTP database, its limitations, and the analysis of its contents.

Factors that influenced the selection of the ten case study WTPs are described below.

- Upper Watershed WTPs are being included in this study for comparison to the Delta WTPs. So that the results would be readily comparable to the Delta WTPs, WTPs with conventional treatment technologies were selected, rather than plants with emerging or unique treatment processes.
- The majority of WTPs in California practice conventional treatment with media filters. A majority of the treatment plants selected for the study use similar practices. As membranes are an emerging technology of interest, however, plants using membrane treatment along side conventional treatment were included in the set.
- At the time of the database completion, about 70 percent of the WTPs treating Delta water used chlorine for primary disinfection, while about 30 percent used ozone. This distribution in disinfection technology is represented in the WTPs selected for the study.
- The size of the agency and WTP were considered. The study team included some WTPs operated by small agencies, because they may be resource limited with respect to meeting the challenges of treating Delta water.
- Treatment plants were selected to maintain the balance of treatment technologies throughout the regions.
- In order to streamline the case studies, treatment plants with a high percentage of alternative source water supplies to the Delta were not selected. This limitation to the selected WTPs is supported by the database, where the majority of the treatment plants treat 80 percent or greater Delta water.

Based on the selected distribution of filtration and disinfection technologies and treatment plant size, the team narrowed the list as described below for each of the regions.

2.2.1 Upper Watershed

The Upper Watershed region includes treatment plants receiving water either directly from, or through a reservoir on, the Sacramento and San Joaquin Rivers and their tributaries. WTPs along the Sacramento River were selected over WTPs on the San Joaquin River in order to focus on treatment of water with low organic carbon and bromide, and to support decisions on the Through-Delta Facility. The selected Upper Watershed WTPs included:

- City of Redding - Foothills WTP – Conventional treatment with post-chlorination; and
- City of Sacramento – Sacramento River WTP – Conventional treatment with pre-chlorination.

It was anticipated that the source water quality at the City of Redding treatment plant would be of much higher quality than the City of Sacramento's source water because Redding is further upstream in the watershed. These two plants represent treatment of high quality source water.

2.2.2 North Bay Aqueduct

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

- The City of American Canyon WTP - Conventional and Membrane treatment with post-chlorination.

The City of American Canyon WTP was selected for the study because it has a conventional treatment process and a parallel membrane process side by side, and it only treats NBA water.

2.2.3 Central/South Delta

Agencies that receive water from central/south Delta locations (other than Clifton Court Forebay) include Contra Costa Water District (CCWD) and the City of Antioch. The City of Tracy receives water from the DMC through the Bill Jones (Tracy) Pumping Plant (a CVP facility). CCWD's Rock Slough intake and Old River intake are in the Southwestern portion of the Delta, northwest of Clifton Court Forebay and the Tracy Pumping Plant. CCWD also has a less frequently used intake at Mallard Slough. The Rock Slough intake pumps water into the Contra Costa Canal, a CVP facility. CCWD stores Delta water in Contra Loma (1,700 AF capacity), Mallard (2,100 AF capacity), Martinez (230 AF capacity), and Los Vaqueros (100,000 AF capacity) Reservoirs. CCWD provides water to a large portion of Contra Costa County, both raw and treated, resale and wholesale, to a variety of municipal, industrial, and agricultural users. The City of Antioch receives raw water from both the Contra Costa Canal and the San Joaquin River, from an intake within the legal limit of the Delta. Treatment plants selected to represent the Central/South Delta include:

- Contra Costa Water District – Bollman WTP – Conventional treatment with intermediate-ozone; and
- City of Antioch – Conventional treatment with pre-chlorine for primary disinfection.

Both the CCWD and the City of Antioch are entirely dependent on the Delta. They offer a unique comparison, because there are intermediate reservoirs for the Central/South Delta plants and the plants treat similar water but with different disinfection technologies.

2.2.4 South Bay Aqueduct

The Harvey O. Banks (Banks) Pumping Plant is at the southern end of Clifton Court Forebay, which was originally constructed to provide a large settling basin for Delta water before it is pumped into the California Aqueduct. From Clifton Court Forebay, the California Aqueduct flows into Bethany Reservoir (5,070 AF capacity), from where the South Bay Aqueduct (SBA) branches off the California Aqueduct. Water entering the SBA has little residence time between the Delta and the WTPs and the SBA is commonly considered to receive water directly from the Delta. The SBA provides water for portions of Alameda and Santa Clara Counties and has both open and enclosed channels and pipelines. SBA water can be stored within Lake Del Valle, which has a total capacity of 77,110 AF (30,000 AF of which is specifically reserved for water supply needs) and Patterson Reservoir, a small, 100 AF storage facility. Treatment plants along the SBA that were selected for this study include:

- Zone 7 Water Agency – Patterson Pass WTP - Conventional treatment processes with pre-chlorine and membrane treatment with post-chlorine; and
- Alameda County Water District (ACWD) WTP # 2 - Conventional treatment process with pre-ozone.

Zone 7 Water Agency – Patterson Pass WTP was selected because it operates both conventional and membrane treatment side by side with primarily Delta water. ACWD WTP # 2 was selected as an example of conventional treatment with ozone disinfection.

2.2.5 California Aqueduct

From Bethany Reservoir, Delta water flows to the SBA (discussed above) and to the California Aqueduct, through which it flows into O'Neill Forebay. Water pumped from the Tracy Pumping Plant through the DMC also flows into O'Neill Forebay. O'Neill Forebay and the San Luis Reservoir are part of the San Luis Joint-Use Complex, which is used for water supply, power generation, and recreation. This complex contains the San Luis reservoir (2.03 million AF capacity, the nation's largest off stream reservoir) among an integrated network of pumping plants, dams, and forebays, and is operated by the DWR. San Luis Reservoir feeds the DMC, which primarily serves agricultural users; the CVP San Felipe Unit, which serves Santa Clara and San Benito Counties; and the SWP's California Aqueduct, which primarily serves drinking water users.

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

Treatment plants along the California Aqueduct and on its East and West Branches were considered for this study. In order to limit the number of WTPs to ten, WTPs off of the other primary branches of the Aqueduct were not considered. The WTPs selected on the California Aqueduct include:

- City of Coalinga – Conventional treatment with post-chlorine;
- Castaic Lake Water Authority (CLWA) – Earl Schmidt WTP – Conventional treatment with pre-ozone; and

- Antelope Valley East Kern (AVEK) – Quartz Hill WTP – Conventional treatment with post- chlorine.

In order to have representation of the many small WTPs along the Aqueduct, the study team selected a small WTP, City of Coalinga. Like several other communities receiving Delta water in the Central Valley, the City of Coalinga has been identified by CDPH as an economically disadvantaged community. As noted earlier, the team anticipated that small WTPs would have special challenges posed by resource constraints. Understanding and quantifying the different challenges and constraints of smaller WTPs provides important perspective for better understanding where the CALFED WQP can play a role in improving Delta drinking water quality. The City of Coalinga participated in the *Issues with Delta Drinking Water Treatment* survey report (CALFED Bay-Delta Program 2005) but could not make staff available to participate in this study. This illustrates the need for special outreach and support for disadvantaged and small WTPs to improve Delta drinking water quality.

The team selected AVEK Quartz Hill WTP and the CLWA Earl Schmidt WTP in order to conduct case studies on WTPs on both the East and West Branches of the California Aqueduct.

2.3 Hypotheses

Study hypotheses were postulated to clarify the quantitative study objectives and to help identify the data collection and analyses objectives. The study hypotheses are categorized by source, conveyance and storage, and treatment process (disinfection and filtration). A list of the information necessary to evaluate each hypothesis follows the hypotheses in each category. Data and/or information limitations prevented evaluation of all of these hypotheses.

Sections 3.0 and 4.0 present the data evaluation and information gathered from the WTPs to support the hypothesis testing. Section 4.0 presents the evaluation of the hypotheses.

2.3.1 Source

The origin of source water plays a large role in its water quality, and is influenced by hydrology, upstream land use and water infrastructure, and, in the Delta, by the hydrodynamics of the Estuary. Within this study, the WQP is interested in both the differences in tributary and Delta water quality and in differences between the different Delta drinking water intakes.

Source Hypotheses:

1. Upper Watershed raw water quality consistently and reliably meets the ROD Delta intake targets of average concentrations of 3 mg/L TOC and 50 μg/L bromide, but the Delta intakes do not.
2. Better raw water quality allows treatment plants to more cost effectively, reliably, and consistently meet water quality regulations.
3. Water quality at each Delta intake is different and therefore has unique water quality challenges related to treatment.
4. Changes in the quality of Delta water prompt WTPs to switch to or blend Delta water with other water and effectively reduce the reliability of the Delta as a drinking water supply.

Data Collection and Analysis:

1. Compare the raw water TOC and bromide concentrations at upper watershed and Delta intakes to ROD targets. Conduct comparisons of data for both the frequency of concern for WTPs (daily) and the WQP targets set in the ROD (running annual average).
2. Compare the average cost per gallon (or other similar operating cost measurement) to treat water at WTPs with upper watershed sources to the costs per gallon at WTPs with Delta sources.

3. Compare water quality data at each Delta intake: annual running averages and daily/monthly averages of TOC, dissolved organic carbon (DOC), TDS or electrical conductivity (EC), bromide, total nitrogen, total phosphorus, turbidity and alkalinity.

2.3.2 Conveyance and Storage

Water in California is often transported great distances and stored in reservoirs or lakes prior to reaching a treatment plant. The study evaluates the role of conveyance and storage for a number of drinking water quality constituents, by creating models that identify key infrastructure and representative data collection points. One way the study evaluates this role is to compare WTP intake water quality between plants receiving Delta water directly and those with intermediate reservoir storage. This study built upon the results and information from the *California SWP Watershed Sanitary Survey 2006 Update* to examine the change in raw water quality within conveyance and storage infrastructure and the primary factors influencing such change.

Conveyance and Storage Hypotheses:

1. Long residence time within conveyance and storage facilities results in changes to water quality constituents, such as TOC/DOC, bromide, nutrients, algae, turbidity and pathogens. For more conservative constituents (e.g., bromide and TDS or EC), longer storage residence times attenuate the variability seen at Delta intakes. For highly reactive constituents (e.g., nutrients and algae), longer residence times in storage change the water quality characteristics.
2. All plants receiving Delta water have T&O issues associated with Delta water, but the nature and extent of their T&O problems are dependent on intake location and their conveyance and storage infrastructure.
3. Treatment plants receiving water directly from the Delta (e.g., via the SBA) have costs and operational challenges beyond those of plants that receive Delta water after longer residence times in storage and conveyance.

Data Collection and Analysis:

1. Compare monthly and daily TOC/DOC, bromide, nutrients, algae, turbidity, and pathogen concentration ranges at WTP intakes versus Delta intake locations to determine the magnitude and timescale of changes in variability. Examine nutrient and algae data availability and speciation and collect information from treatment plants on the frequency and timing (season, month) of algae growth episodes requiring treatment. Identify what prompts changes in source water operations and/or treatment (e.g., increases in constituent concentration, operational triggers, and/or customer complaint levels).
2. Compare chlorophyll-a and/or algae cell counts at WTP intakes and Delta intakes. Compare systems with minimal or small storage reservoirs to systems with larger storage reservoirs along the California Aqueduct to evaluate the influence of reservoir storage on algae growth. Evaluate customer complaint information to identify the degree to which algae growth in conveyance facilities affects finished water quality.
3. Compare the intake water quality at Delta WTPs without intermediate storage to the intake quality at plants receiving Delta water with intermediate storage and where the water has long residence times in conveyance structures (e.g., SBA versus California Aqueduct plants). Identify water quality variability. Compare yearly costs per gallon for operation.

2.3.3 Treatment

A goal of this study is to begin to quantify how Delta water quality influences the ability of treatment plants to meet current and future regulations and local objectives. The WQP recognizes that treated water quality is driven by a number of factors, such as supply, economics, and customer expectations, many of which are far beyond the scope of the WQP or its state and federal implementing agencies. However, the WQP is seeking to understand its role in treated water quality, build a strategy towards better water quality, prioritize actions, and develop quantitative performance measures to fulfill the state's role in improving source (specifically Delta) water quality. In another study, CALFED is evaluating the results and transferability of CALFED-funded alternative treatment technology studies.

The hypotheses regarding treatment address both disinfection and filtration, as follows:

- Because the use of ozone as opposed to chlorine changes the source water concern from TOC to bromide and the formation of DBPs from TTHMs and HAAs to bromate, the disinfection hypotheses below are intended to evaluate the effectiveness of ozone and potential benefits or degradation to finished water quality.
- The filtration hypotheses are intended to evaluate the benefits of conventional and membrane filtration for organic carbon removal, overall reduction in DBP formation, and pathogen removal.

Treatment Hypotheses:

1. Higher raw water TOC concentrations lead to increased DBP formation.
2. Plants employing alternative disinfectant technologies:
    i. Have lower DBP concentrations and/or meet maximum contaminant levels (MCLs) more reliably;
    ii. Achieve higher log removals; and
    iii. Are better prepared to meet future regulations (e.g., lower DBP MCLs).
3. Current conventional filtration processes in use in California provide sufficient filtration/removal of organic carbon in Delta water.
4. Compared with conventional filtration, membrane filtration achieves as good or better finished water quality (pathogens, TOC, and turbidity).

Data Collection and Analysis:

1. Collect daily TOC, DOC, and bromide data at WTP intakes and daily TTHM, daily HAA, and all available bromate data from finished water for the years 2004 through 2006. Compare intake WTP water quality to other key system locations, and examine how Delta water quality influences treated water quality.
2. From WTP representatives, obtain details on their disinfection processes, their drivers of disinfection use, and their log removal credits achieved. Analyze the data collected in (1) and compare results based on different disinfection schemes to assess hypotheses (2.i) – (2.iii).
3. Collect daily TOC, DOC, turbidity, and pathogens/indicator microorganism data for WTP intakes, after pre-treatment, and from finished water. Compare organic carbon and turbidity removals for conventional and membrane filtration.

3. WATER QUALITY

The primary constituents presented in this water quality discussion are TOC, bromide, and turbidity; these water quality constituents are consistently monitored both in the Delta and at WTPs, and they provide some of the most complete data sets available. This section describes data sources and monitoring locations (Section 3.1) and discusses the characteristics of the data (Section 3.2). Section 3.3 presents an evaluation of the ROD targets for TOC and bromide. For each of the regions covered by this study, Section 3.4 presents TOC, turbidity, and bromide data. This data is useful in comparing the water quality at the Delta intakes to that of the Upper Watershed intakes. This section also examines changes in water quality through conveyance and storage. Section 3.4 discusses algae growth and presents T&O complaint data, and Section 3.5 includes a discussion of chemical addition and the cost to treat water due to differences in water quality. Finally, Section 3.6 covers DBP formation and presents DBP concentration data for the study WTPs.

3.1 Data Sources and Locations

For this study, the study team collected source water, conveyance, and storage data from a subset of locations monitored by DWR, the United States Geological Survey, and CCWD. The monitoring locations were chosen to represent water quality through the raw water system, from the Delta intakes through the canals and reservoirs to the WTP intakes. Representatives of the WTPs participating in the study provided data for their intakes.[1] For the Delta intakes, locations in the SWP, and the Sacramento River at Hood the study team downloaded data from DWR's Water Data Library and California Data Exchange Center. These data are provisional and may not have been checked for their quality by their source organizations.

The study team requested water quality monitoring results for the period from 2004 through 2006 for TOC/DOC, bromide, turbidity, nutrients, algae cell counts or chlorophyll-a, pathogens and pathogen indicators, and finished water DBPs. The period from 2004 through 2006 was selected because it was anticipated that the majority of WTP process modifications to meet DBP regulations and the Long Term Enhanced Coagulation Rule would have been completed by 2004. In addition, the period was limited to focus on the changes through the system as opposed to understanding water quality at the Delta intakes and the WTP intakes for an extended period of time. The study team also requested compiled counts of T&O complaints, treatment chemical usage rates and associated costs for water treatment. Appendix B contains *Approach to the Detailed Study of Delta Drinking Water Quality,* which includes the detailed information request.

Figure 3-1 shows prominent features and monitoring locations within the Delta drinking water system. The schematic displays water movement from upstream (top of page) to downstream (bottom of page). The figure shows all SWP reservoirs, as well as canal checks where monitoring is conducted, but excludes Coastal Branch locations, which are not included in this study. The following sections describe data collection locations by region.

---

[1] Nine of the ten study WTPs provided data; the City of Coalinga was unable to provide data within the timeframe of the study. Zone 7 Patterson Pass WTP data is included in the database but due to time constraints it could not be included in the analysis presented here.

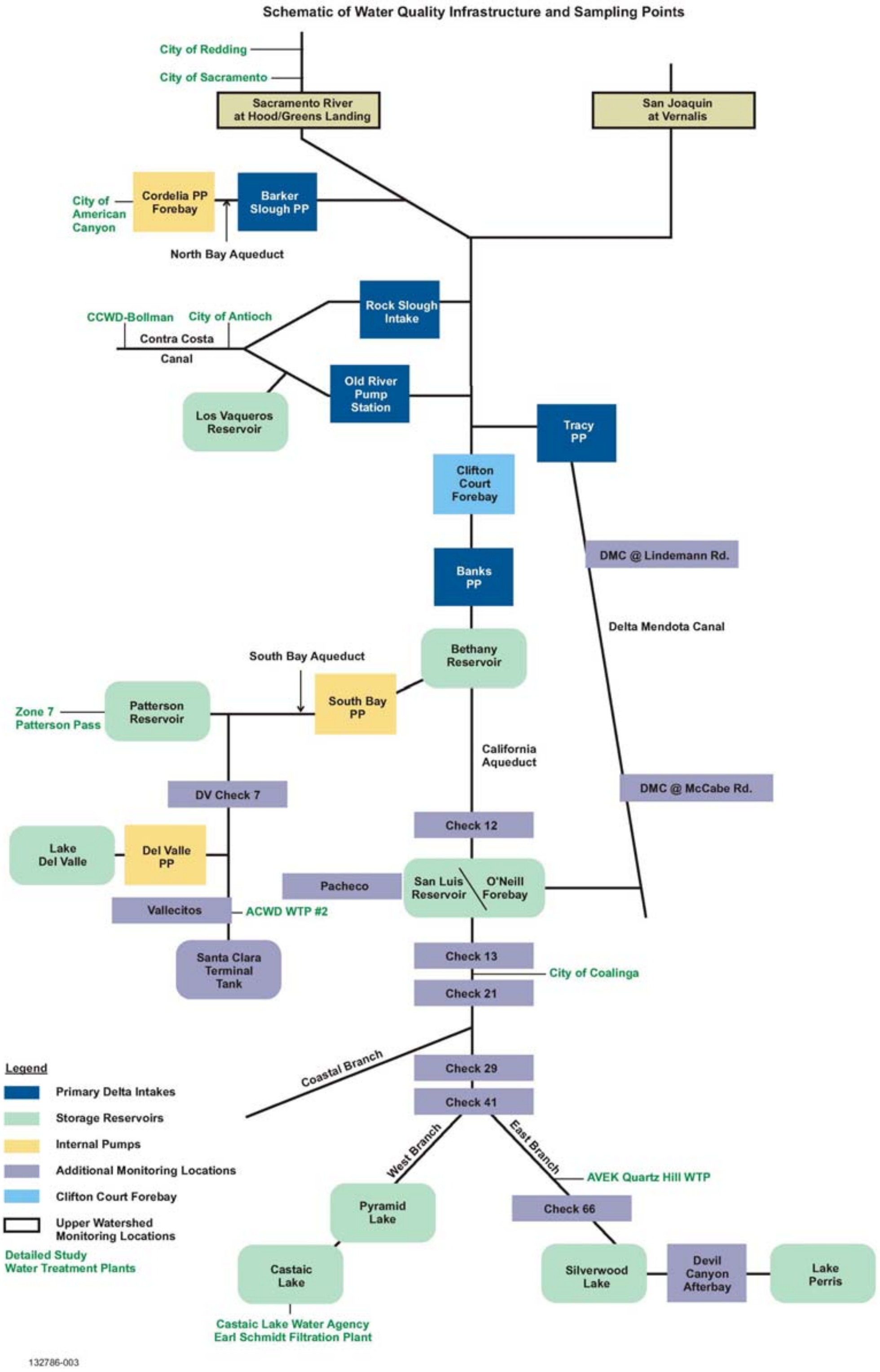


Figure 3-1. Schematic of Water Quality Infrastructure and Monitoring Locations

3.1.1 Upper Watershed Data Sources and Locations

For the Upper Watershed region, the Cities of Redding and Sacramento provided data from their intakes on the Sacramento River for the Foothill WTP and the Sacramento WTP, respectively. Because bromide concentrations are low in the raw water for these WTPs, it is not a treatment concern, and these cities do not monitor bromide regularly. To represent bromide concentrations in raw water for the Upper Watershed region, the study team collected DWR monitoring data for bromide concentrations in the Sacramento River at Hood. Hood is south of Sacramento and north of Barker Slough (Figure 3-1). Data from the San Joaquin River is not presented in this report because WTPs from the San Joaquin River watershed were not included in this study.

3.1.2 North Bay Aqueduct Data Sources and Locations

The study team collected data from the Barker Slough Pumping Plant and the City of American Canyon WTP to represent the North Bay Aqueduct region. The study team was unable to collect data for turbidity, speciated DBPs, and pathogens for the City of American Canyon WTP within the time frame of this project. The City of American Canyon WTP operators do not typically sample for nutrients, algae, or 2-methylisoborneol (MIB) and geosmin. They also do not have any reported T&O complaints associated with algae.

3.1.3 Central/South Delta Data Sources and Locations

CCWD and the City of Antioch provided data for the Central/South Delta intakes, storage, and conveyance. CCWD provided TOC, bromide, and turbidity data for the Contra Costa Canal system, including its Rock Slough and Old River intakes and Los Vaqueros Reservoir. They provided finished water quality data from the CCWD Bollman WTP. Raw turbidity and bromide were not provided for the CCWD-Bollman WTP. The CCWD Bollman WTP TOC data presented in this section are not separated by source, (i.e., Mallard Reservoir vs. Contra Costa Canal); however, Contra Costa Canal sources are presented separately. The City of Antioch supplied data from its WTP, which treats water from Contra Costa Canal upstream from Mallard Slough, from the San Joaquin River, or from Antioch Municipal Reservoir. The City of Antioch WTP intake data are not separated according to the source Antioch was utilizing.

3.1.4 South Bay Aqueduct Data Sources and Locations

For the SBA, ACWD provided data for its WTP#2 and data was obtained by the study team from DWR Water Data Library for Banks Pumping Plant, Del Valle Check 7 (DV Check 7), and Santa Clara Terminal Tank (see Figure 3-1). During wet years, the majority of water in Lake Del Valle comes from local runoff. Zone 7 Patterson Pass WTP data is included in the database for future analysis but the study team did not receive the data in time to include it in the water quality analysis.

3.1.5 California Aqueduct Data Sources and Locations

The study team obtained data for Banks Pumping Plant, Check 13, Check 41, and Castaic Lake Outlet Tower from the DWR data library. AVEK provided data from its Quartz Hill WTP to represent the East Branch of the aqueduct. CLWA provided data from its Earl Schmidt Filtration Plant to represent the West Branch of the aqueduct. Figures contained in this section for the California Aqueduct present the WTP intake and Check 13 data to demonstrate the water quality difference between the East and West Branch of the Aqueduct. Appendix Figures C-15 through C-17 presents data for TOC, bromide, and turbidity at the other locations.

3.2 Data Characteristics

The study team found gaps in the data, and noted the factors that could affect the quality of the data. This subsection describes these data gaps and frequency, data collection methods, and data analysis and presentation.

3.2.1 Data Gaps and Frequency

Monitoring conducted for - and in addition to - regulatory requirements is different at each WTP. Several gaps exist in the data presented here.

- In the Upper Watershed, the City of Redding has high source water quality and does not monitor TOC as often as other WTPs because its raw water TOC is consistently low.
- Neither the City of Redding nor the City of Sacramento monitors bromide because it is not a treatment concern; their raw waters have consistently low bromide concentrations.
- Most of the WTPs, regardless of region, do not monitor for nutrients, MIB, or geosmin. MIB and geosmin are algal by-products that indicate T&O concerns in water. CCWD does monitor for MIB and geosmin in raw water at locations in the Contra Costa Canal system weekly from April through October. DWR monitors MIB and geosmin at Clifton Court, Banks Pumping Plant, and locations in the SBA and California Aqueducts and reports results to the SWP Contractors weekly (SWP Contractors Authority 2007).

3.2.2 Data Collection Methods

The water quality data collected for the WTPs may use different analytical methods that would produce differing results if applied to the same samples. TOC values obtained with the combustion method, for example, are typically higher than TOC values obtained with the oxidation method. DWR uses both of these methods to analyze samples from locations in the SWP. Information regarding the analytical methods employed by the WTPs, which may differ from plant to plant, is not available at this time.

Taste and odor complaints are compiled and categorized differently by each WTP as well. The study team attempted to limit the reported T&O complaints in Table 3-1 to those associated with algae in the raw water supply.

3.2.3 Data Analysis/Presentation

The data presentation within this section and the companion appendix includes time series scatter plots and box plots. Data is presented as a continuous line when the frequency of the data collection was daily and as symbols connected by lines when the frequency of data collection was less than daily. Each individual symbol represents a discrete value in the time series graphs and indicates the frequency of data collection at that location.

Box and whisker plots (box plots) were produced using the Grapher 6.0 Software Package. The extents of the box represent the upper 75th percentile and lower 25th percentile values (i.e., the range of the middle 50 percent of data points) and the lines extending from the box present the highest and lowest values in the data set. The horizontal line within each box represents the median value.

3.3 Delta Intake TOC and Bromide Running Annual Average

The ROD targets for the Delta intakes are an average of 3 mg/L TOC and 50 μg/L bromide. This has been interpreted to mean a running annual average, which is a typical regulatory calculation and a typical statistical average when looking at a source water. While intake turbidity values are important to the drinking water treatment agencies, the WQP has not set a target value for turbidity. A running annual average is the average value of data collected over the one year period prior to the date for which the average is presented. For example, the running annual average for the date 01/01/2004 would be the average of the data values for the period from 01/01/2003 through 01/01/2004.

- **TOC.** The running annual average TOC at all of the Delta intakes exceeds the ROD targets with the highest running annual average at Barker Slough intake, which at times has exceeded 8 mg/L (Figure 3-2).
- **Bromide.** The only intake that meets the ROD target for bromide is Barker Slough, which has running annual average bromide concentrations peaking at about 50 µg/L (Figure 3-3).

While running annual averages provide a summary, and a means to quickly compare the average concentration from one intake to another, they do not reflect the variability in the bromide and TOC that the WTPs receive at their intakes. For the water agencies, using the Barker Slough intake as an example, TOC concentrations can vary from about 4 to 22 mg/L (Figure 3-4). This fluctuation causes the operators to adjust to the increasing TOC concentrations; they operate to their incoming concentration rather than an annual average TOC concentration. A great deal of variation is seen in the TOC concentrations at the other intakes and is presented in Appendix C (C-1 – 3). As with TOC, bromide concentrations vary greatly at Rock Slough intake, Old River intake, and Banks Pumping Plant (Figure 3-5, Appendix C-4-6). The variable TOC and bromide concentrations make it difficult to optimize treatment to minimize DBP formation; depending on the WTP, this variability can be more challenging than the high concentrations.

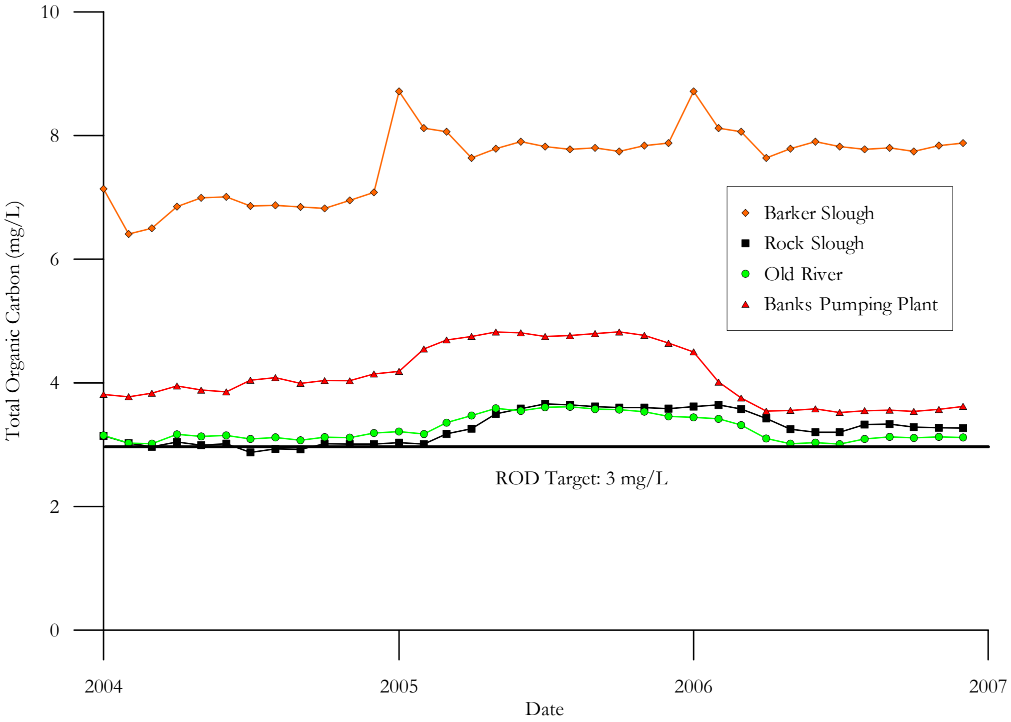


Figure 3-2. TOC Running Annual Average at Barker Slough Intake, Banks Pumping Plant, Old River Intake and Rock Slough Intake 2004 - 2006

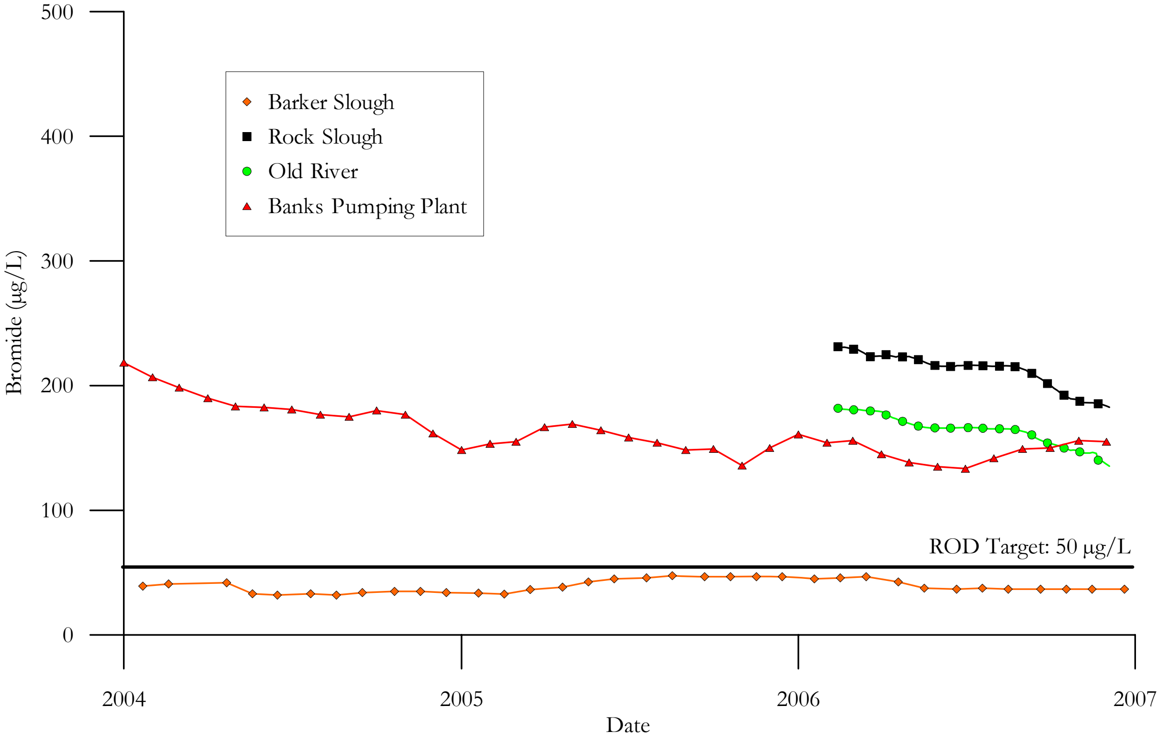


Figure 3-3. Bromide Running Annual Average at Barker Slough Intake, Banks Pumping Plant, Old River Intake and Rock Slough 2004 - 2006

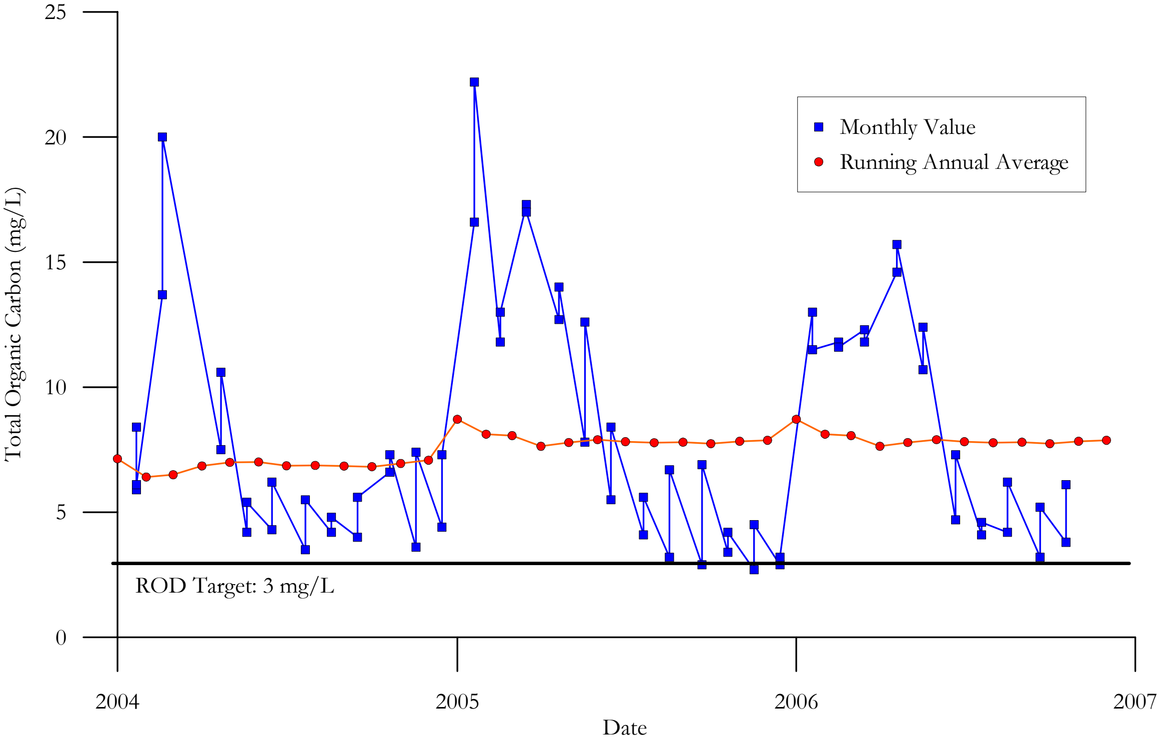


Figure 3-4. TOC Running Annual Average and Discrete Concentrations for Barker Slough Pumping Plant 2004 - 2006

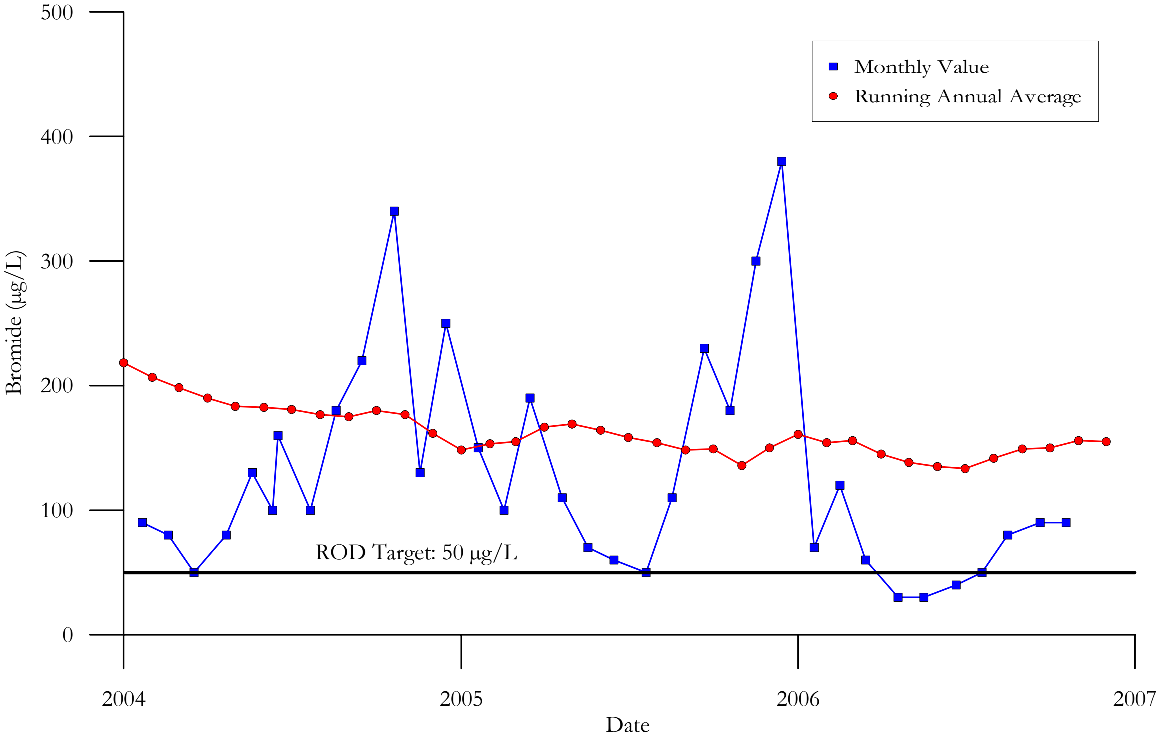


Figure 3-5. Bromide Running Annual Average and Discrete Concentrations at Banks Pumping Plant Intake 2004 - 2006

3.4 TOC, Turbidity, and Bromide Data and Comparisons

For each of the regions covered by this study, Sections 3.4.1 through 3.4.6 present and compare TOC, turbidity, and bromide data, where available.

3.4.1 Upper Watershed TOC, Turbidity, and Bromide

The City of Redding Foothill WTP and City of Sacramento, Sacramento River WTP both take raw water through enclosed pipelines directly from the Sacramento River. The Foothill WTP intake is 9 miles downstream from Shasta Dam and one mile downstream from Keswick Dam. Only one significant tributary, Spring Creek, joins the Sacramento River between Keswick Dam and the Foothill WTP intake.

- **TOC and Turbidity.** Lake Shasta attenuates most water quality constituents, causing the Foothill WTP raw water to have low TOC concentrations and low turbidity levels, with minimal variability for these constituents (Figure 3-6 and 3-7 and Appendix C-7). The Sacramento River WTP intake, which is downstream from the Sacramento River's confluence with the American River, has higher and more variable concentrations of TOC and turbidity than the Foothill WTP (Figure 3-6 and 3-7 and Appendix C-7).
- **Bromide.** Bromide concentrations along the Sacramento River are typically very low, sometimes below the detection limit.

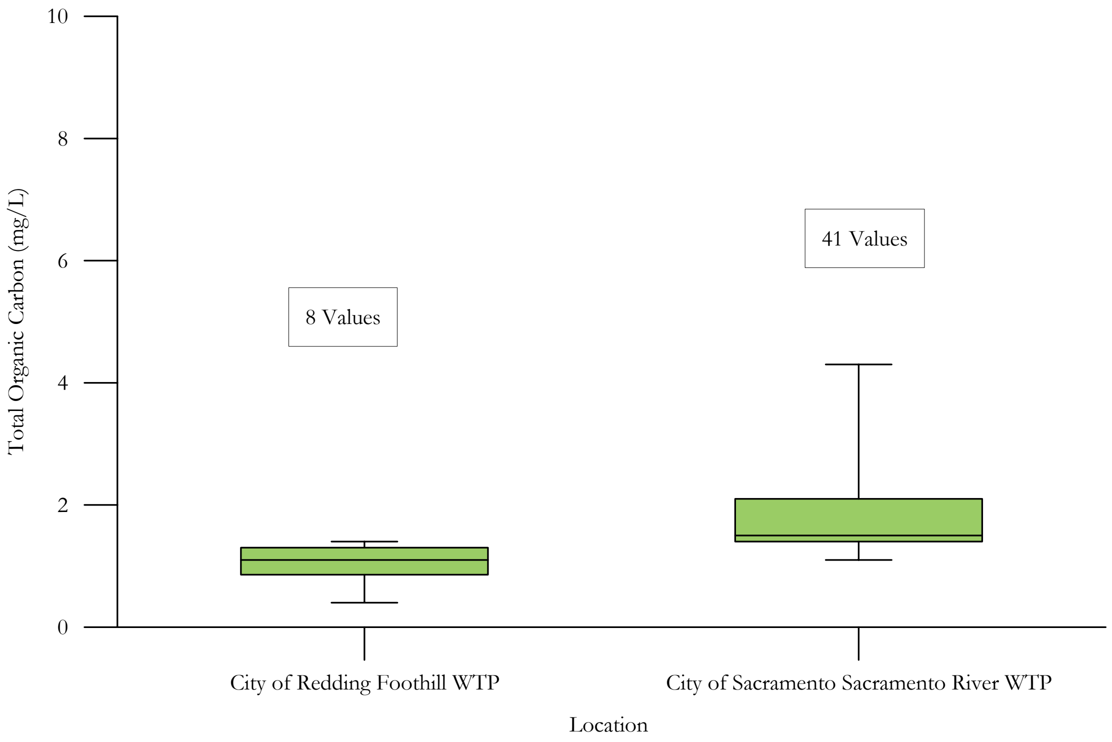


Figure 3-6. Intake TOC Concentration Ranges and Medians at City of Sacramento, Sacramento River WTP and City of Redding Foothill WTP 2004 - 2006

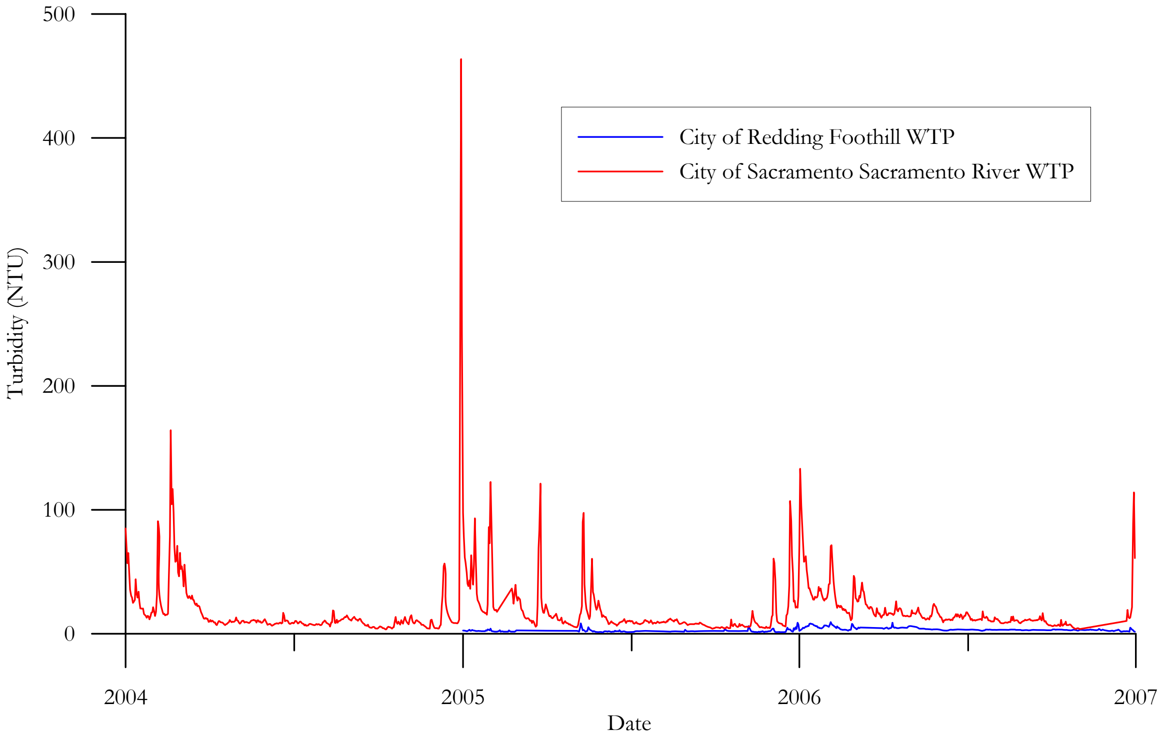


Figure 3-7. Intake Turbidity Daily Values at the City of Sacramento, Sacramento River WTP and City of Redding Foothill WTP 2004 - 2006

3.4.2 North Bay Aqueduct TOC, Turbidity, and Bromide

The Barker Slough watershed, which surrounds the intake for the NBA, significantly degrades the water quality from the Sacramento River. Figures 3-8 and 3-9 present data from the Sacramento River at Hood along with NBA data (Barker Slough and City of American Canyon) to highlight the difference between water quality in the Barker Slough watershed and other locations.

- **TOC and Turbidity.** Because of degradation in the Barker Slough watershed, the NBA intake has high episodic TOC and turbidity (Figure 3-8 and 3-9). As Figure 3-2 demonstrated, the Barker Slough intake has the highest TOC concentration of the regions evaluated in this study.
- **Bromide.** The Barker Slough watershed contributes bromide to the water; however, bromide concentrations vary from 20 – 100 µg/L and typically remain less than 50 µg/L but (Figure 3-10 and Appendix C-8).

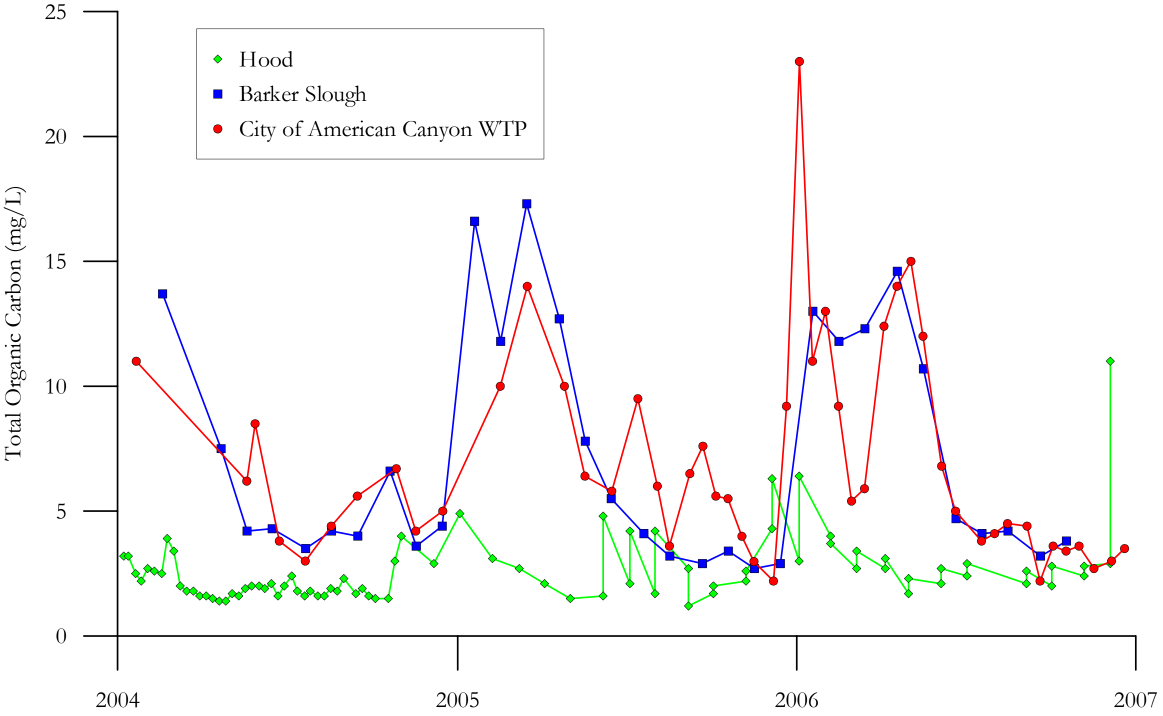


Figure 3-8. TOC Concentrations at Sacramento River at Hood, Barker Slough Pumping Plant, and American Canyon WTP 2004 - 2006

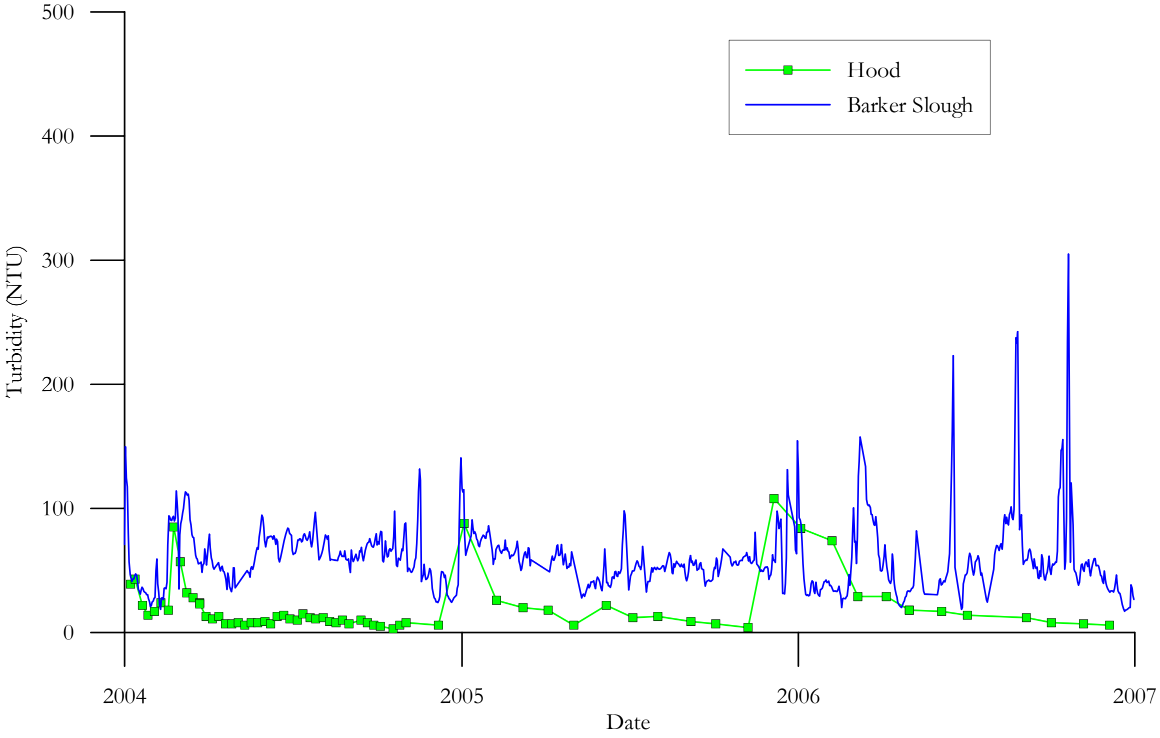


Figure 3-9. Turbidity Levels at Sacramento River (at Hood) and Barker Slough Pumping Plant 2004 – 2006

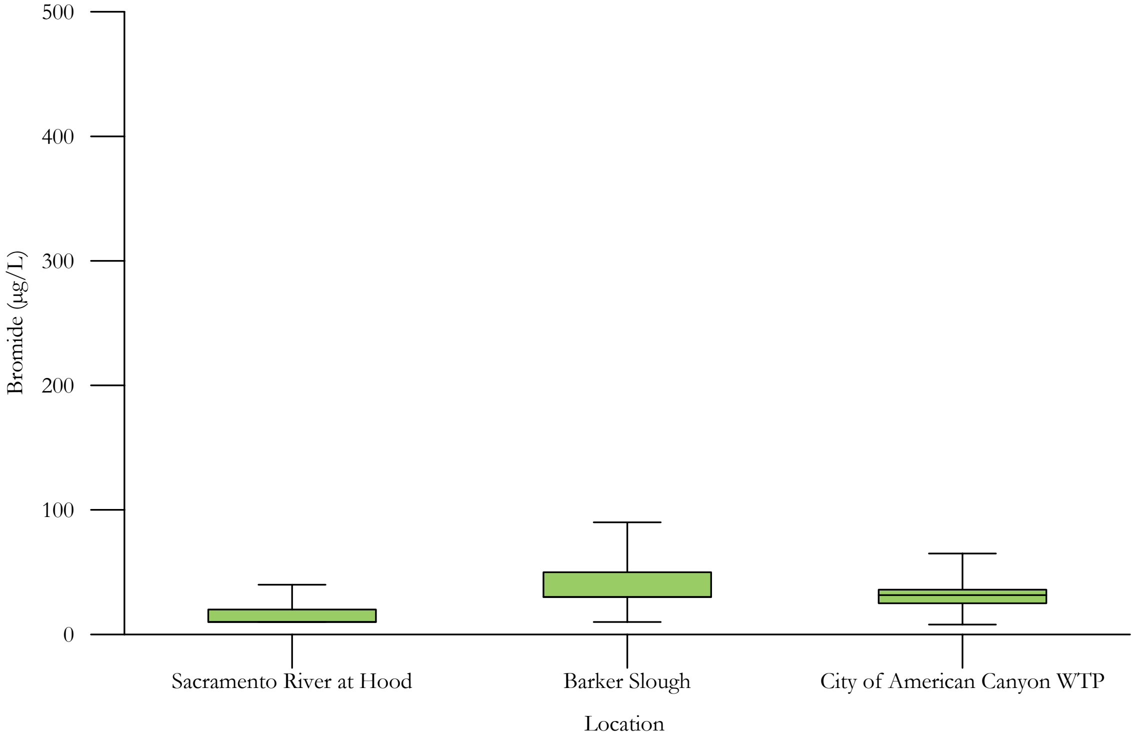


Figure 3-10. Bromide Concentration Ranges and Medians at Sacramento River (at Hood), Barker Slough Pumping Plant, and City of American Canyon WTP 2004 - 2006

3.4.3 Central/South Delta TOC, Turbidity, and Bromide

The Central/South Delta region includes the Contra Costa Canal, operated by CCWD, and CCWD Bollman and City of Antioch WTPs. The Contra Costa Canal takes water from intakes at Rock Slough, Old River, and in the western Delta at Mallard Slough. CCWD stores Old River intake water in Los Vaqueros Reservoir and stores Contra Costa Canal water in Contra Loma and Mallard Reservoirs. The City of Antioch operates Antioch Municipal Reservoir, which is fed from Contra Costa Canal and from its San Joaquin River intake. The City of Antioch takes water from the Contra Costa Canal upstream of the Mallard Slough intake. The data presented for the City of Antioch WTP intake is not separated by source.

- **TOC.** TOC concentrations in the Contra Costa Canal intakes, Los Vaqueros Reservoir, and WTP intakes average about 3 mg/L (Figure 3-11 and Appendix C-9). Values at Los Vaqueros Reservoir reflect attenuation of variability in the reservoir but do not show the reservoir acting as a sink or source of TOC, as the median concentration in Los Vaqueros Reservoir is similar to that of the Old River intake from which it is filled. Concentrations at the City of Antioch WTP are slightly higher and more variable than those at Bollman WTP. This may be a result of attenuation in Mallard Reservoir at Bollman or because Antioch utilizes different water sources.
- **Bromide.** Bromide in Contra Costa Canal at Rock Slough is typically greater at MP 0.0 than at MP 3.97 (Figure 3-12, Appendix C-10) and greater range of values is present at MP 3.97 than at MP 0.0. This is likely due to increased sampling at MP 3.97. The median concentration of bromide at the Old River intake is less than that at Rock Slough; however, higher concentrations have been detected at Old River. Concentrations in Los Vaqueros Reservoir vary from non-detectable levels to 200 μg/L, with an average 100 μg/L, while intake concentrations can be as high as 800 μg/L. Operators keep the bromide and chloride concentrations in Los Vaqueros Reservoir low by filling the reservoir only when chloride at Old River is 50 mg/L or less. The City of Antioch does not monitor bromide at its WTP intake. Bromide data was also not provided for Bollman WTP.
- **Turbidity.** Figure 3-13 and Appendix C-11 show turbidity data for the Central/South Delta. Monthly values were provided for Rock Slough and Old River intakes and Los Vaqueros Reservoir, and daily values were provided for City of Antioch WTP intake. The more frequent data from the City of Antioch reflects greater variability than the Delta intake and Los Vaqueros Reservoir data do; however, the median concentrations are similar. The City of Antioch also experiences spikes in turbidity when its source is switched to the Contra Costa Canal.

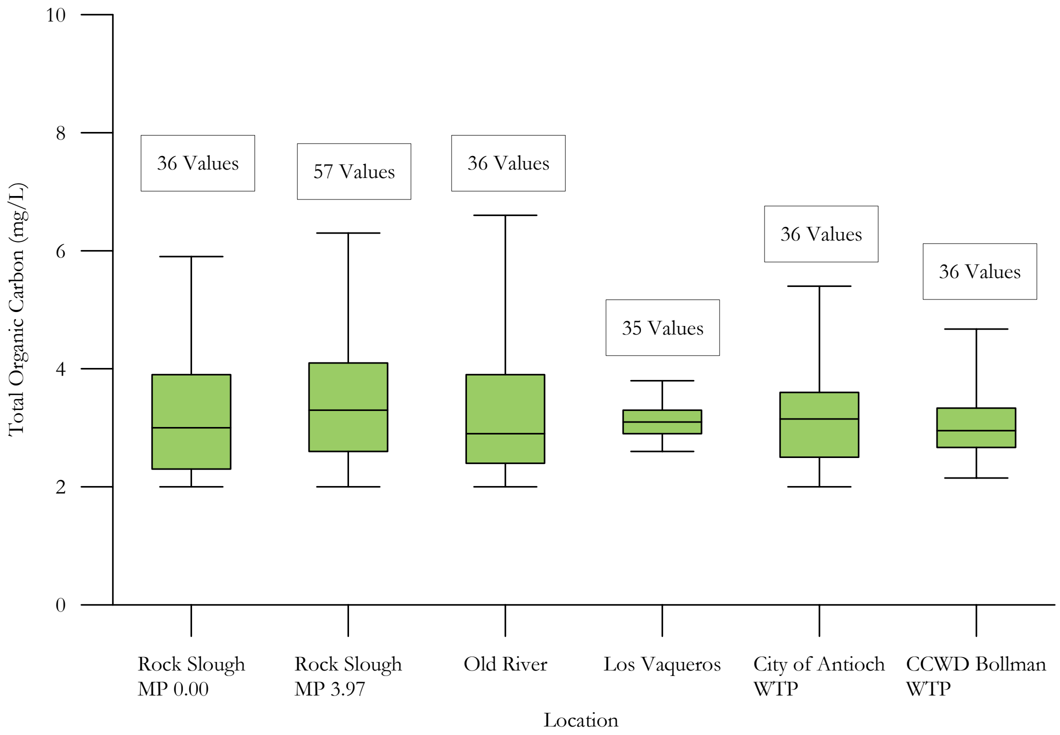


Figure 3-11. Central/South Delta TOC Concentration Ranges and Medians 2004 – 2006

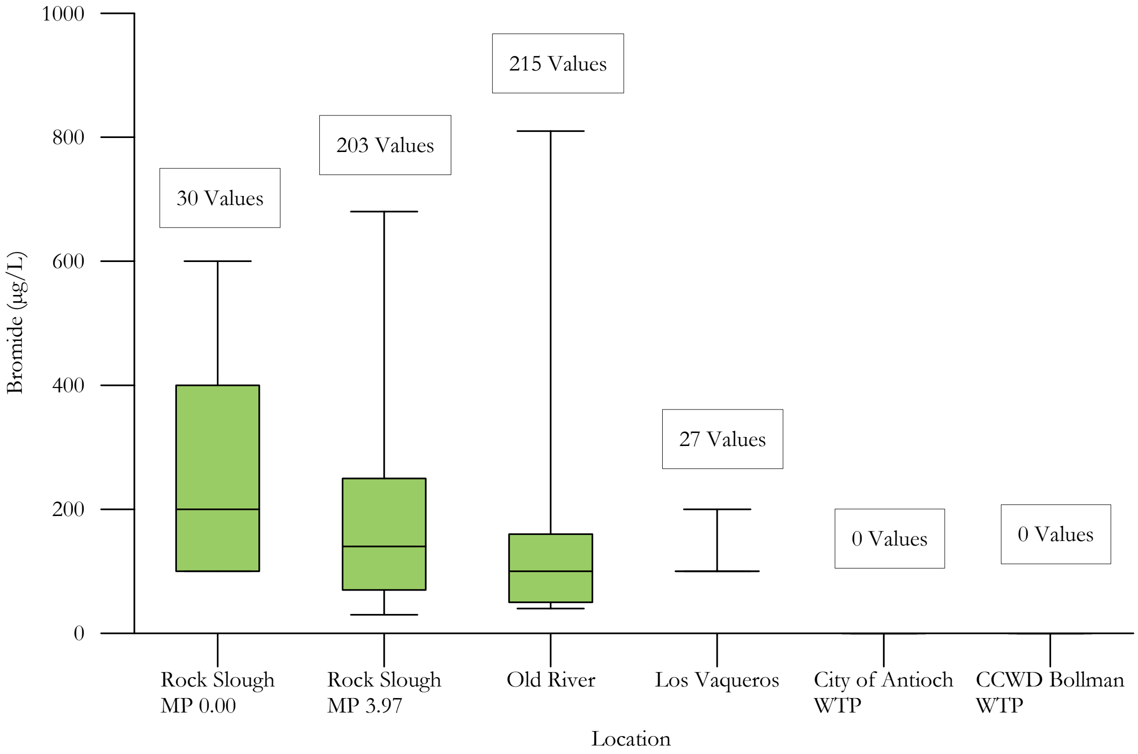


Figure 3-12. Central/South Delta Bromide Ranges and Medians 2004 - 2006

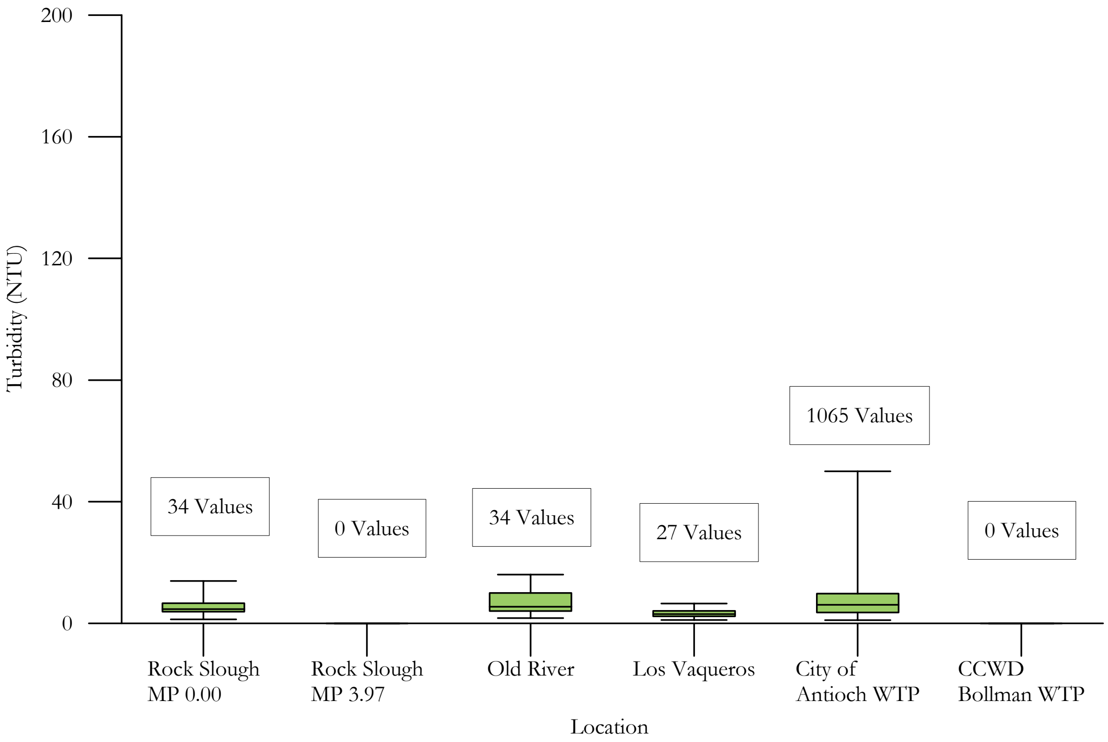


Figure 3-13. Central/South Delta Turbidity Ranges and Medians 2004 - 2006

3.4.4 South Bay Aqueduct TOC, Turbidity, and Bromide

Water in the SBA comes from the Delta via Banks Pumping Plant, through Bethany Reservoir, and through the South Bay Pumping Plant. Water from Lake Del Valle may be blended into the SBA. As noted above, Lake Del Valle holds mostly local runoff, but it is also supplied by the SBA, particularly in dry years. Both the Zone 7 Patterson Pass WTP and the ACWD WTP # 2 intakes receive Lake Del Valle water through the SBA.

- **TOC.** The median concentration at ACWD WTP #2, downstream of DV Check 7, is similar to the median concentration at Banks and at DV Check 7 (Figure 3-14 and Appendix C-12). The TOC median, 25th, and the 75th percentile are slightly less at the Zone 7 Patterson Pass WTP. Zone 7 Patterson Pass WTP receives water from the top of the SBA through an overflow weir into the Patterson Pass Reservoir. As a result, agency staff feel that they receive a higher water quality at their Patterson Pass WTP than their other WTP also on the SBA that does not receive water through an overflow weir on the SBA. The Patterson WTP staff has noticed that they also receive some attenuation of TOC and turbidity concentrations in the reservoir (discussed further in Section 4.0). ACWD WTP #2 does not have intermediate storage between the aqueduct and the plant and therefore does not see attenuation of Delta water quality. This is in agreement with the *California SWP Watershed Sanitary Survey 2006 Update,* which showed that monthly mean TOC concentrations at Banks, DV Check 7, and the ACWD intake are similar and follow the same seasonal trend, with the highest concentrations occurring in the wet months and the lowest concentrations occurring in the summer (SWP Contractors Authority 2007).
- **Bromide.** Bromide also appears to be consistent in the SBA between Banks, DV Check 7, ACWD WTP #2 and Santa Clara Terminal Tank (Figure 3-15 and Appendix C-13). Bromide at ACWD WTP # 2 intake is monitored more frequently than at the other SBA locations. Zone 7 Patterson Pass WTP does not measure bromide regularly since they do not practice ozone disinfection. The

consistent concentrations through the aqueduct are in agreement with the findings of the *California SWP Watershed Sanitary Survey 2006 Update.*

- **Turbidity.** Turbidity levels are consistent through the SBA locations, besides Zone 7 Patterson Pass WTP, with median values between 6 and 12 NTU (Figure 3-16). A greater range of turbidity levels have been detected at Banks Pumping Plant and ACWD WTP # 2 intake; however, these trends are based on more frequent analysis, daily, at Banks Pumping Plant and ACWD WTP #2, and monthly at DV Check 7 and Santa Clara Terminal Tank. The overall range, median, 25th, and 75th percentile turbidity values are all lower for the Zone 7 Patterson Pass WTP. This reduction in turbidity concentration and variability may be the way in which Zone 7 collects water in the Patterson Pass reservoir and/or attenuation within the Reservoir. Peaks in turbidity at Banks do not appear to correspond with peaks at the ACWD WTP # 2 intake, suggesting some attenuation through Bethany Reservoir and conveyance (Appendix C-14). Peaks in turbidity in the SBA can evolve quickly, presenting a challenge to treatment (SWP Contractors Authority 2007).

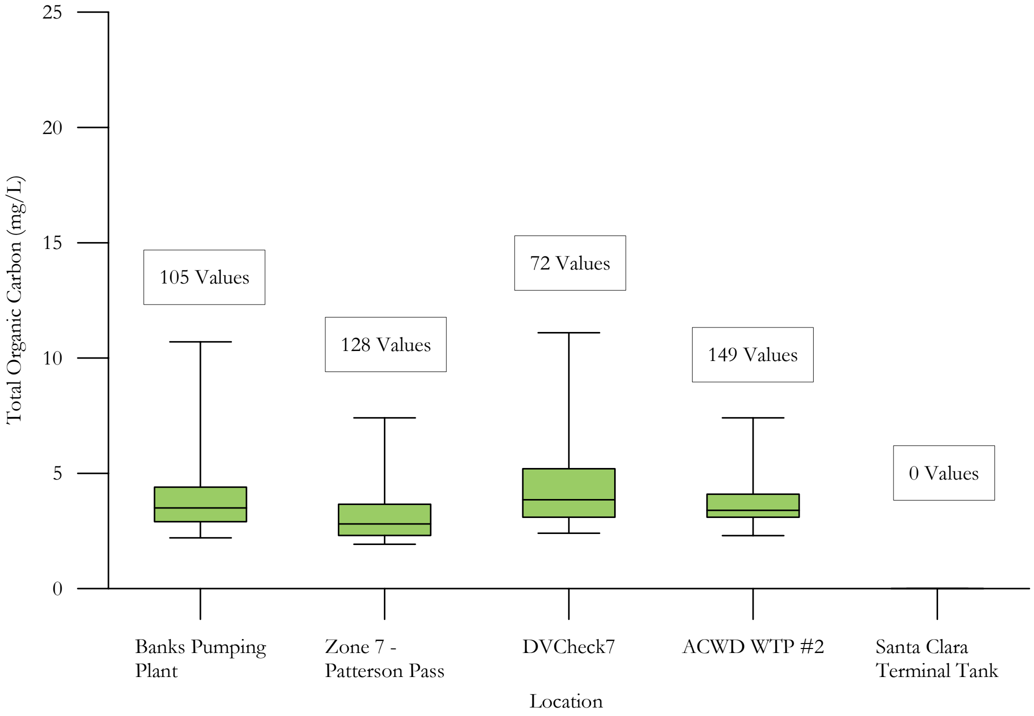


Figure 3-14. TOC Ranges and Medians in the South Bay Aqueduct 2004 – 2006

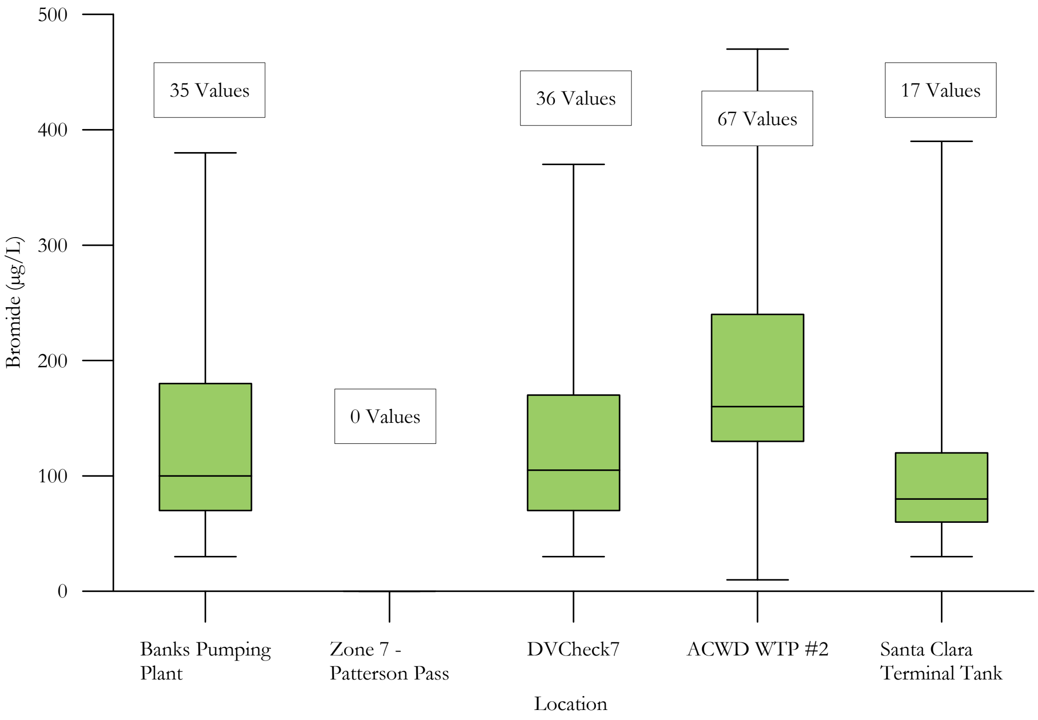


Figure 3-15. Bromide Ranges and Medians in the South Bay Aqueduct 2004 – 2006

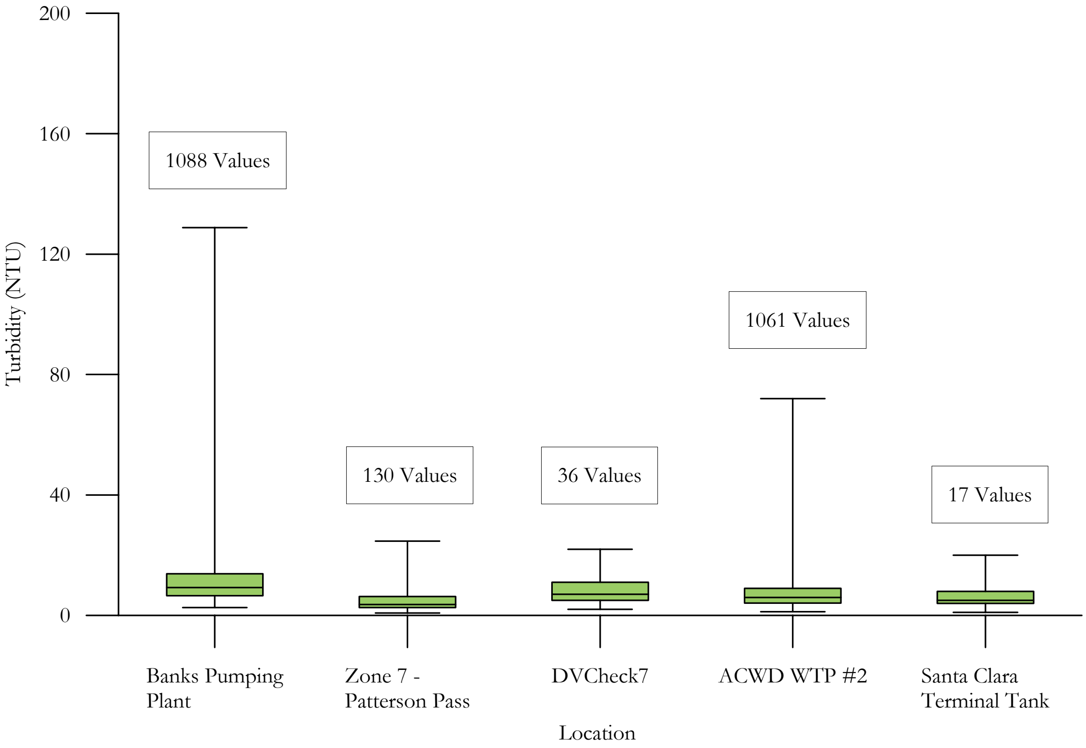


Figure 3-16. Turbidity Ranges and Medians in the South Bay Aqueduct 2004 - 2006

3.4.5 California Aqueduct TOC, Turbidity, and Bromide

Box plots presenting TOC, turbidity, and bromide along the California Aqueduct include data from; Banks Pumping Plant, Check 13, Check 41 Castaic Lake on the West Branch, CLWA Earl Schmidt Filtration Plant, and AVEK Quartz Hill WTP.

Median concentrations of TOC, bromide, and turbidity during the period from 2004 through 2006 do not change through the aqueduct (Appendix C-15 – C-17); however, attenuation of variability is seen in Castaic Lake. The *California SWP Watershed Sanitary Survey 2006 Update,* which contains data from 2001 through 2005, found that turbidity increases and becomes more variable along the aqueduct south of San Luis Reservoir, and that that there is a "substantial increase" in bromide between Banks and San Luis Reservoir (State Contractors Authority 2007).

- **TOC.** TOC is lower and less variable at CLWA than at Check 13 (Figure 3-17). TOC at AVEK Quartz Hill WTP is more variable than that at CLWA, Earl Schmidt Filtration Plant reflecting the attenuation in Castaic Lake.
- **Bromide.** Bromide is similar along the California Aqueduct between Check 13 and Check 41, but variation is again attenuated in Castaic Lake at the CLWA Earl Schmidt Filtration Plant intake (Figure 3-18) Bromide concentrations are less variable at the CLWA Earl Schmidt Filtration Plant intake than at Check 13 (Figure 3-18). Data was not available for the AVEK Quartz Hill WTP.
- **Turbidity.** Turbidity is typically less variable in Castaic Lake than upstream or on the East Branch at AVEK Quartz Hill WTP (Figure 3-19). The turbidity spike at the CLWA Earl Schmidt Filtration Plant that occurred in 2005 was due to record rainfall that mobilized a great deal of sediment and detritus (Figure 3-19). Other spikes in turbidity at CLWA's intake can occur, particularly when the lake level is low (qualitative discussion).

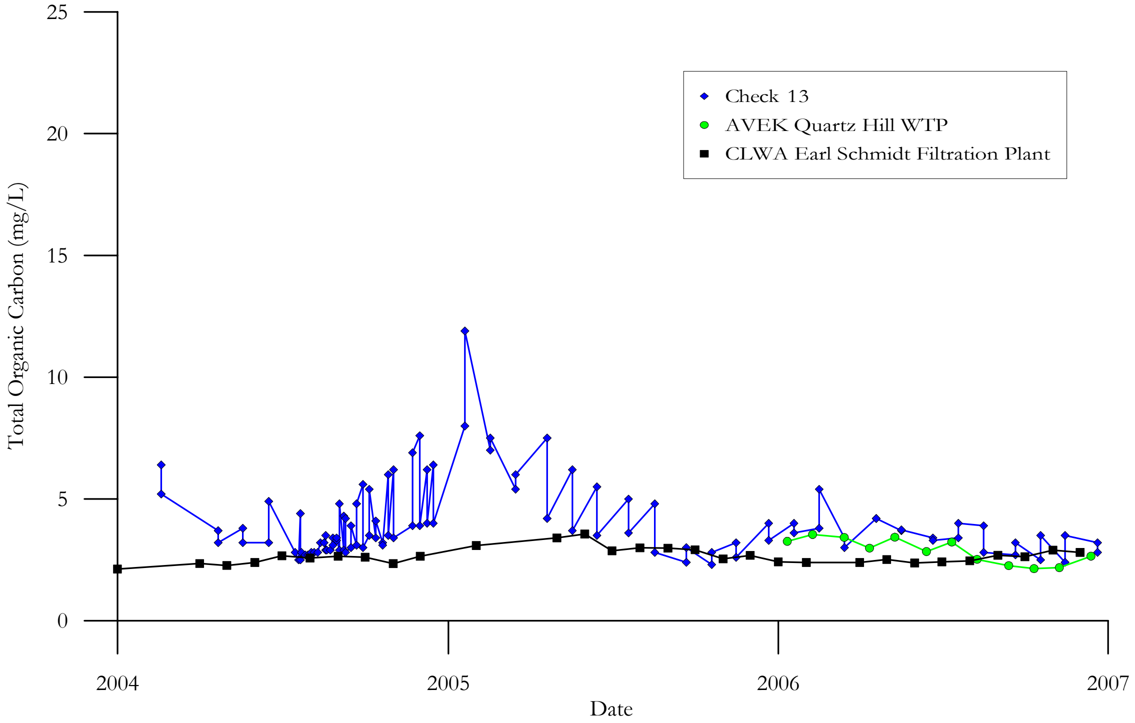


Figure 3-17. TOC Concentrations at Check 13, AVEK, and CLWA WTPs 2004 – 2006

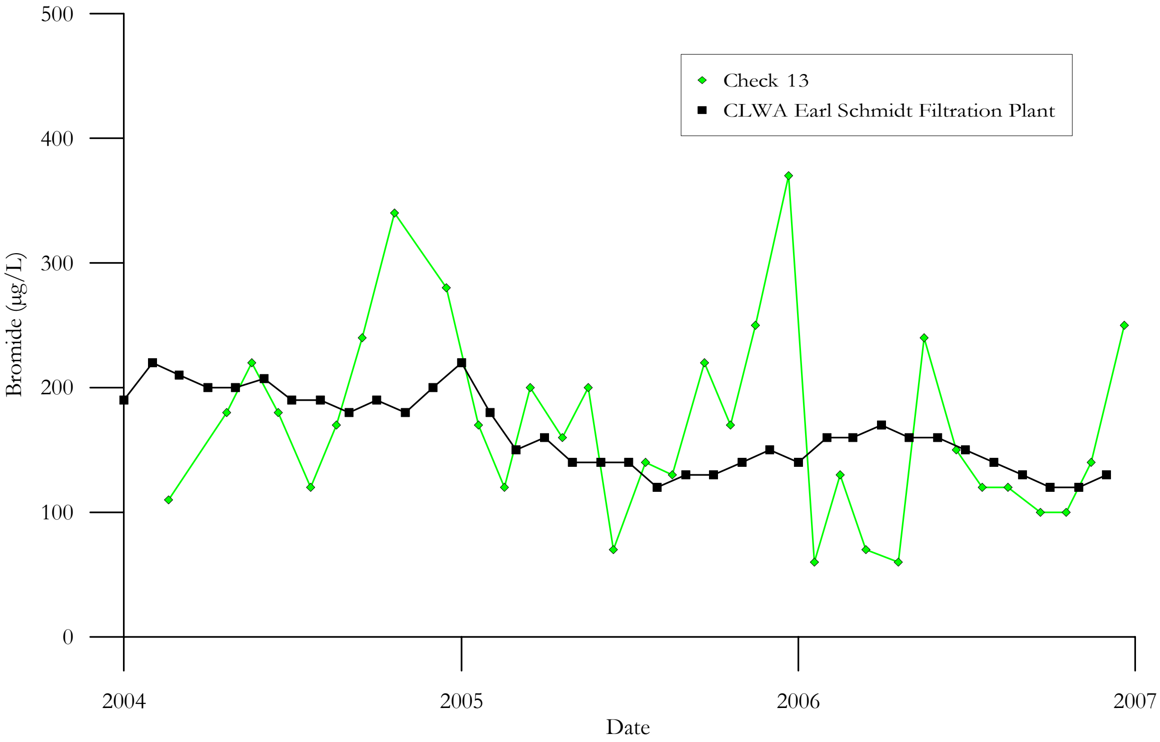


Figure 3-18. Bromide Concentrations at Check 13, and CLWA Earl Schmidt Filtration Plant 2004 - 2006

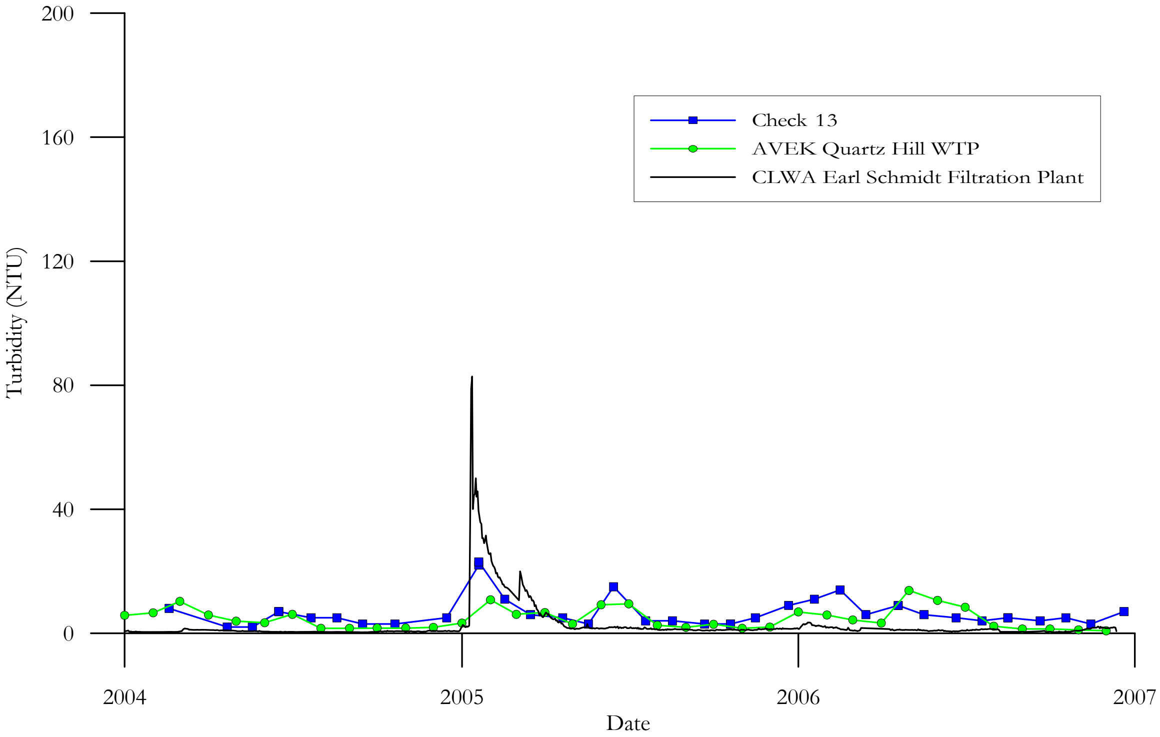


Figure 3-19. Turbidity Levels at Check 13, AVEK, and CLWA WTPs 2004 – 2006

3.5 Algae Growth and Associated Taste and Odor

Algae growth in the raw water supply can cause operational difficulties at treatment plants and inhibit treatment process effectiveness. Algae also cause T&O if not treated, which can lead to consumer complaints.

In the Upper Watershed region, Lake Shasta is nutrient limited and therefore does not have any significant algae growth. Algae blooms do occur on the American River but are less typical on the Sacramento River because it is deeper. As a result, the City of Sacramento does receive some T&O complaints early in the season.

The algal by-products MIB and geosmin are monitored in raw water in the Contra Costa Canal, SBA, and California Aqueduct. As discussed in the *California SWP Watershed Sanitary Survey 2006 Update*, peaks in these compounds occur at Clifton Court Forebay and Banks Pumping Plant in the summer and can last for weeks. Peaks at Banks Pumping Plant travel quickly to the SBA. Peaks within the California Aqueduct may originate in the Delta or within the aqueduct itself. When these compounds originate in the Delta, their concentrations decrease as the water moves through the system. San Luis Reservoir has low levels of MIB and geosmin but the Southern California Reservoirs can have levels high enough to cause T&O concerns. High levels are found in Castaic Lake, Lake Perris, and Silverwood Lake in the summer (SWP Contractors Authority 2007).

For the Contra Costa Canal, CCWD provided algae cell counts collected weekly at its Old River and Rock Slough intakes (Figures C-18 and 19). These data show that algae are typically present at the intakes. The lowest values occur in late fall and winter and peaks occur from April through September.

The study team requested T&O consumer complaint data from the participating WTP representatives for whichever six month period from 2004 through 2006 had the highest number of complaints linked to algae for their WTP. Table 3-1 presents this complaint data.

Table 3-1. Consumer Complaint Numbers for the 6 Month Period Having the Highest Number of Complaints[1]

Water Treatment Plant	Number of Complaints	Time Period
City of Redding Foothill WTP	0	2004 - 2006
City of Sacramento, Sacramento River WTP	21	Jan – Jun 2006
City of American Canyon WTP	0	2004 - 2006
City of Antioch WTP	35	Apr – Sep 2006
CCWD Bollman WTP	77	Jul – Dec 2006
ACWD WTP #2	33	Apr – Sep 2005
AVEK Quartz Hill WTP	W	
CLWA Earl Schmidt Filtration Plant	W	

[1]WTPs were asked to provide the time period of the highest number of complaints from 2004- 2006

W: wholesalers, do not collect information

The City of Redding has not had any complaints linked to algae because algae blooms have not occurred on the Sacramento River near its intake. The City of Redding intake is approximately 9 miles downstream from Lake Shasta, which is nutrient limited, inhibiting algae growth.

The City of Sacramento had 21 T&O complaints linked to algae from January through June of 2006. The Sacramento River WTP intake is located just downstream from the confluence of the Sacramento and American Rivers. Some algae blooms do occur on the Sacramento River at the intake, but algae growth more often occurs in the American River and affects City of Sacramento's American River WTP.

Data were not provided by the City of American Canyon. While the waters in Barker Slough are nutrient rich and algae growth does occur in Napa Turnout Reservoir, T&O complaints linked to algae have not been reported to DWR by the NBA contractors (SWP Contractors Authority 2007). The City of American Canyon plans to install two closed-top tanks for raw water storage at the WTP to replace existing storage tanks and help control algae growth.

The City of Antioch had 35 T&O complaints linked to algae from April through September of 2006. The City installed SolarBees® to control algae growth in the Municipal Reservoir in June 2006. Operators also apply copper sulfate to the reservoir to control algae growth. CCWD had 77 T&O complaints linked to algae blooms in September and November 2006. The majority of CCWD T&O complaints resulting from algae growth are linked to Mallard Reservoir, which does not influence the City of Antioch's Contra Costa Canal supply. CCWD conducts many activities to control algae and aquatic plant growth in its canal and reservoirs. In Mallard Reservoir CCWD applies chelated copper and sodium carbonate peroxyhydrate for algae control. The most algae growth in Contra Costa Canal occurs in the unlined portion of the canal at Rock Slough. CCWD applies chelated copper and conducts harvesting in this portion of the canal. CCWD monitors MIB and geosmin and conducts flavor profile analyses of its raw and treated water daily from April through September.

Representatives of the ACWD WTP #2, which uses conventional treatment with ozone, feel that most of their issues with T&O are taken care of with ozone. However, they still receive T&O complaints at their Mission San Jose Water Treatment Plant that they also operate and does not have ozone. Algae shortens filter runs and clogs strainers at the Zone 7 Patterson Pass WTP. Copper sulfate is applied by DWR to the SBA to help control algae growth.

AVEK and CLWA are both wholesale suppliers and do not manage consumer taste and odor complaints directly. Taste and odor problems at AVEK typically occur in the late summer and early fall. DWR treats algae blooms in the California Aqueduct with copper sulfate.

3.6 Chemical Addition/Cost to Treat

During pre-treatment, WTP operators add coagulants and polymers to help settle and remove dissolved solids (turbidity and TOC) in the water. As raw water turbidity and TOC concentrations increase, the coagulant and/or polymer doses typically increase as well. Table 3-2 presents the pre-treatment coagulant dosage ranges for the period 2004 through 2006, and the TOC and turbidity median values.

- In the Upper Watershed region, both the Foothill and Sacramento River WTPs use very low coagulant doses; this is directly related to the raw water TOC and turbidity values seen at the WTPs. The Foothills and Sacramento River WTPs opt to suspend treatment during episodes of higher turbidity, rather than increase chemical addition.
- The City of American Canyon WTP has the highest range in coagulant dose and its operators increase the coagulant dose based on incoming TOC concentrations. The other treatment plants using Delta water tend to have chemical dosing based on incoming turbidity and their operators find that when they are achieving effective turbidity removal they also are able to achieve sufficient percent TOC removal to meet TOC removal regulations.
- The CLWA Earl Schmidt Filtration Plant receives water that is less variable and has lower concentrations with respect to TOC and turbidity than other plants treating Delta water because of the long residence times its raw water has in the reservoirs along the West Branch. The Earl Schmidt Filtration Plant's chemical dosing is similar to the low doses at the WTPs on the Sacramento River.
- The AVEK Quartz Hill WTP, which is on the East Branch of the California Aqueduct and has minimal reservoir storage, has higher chemical dosing, as do the Central/South Delta and SBA WTPs that frequently receive water directly from the Delta with minimal storage.

Table 3.2. Typical Pre-Treatment Chemical Doses and Median TOC and Turbidity Values at WTP Intake

Water Treatment Plant	Coagulant	Dose Range (mg/L)	Polymer	Dose Range (mg/L)	Median TOC (mg/L)	Median Turbidity (NTU)
City of Redding Foothills WTP[1]	PACl	1.5 to 3	Cationic polymer	1	1.1	2.8
City of Sacramento, Sacramento River WTP[1]	Alum	11 to 28			1.5	10.9
City of American Canyon WTP[2]	Acidified Alum	50 to 120			5.6	
City of Antioch WTP	Alum	45			3.2	6.1
CCWD Bollman WTP	Alum	40	Cationic Polymer	1.0 – 1.5	2.9	
Zone 7 Patterson Pass WTP	$FeCl_3$	26				
ACWD WTP #2	$FeCl_3$	11 to 33	Cationic Polymer	1.5 to 3.1	3.4	6.0
AVEK Quartz Hill WTP	Alum	40 to 55	Cationic Polymer	1 to 2	2.9	3.3
CLWA Earl Schmidt Filtration Plant	$FeCl_3$	1	Cationic Polymer	1	2.6	1

[1] WTP does not typically treat high turbidity waters. WTP suspends treatment during high turbidity events.

[2] Alum addition controlled by TOC concentration due to numerous episodic high TOC events reaching > 20 mg/L TOC.

While chemical addition is not a direct measure of the cost to treat, increases in chemical dosing result in increased operations and maintenance (O&M) costs. An approximate range of 10 – 20 percent of treatment O&M costs can be attributed to pre-treatment chemical costs, chemical injection, and sludge handling. This includes labor and repair of equipment. The effects of higher chemical costs on treatment costs are influenced by several issues, as follows.

- Higher chemical purchase costs. Alum and ferric chloride have been increasing in cost at a much higher rate than inflation. Between 2005 and 2006 San Francisco Bay Area costs for alum increased 25 percent, to \$199/dry ton and ferric chloride costs increased 41 percent, to \$465/dry ton.
- Higher sludge handling and disposal costs. In the industry "sludge calculation equation," 44 percent of the alum dose is assumed to end up as sludge. This value is even higher for ferric chloride. Increasing the amount of sludge in a basin usually requires an increase in the amount of water needed to draw it from the basins. This water must be removed and re-pumped, and some is lost. Costs are incurred from water loss, energy, and ultimate sludge disposal.
- Greater chemical system capital cost for storage tank(s), chemical containment, transfer and metering pumps, and associated improvements. Utilities generally seek to maintain a 30-day supply of chemicals on hand, so as use increases, the storage requirements increase.
- Metering and pumping equipment changes, which may be required for higher doses.
- Changes to the flash or rapid mixing equipment may be needed to effectively disperse higher doses.
- More frequent basin cleanings and/or more labor to periodically remove sludge deposits from basins.

In summary, WTPs on Delta water use significantly higher chemical doses than the WTPs with intakes on the Sacramento River due to higher TOC concentrations and turbidity levels. As a result, the cost to treat per-gallon with respect to O&M costs for pre-treatment chemicals and sludge handling is higher for WTPs using Delta water than it is for WTPs in the Upper Watershed (for those WTPs included in this study). The data obtained in this study was not sufficient for comparison among the different regions that treat Delta water and the comparison was limited to Delta versus Upper Watershed plants.

In addition to reporting higher chemical dosing, representatives from the majority of the participating WTPs using Delta water indicated that their low and variable alkalinity raw water is challenging to treat and that it is difficult to optimize organics removal and minimize DBP formation. Daily or seasonally variable alkalinity requires the operators to adjust chemical dosing continually. The alkalinity for all of the WTPs is typically less than 50 mg/L and can be as low as 20 mg/L. Overall, coagulation and pre-treatment is challenging for Delta WTPs due to the water chemistry.

3.7 Disinfection By-Product Formation

DBP formation is dependent on the concentration of TOC, bromide, disinfectant, and on disinfectant contact time during disinfection. Ultimately, DBP formation at any WTP is dependent on the entire process train, including point of disinfectant application, type of disinfectant, and the amount of DBP precursors removed during pre-treatment and filtration. DBP minimization is a balance between economics and achieving disinfection sufficient to meet regulatory requirements. Comparisons between WTPs treating source water containing minimal DBP precursors and other WTPs with high concentrations of DBP precursors must be undertaken cautiously and must consider these factors.

This section presents a single WTP quarterly sample for speciated THM and HAA concentrations from September through December (Figures 3-20 and 3-21). This DBP data was obtained from the sample point closest to the outlet of the WTP. Speciated DBP data was only available for seven of the study WTPs at the time the report was prepared. Of those WTPs, CCWD Bollman WTP, ACWD WTP # 2, and CLWA Earl Schmidt Filtration Plant use ozone as their primary disinfectants. The concentrations of THMs and HAAs formed at these WTPs are anticipated to be lower than at other plants because these WTPs use chlorine or chloramines for disinfection redundancy and distribution system residual only and the THMs and HAAs typically are only formed in the distribution system (after the sample point). All of the WTPs for which speciated data was available had very low DBP concentrations leaving their WTPs. Representatives of a few of the WTPs treating Delta water reported additional problems in meeting DBP objectives (and MCLs) when bromide and TOC where simultaneously high in their source water (typically, in November and December) because they have higher brominated DBPs, bromoform, bromodichloromethane, dibromoacetic acid, and monobromoacetic acid. While the Delta water WTPs included in this study are all able to meet DBP MCLs, their operators find it challenging to keep the concentrations low when both brominated and chlorinated DBPs are formed.

As expected, the Upper Watershed WTPs (City of Redding Foothill WTP and City of Sacramento, Sacramento River WTP), where bromide concentrations in the raw water are very low, primarily have only chlorinated DBPs and have minimal-to-non-detectable concentrations of the brominated DBPs in their finished water. All of the WTPs treating Delta water, even those using ozone, showed significant concentrations of the brominated DBPs in their finished water. There is speculation that brominated DBPs may be more carcinogenic than chlorinated DBPs, and there is potential to form different DBPs with higher bromide concentrations.

Figure 3-22 presents bromate data from CCWD Bollman and ACWD WTP #2, two of the three WTPs that practice ozone disinfection. At the time of this report ozone bromate data from the CLAWA Earl Schmidt Filtration Plant was not available. Both WTPs receive high and variable bromide concentrations and practice bromate formation minimization strategies. Typically both WTPs have bromate concentrations less than 5 μg/L.

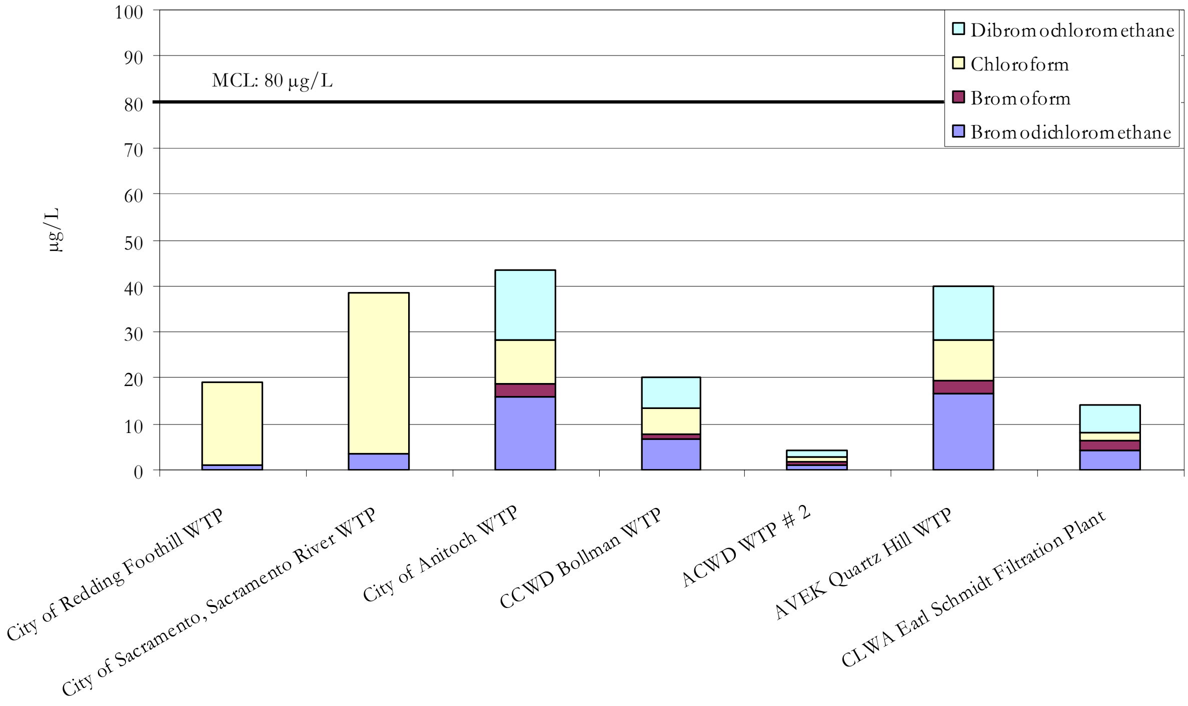


Figure 3-20. THM Speciation for Study WTPs Fourth Quarter, September – December, 2006

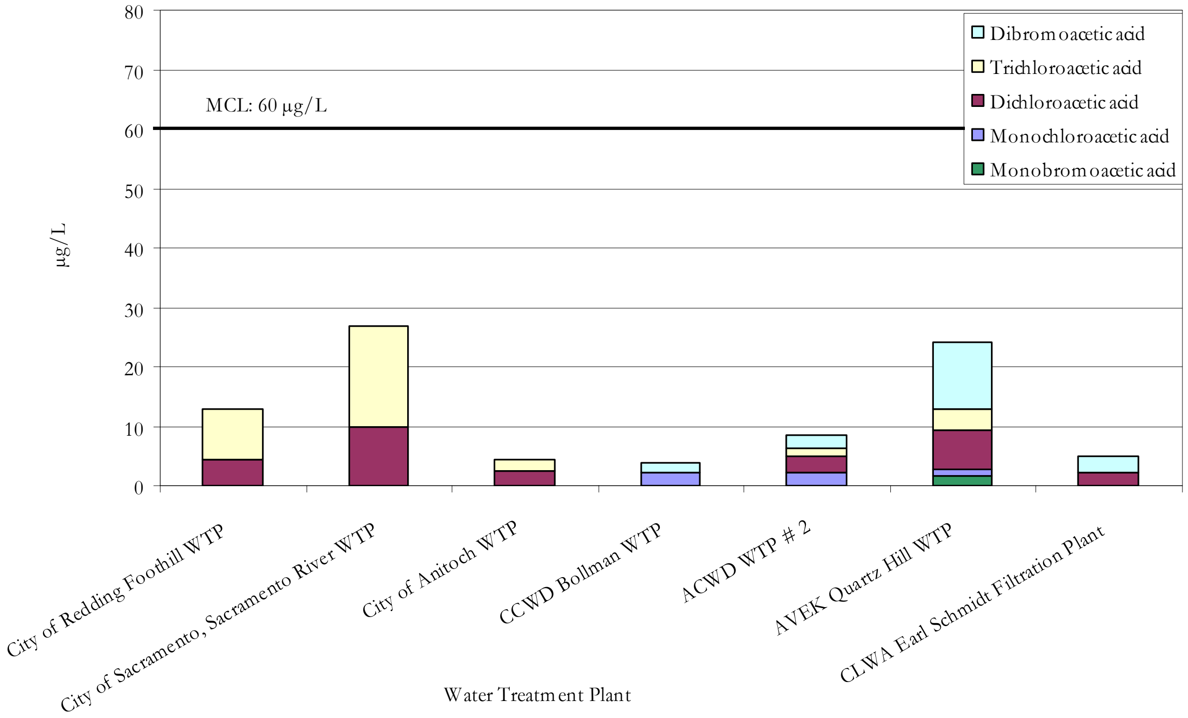


Figure 3-21. HAA Speciation for Study WTPs Fourth Quarter, September – December, 2006

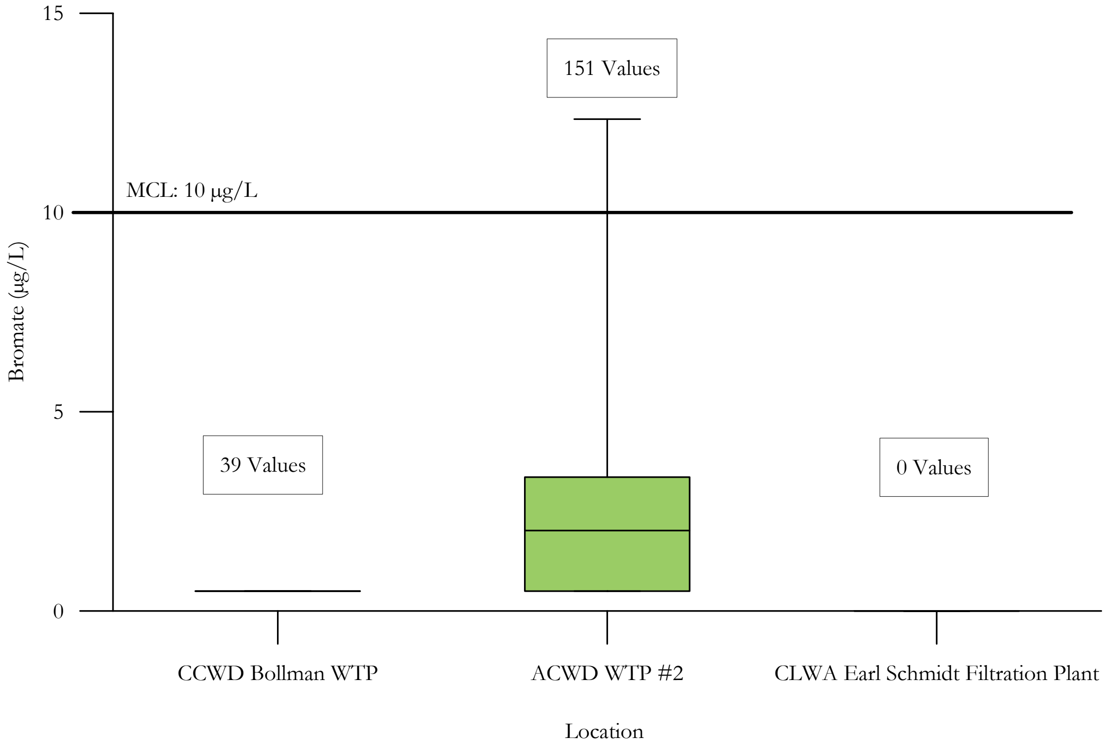


Figure 3-22. Bromate Ranges and Medians from 2004 – 2006 for Study WTPs Using Ozone

4. WATER TREATMENT PLANT CONCEPTUAL MODELS

This section explains the use of conceptual models and presents the conceptual models developed for the study.

4.1 Conceptual Model Use

Conceptual models define and describe environmental systems; describe issues or problems within a system; and identify solution areas. The conceptual models developed for this study represent Delta drinking water quality from source water intakes through WTPs, considering the whole path as a "system" and depicting the processes and factors that affect water quality. The conceptual models also facilitate comparisons between WTPs treating Delta water and WTPs treating Upper Watershed water. The conceptual models aid in understanding water quality impacts through the system and can help guide the WQP in determining how to meet ELPH objectives and improve drinking water quality.

4.2 Conceptual Model Framework

The Conceptual Model Framework, Figure 4-1, was developed from the ELPH diagram (Appendix A) to further clarify the components of the ELPH diagram and provide additional context for working toward the ELPH goal. Starting from this generic representation of the system, the study team developed specific conceptual models for each of the WTPs in the study. The Conceptual Model Framework was used to develop an information collection outline for meetings with WTP representatives. At these meetings, the study team gathered data to support hypotheses testing and qualitative information to augment the data analysis.

The Conceptual Model Framework is divided into three rows: boundary conditions and constraints; water supply and treatment system; and water quality improvements. The model also divides the system into three system components: source; conveyance and storage; and treatment. The boundary conditions and constraints include the infrastructure that distributes and treats the water and the ways in which the WTPs are bounded with respect to their water supplies. The water supply and treatment system portion discusses processes or elements within the system components that affect water quality, constituent concentrations, and how some of these constituents change through each of the system components. The focus of the water supply and treatment system is how changes in water quality or initial water quality conditions ultimately affect drinking water treatment. The water quality improvement section summarizes the actions that have been taken by WTP agencies to improve treated water quality or economics, and includes possibilities that the agencies are investigating (e.g., changes in infrastructure or methods that could improve water quality). The water quality improvement section also identifies areas in which the WTP agencies would like to see water quality improvements, but over which they have no control. Potential areas in which the WQP could assist in meeting ELPH objectives are included in the water quality improvement section.

4.3 Water Treatment Plant Conceptual Models

The objectives in developing individual conceptual models were to: identify primary infrastructure components of conveyance, storage, and treatment that could potentially impact water quality; describe boundary conditions and constraints in water supply; and identify impacts to water quality through the system. The focus of all the elements and system categories of the conceptual models is to evaluate water quality changes through the system. The study team developed individual WTP conceptual models based on the information collected in meetings with WTP representatives, and on information obtained from reports including sanitary surveys and integrated regional water management plans. The individual plant conceptual models organize information in the same manner as the Conceptual Model Framework (Section 4.2).

The conceptual models use abbreviations and acronyms that have been introduced previously in the text. All abbreviations and acronyms used in this report are defined in the abbreviation and acronyms list presented at the beginning of this report. Important drinking water treatment technology and information contained in this model was presented in Section 2.1. Solid teal arrows from one system component to the next indicate flow to the next system component. Light green arrows within the system components refer to flow/changes to water quality with in the system component. A light green arrow is used between storage and conveyance to link those components together where appropriate. Light green arrows from the disinfection box are used in the treatment component of the water supply and treatment system to indicate the point of disinfectant application (pre or post-filtration).

As an example, the ACWD WTP #2 conceptual model is provided after the Conceptual Model Framework as Figure 4-2. Appendix D contains the remaining WTP conceptual models. The sections below highlight each conceptual model and describe notable facets of each system. For details, refer to the conceptual models themselves.

4.3.1 Upper Watershed

Both the City of Redding Foothills WTP and City of Sacramento River WTP receive water through intakes that take water directly from the Sacramento River through an enclosed pipeline. For both of these WTPs, no significant conveyance or storage structures affect water quality prior to treatment. Both WTPs use low doses of pre-treatment chemicals, because their raw water has very low TOC and turbidity concentrations. During most of the year, the Foothill WTP is operated as a direct filtration plant because its raw water has turbidities of less than 5 NTU and the residence time in its sedimentation basins do not provide a significant amount of settling at such low turbidities. In the winter time when turbidities are higher, the sedimentation basins at Foothill WTP are used to equalize the higher incoming turbidities. The City of Sacramento balances the operation of the Sacramento River WTP and the Fairbairn WTP (not modeled) for optimal water quality and operation costs. When turbidity levels are higher than 10 NTU, the Foothill WTP suspends treatment and waits for the short turbidity events to pass. The Sacramento River WTP also likewise suspends treatment during high turbidity episodes. During episodic turbidity or algae events, operation at the plants can be suspended or cut back to treat the highest water quality. Neither treatment plant in the Upper Watershed currently has concerns about meeting DBP MCLs or anticipates that this will be a problem in the future.

4.3.2 North Bay Aqueduct

The Sacramento River water drawn into the NBA becomes significantly degraded due to the NBA intake's location in Barker Slough. The Barker Slough watershed degrades the Sacramento River source water significantly, and the NBA has the highest TOC concentration of the Delta intakes (see Section 3.0). The NBA water is pumped to the individual WTPs from Barker Slough intake through an underground pipeline that has minimal impact on water quality. Barker Slough Watershed contributes turbidity, TOC, metals, and bromide, particularly during storm events, causing a great deal of variability. The alkalinity in this source water drops significantly during rain events. Alkalinity variability and high TOC concentrations make NBA water difficult to treat.

The City of American Canyon WTP operates a conventional treatment system with multi-media filters in parallel to a membrane treatment plant. The membrane treatment train consistently meets finished water turbidity requirements with less operator attention than is needed for the conventional system. Operators at this WTP use a combined acidified alum mix for TOC removal on both treatment trains. While the WTP's percent TOC removal is high, the incoming TOC concentrations can be greater than 20 mg/L, and the agency struggles to meet DBP regulations and is concerned about meeting future TOC regulations. This fall, the City of American Canyon will be conducting pilot evaluations to investigate additional organic carbon removal strategies.

Limiting water quality degradation and variability from Barker Slough watershed or proceeding with projects to re-locate the NBA intake would provide the WTPs on the NBA the most beneficial improvement to drinking water quality. Additional pilot evaluations and integrating information from other facilities on organic carbon removal would also be helpful.

4.3.3 Central/South Delta

CCWD operates three intakes on the Delta, (Old River, Rock Slough, and Mallard Slough), and has four reservoirs, (Los Vaqueros, Mallard, Martinez and Contra Loma Reservoirs). The Mallard Slough intake is used rarely, because it has high chloride concentrations. Los Vaqueros is the largest reservoir and is used solely as a blending source for the canal when Delta water quality degrades. CCWD supplies water via the Contra Costa Canal to its WTPs, including Bollman, which was included in the study, and supplies raw water to its contractors.

The City of Antioch purchases water from CCWD, but also operates an independent intake within the legal limit of the Delta, using San Joaquin River water rights. Antioch purchases water from CCWD when the chloride concentration at its Delta intake is greater than 250 mg/L. The City of Antioch is concerned about population growth in the San Joaquin River Valley and Delta and its potential to degrade the water quality of its independent supply.

CCWD has the ability to balance the use of its intakes and its reservoirs based on water quality. The use of the intakes and the reservoirs is, however, strictly bounded by water rights and biological opinions. Due to water quality constraints and legal limitations, the water in the Contra Costa Canal remains highly variable. When possible, CCWD operates Mallard Reservoir as a forebay to the Bollman WTP because it attenuates some of the variability in CCWD's raw water quality.

Both CCWD and the City of Antioch have made treatment modifications to limit DBP formation given current Delta water quality conditions and therefore feel that they are capable of meeting DBP regulations in the future. CCWD has implemented -intermediate ozone at the Bollman WTP, which limits THM and HAA formation in its distribution system, but the system must be managed to prevent bromate formation. The City of Antioch pre-chlorinates and achieves its disinfection contact time credit through its sedimentation basins. The City of Antioch produces water low in THM and HAA concentrations (Figure 3-20, 3-21, and Appendix graphs).

The City of Antioch would like to address concerns regarding the potential impact to the water quality on their independent supply and potentially relocate their intake for better a water quality that would allow for a more reliable and consistent supply.

4.3.4 South Bay Aqueduct

Most of the WTPs along the SBA receive water directly from the Delta and the raw water quality at their treatment plants is similar to the Delta water quality (SWP Contractors Authority 2007). The Delta water quality is highly variable and low in alkalinity. Algae growth in Clifton Court Forebay and along the SBA causes pH fluctuations, operational challenges, and associated T&O events. ACWD and Zone 7 also have shared water rights for natural flow to Lake Del Valle, which is usually filled by local runoff, but can be filled with Delta water during dry years. The water in Lake Del Valle is lower in TOC and turbidity and higher in alkalinity than Delta water. SBA contractors send requests to DWR for releases from Lake Del Valle to offset low alkalinity or degraded water quality episodes associated with their Delta source. Typically the lake is drawn down in the fall to make room for water supply and flood storage. Lake Del Valle's usable storage is limited, because it is a multiple use facility and is typically kept at a full pool in the summer for recreation.

Alameda County Water District (ACWD) WTP #2 practices pre-ozonation at its conventional treatment plant with dual-media filters. Ozone has been effective at eliminating the plant's T&O issues, which are associated with algae growth. ACWD also operates a membrane treatment plant, Mission San Jose WTP, on the same source water and has found its conventional filters run more reliably than membrane filters do on the Delta source water.

Zone 7 Patterson Pass WTP receives water from the Patterson Reservoir, which receives the top two feet of SBA water (which has the highest quality in the SBA) via an overflow weir. The Patterson Pass WTP operates upflow clarifiers followed by a multi-media filters and membrane filters in parallel. Algae growth has caused shortened filter run times on the media filters and clogged intake screens on the membrane side. The water quality variability and algae growth are even more challenging at Zone 7's Del Valle WTP; it does not have a reservoir in which to attenuate the raw water variability and settle some of the solids. Zone 7 plans on installing ozone at its new Altamont WTP because of the successes with ozone at ACWD WTP #2.

Potential areas to improve drinking water quality for SBA contractors are listed below.

- Improve Delta source water quality to limit variability in pH, alkalinity, TOC, and bromide, and decrease bromide and TOC concentrations.
- Develop alternatives to using copper sulfate to so that algae growth can be more frequently and consistently managed in Clifton Court Forebay and the SBA.
- Cover the open portions of the SBA to limit algae growth and associated problems.
- Improve the operation and maintenance of the drainage ditch near Bethany Reservoir to limit pathogen contributions.

4.3.5 California Aqueduct

Three treatment plants that receive water at different locations off of the California Aqueduct were selected for the study. Unfortunately, the City of Coalinga was not able to participate or provide data within the time frame of the study due to staff resource limitations. A conceptual model was developed for the City of Coalinga WTP based on a previous study, *Issues with Delta Water Treatment* (Brown and Caldwell, 2005); however, it does not reflect current, direct input from representatives of the City of Coalinga WTP. During this earlier study, the City of Coalinga WTP staff discussed previous episodes of DBP non-compliance. The staff has been attempting to adjust WTP process operations to more consistently meet DBP MCLs. This challenge with meeting DBP MCLs and the plant's staff limitations demonstrate the need for the CALFED WQP to provide outreach and communication more directly to disadvantaged communities and small WTPs. Direct outreach may help identify specific opportunities to improve drinking water quality at the level of WTPs statewide.

CLWA Earl Schmidt Filtration Plant receives water from the West Branch of the California Aqueduct through a series of three reservoirs, Quail, Pyramid, and Castaic Lakes. Because of these reservoirs, the high TOC and turbidity concentrations and water quality variability seen at Banks Pumping Plant and through the California Aqueduct are not seen at the Earl Schmidt Filtration Plant. In addition, the Earl Schmidt Filtration plant uses ozone, which aids in organic carbon removal. Prior to the installation of its ozone facilities, limiting the formation of brominated THMs was difficult when both bromide and TOC were high in the source water. When Castaic Lake is drawn down it does not attenuate or settle out TOC and turbidity as well as it does with higher water levels. During periods of shorter storage residence time, the Earl Schmidt Filtration Plant receives water with higher and more variable TOC and bromide concentrations and turbidity levels than it does when storage time is longer, which is more difficult to treat.

AVEK Quartz Hill WTP is on the West Branch of the California Aqueduct and does not have reservoirs to buffer the quality of water from the Delta. In addition to variable TOC and turbidity concentrations in this WTP's raw water, alkalinity levels create difficulties for coagulation. DBP formation, particularly in the winter when TOC and bromide are the highest, is problematic for this WTP. The Quartz Hill WTP is undergoing an expansion and switching to ozone and biologically active filters. However, the AVEK staff is concerned about bromate formation when the switch to ozone is made, because the plant's raw water has the high bromide concentrations.

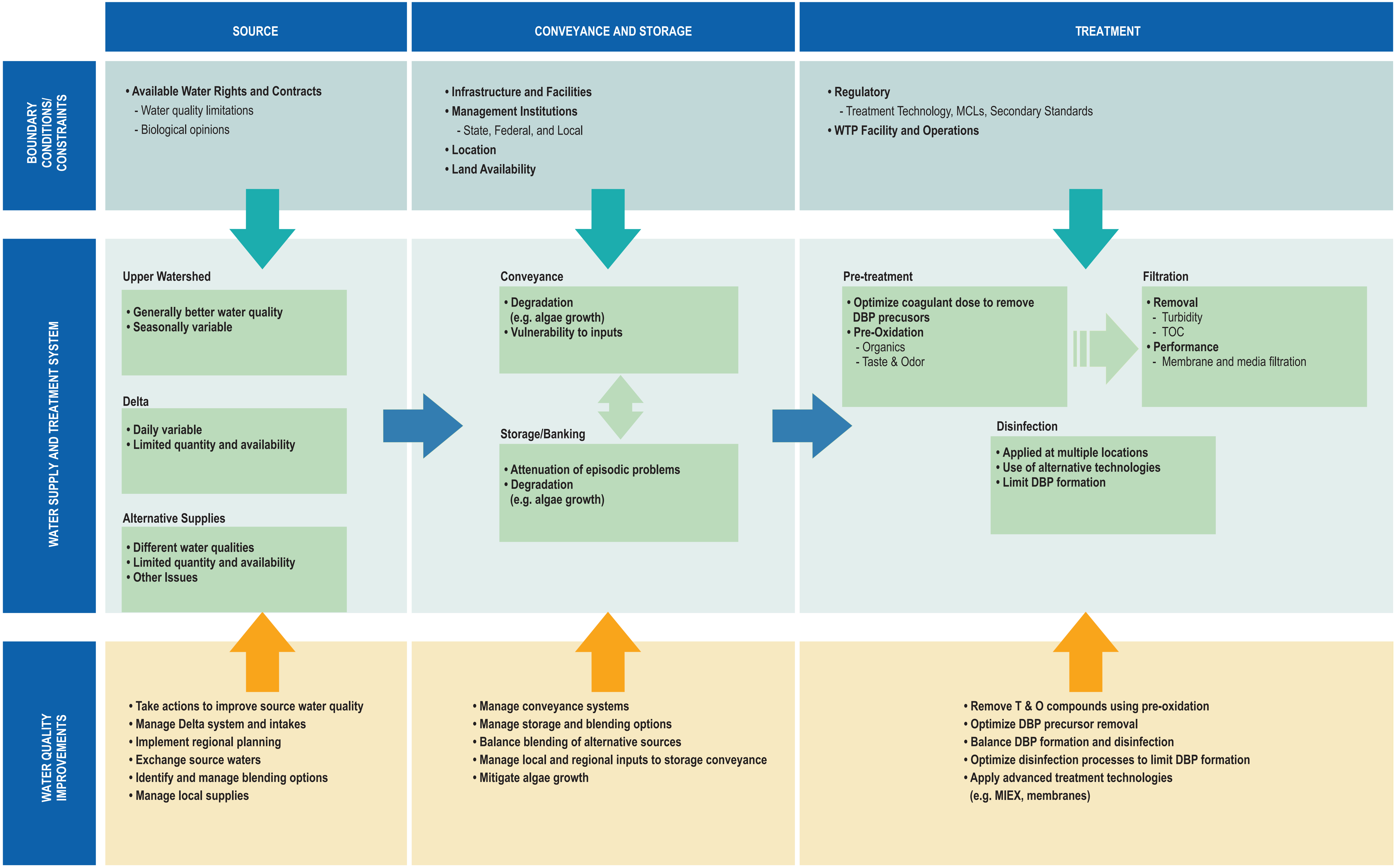
Figure C-29, a time series of bromide and TOC concentrations at Banks Pumping Plant, was prepared to assist in studying occasions when the high TOC and bromide concentrations occur simultaneously. Unfortunately, the data at this location is limited and it is be necessary to get intake bromide and TOC concentrations and speciated DBP formation information from the individual WTPs to investigate this.

The Earl Schmidt WTP has significantly less difficulty treating Delta water than other WTPs because of the buffering effect provided by Castaic Lake and its other reservoirs, through which the Delta water flows downstream from where the California Aqueduct splits into its East and West Branches. The WTPs that receive water directly from the California Aqueduct have problems and challenges similar to those experienced by WTPs located closer to the Delta.

Potential areas for water quality improvements on the California Aqueduct are listed below.

- Improve Delta source water quality to limit variability in pH, alkalinity, TOC, and bromide, and decrease bromide and TOC concentrations.
- Develop alternatives to using copper sulfate to so that algae growth can be more frequently and consistently managed in Clifton Court Forebay and along the California Aqueduct.
- Develop additional storage along the California Aqueduct to attenuate variability in TOC, bromide, and turbidity.
- Continue to investigate strategies to minimize bromate formation.
- Provide real time data forecasting, particularly for plants receiving water directly off of the California Aqueduct without storage.

FIGURE 4.1 CONCEPTUAL MODEL FRAMEWORK



SOURCE

BOUNDARY CONDITIONS/ CONSTRAINTS

- **Available Water Rights and Contracts**
  - Water quality limitations
  - Biological opinions

WATER SUPPLY AND TREATMENT SYSTEM

Upper Watershed

- Generally better water quality
- Seasonally variable

Delta

- Daily variable
- Limited quantity and availability

Alternative Supplies

- Different water qualities
- Limited quantity and availability
- Other Issues

WATER QUALITY IMPROVEMENTS

- Take actions to improve source water quality
- Manage Delta system and intakes
- Implement regional planning
- Exchange source waters
- Identify and manage blending options
- Manage local supplies

CONVEYANCE AND STORAGE

BOUNDARY CONDITIONS/ CONSTRAINTS

- **Infrastructure and Facilities**
- **Management Institutions**
  - State, Federal, and Local
- **Location**
- **Land Availability**

WATER SUPPLY AND TREATMENT SYSTEM

Conveyance

- Degradation (e.g. algae growth)
- Vulnerability to inputs

Storage/Banking

- Attenuation of episodic problems
- Degradation (e.g. algae growth)

WATER QUALITY IMPROVEMENTS

- Manage conveyance systems
- Manage storage and blending options
- Balance blending of alternative sources
- Manage local and regional inputs to storage conveyance
- Mitigate algae growth

TREATMENT

BOUNDARY CONDITIONS/ CONSTRAINTS

- **Regulatory**
  - Treatment Technology, MCLs, Secondary Standards
- **WTP Facility and Operations**

WATER SUPPLY AND TREATMENT SYSTEM

Pre-treatment

- Optimize coagulant dose to remove DBP precusors
- Pre-Oxidation
  - Organics
  - Taste & Odor

Filtration

- Removal
  - Turbidity
  - TOC
- Performance
  - Membrane and media filtration

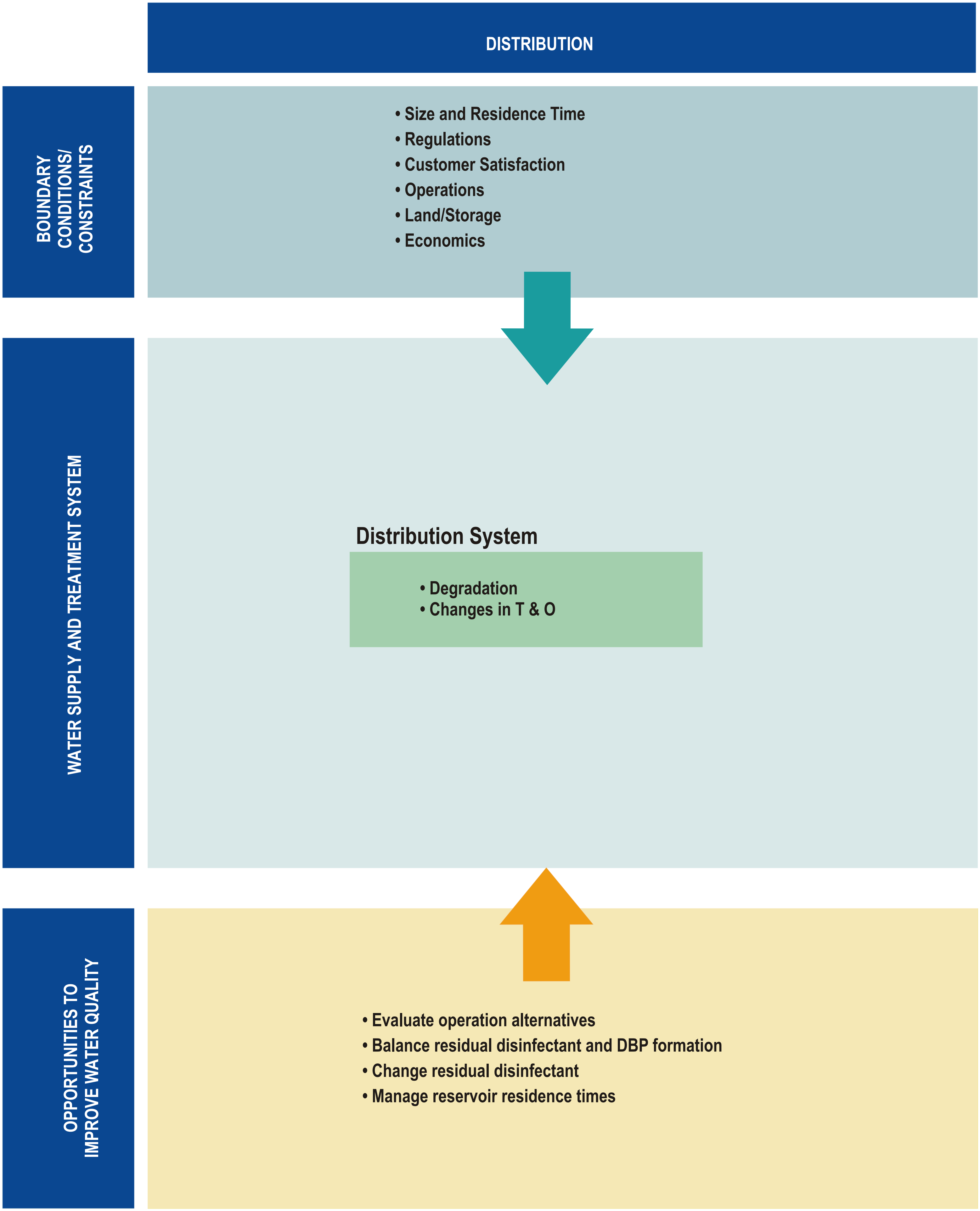
Disinfection

- Applied at multiple locations
- Use of alternative technologies
- Limit DBP formation

WATER QUALITY IMPROVEMENTS

- Remove T & O compounds using pre-oxidation
- Optimize DBP precursor removal
- Balance DBP formation and disinfection
- Optimize disinfection processes to limit DBP formation
- Apply advanced treatment technologies (e.g. MIEX, membranes)

FIGURE 4-1. CONCEPTUAL MODEL FRAMEWORK



DISTRIBUTION

BOUNDARY CONDITIONS/ CONSTRAINTS

- Size and Residence Time
- Regulations
- Customer Satisfaction
- Operations
- Land/Storage
- Economics

WATER SUPPLY AND TREATMENT SYSTEM

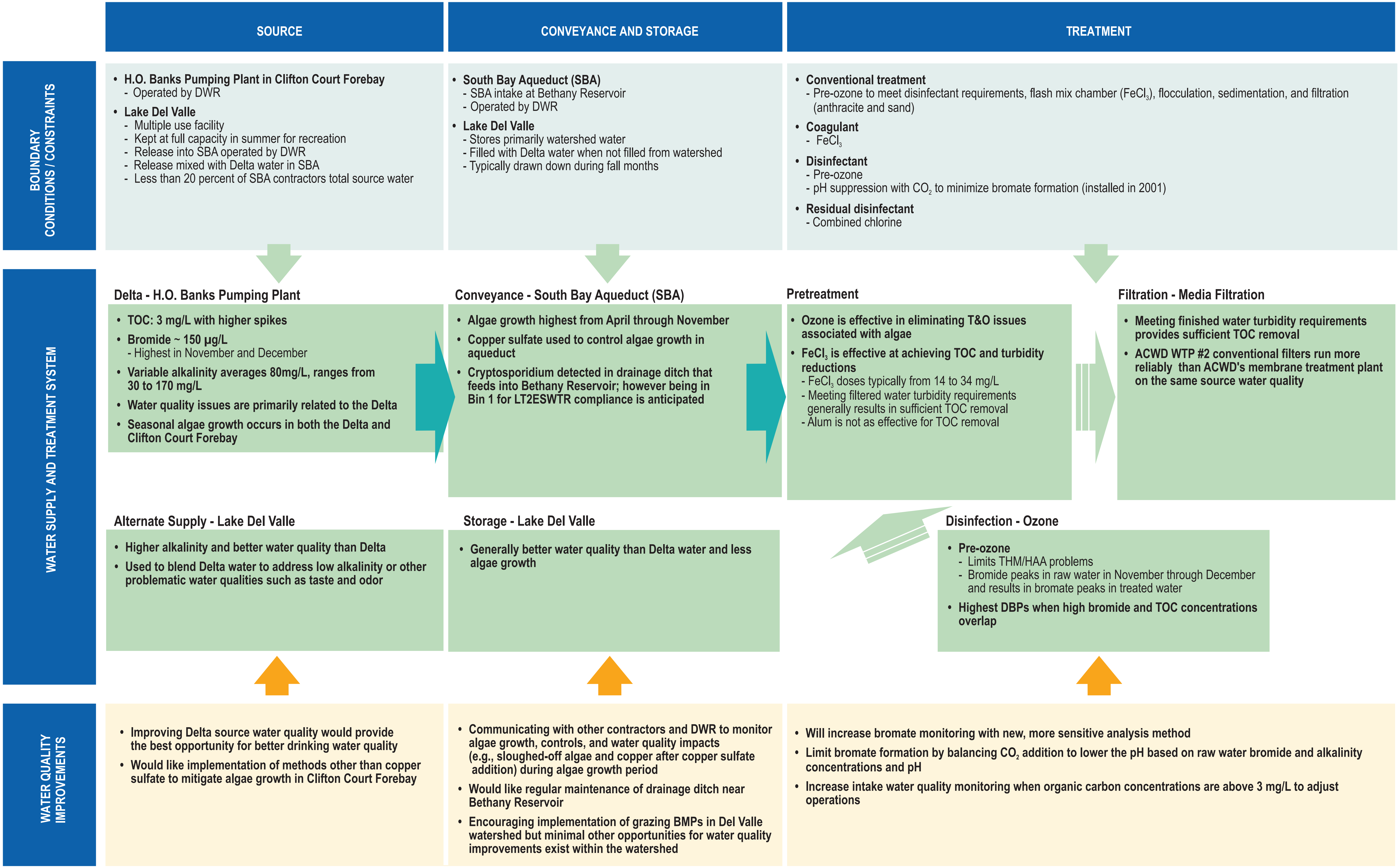
Distribution System

- Degradation
- Changes in T & O

OPPORTUNITIES TO IMPROVE WATER QUALITY

- Evaluate operation alternatives
- Balance residual disinfectant and DBP formation
- Change residual disinfectant
- Manage reservoir residence times

FIGURE 4-2. SOUTH BAY AQUEDUCT- ALAMEDA COUNTY WATER DISTRICT, WTP # 2 CONCEPTUAL MODEL



SOURCE | CONVEYANCE AND STORAGE | TREATMENT

BOUNDARY CONDITIONS / CONSTRAINTS

Source

- **H.O. Banks Pumping Plant in Clifton Court Forebay**
  - Operated by DWR
- **Lake Del Valle**
  - Multiple use facility
  - Kept at full capacity in summer for recreation
  - Release into SBA operated by DWR
  - Release mixed with Delta water in SBA
  - Less than 20 percent of SBA contractors total source water

Conveyance and Storage

- **South Bay Aqueduct (SBA)**
  - SBA intake at Bethany Reservoir
  - Operated by DWR
- **Lake Del Valle**
  - Stores primarily watershed water
  - Filled with Delta water when not filled from watershed
  - Typically drawn down during fall months

Treatment

- **Conventional treatment**
  - Pre-ozone to meet disinfectant requirements, flash mix chamber ($FeCl_3$), flocculation, sedimentation, and filtration (anthracite and sand)
- **Coagulant**
  - $FeCl_3$
- **Disinfectant**
  - Pre-ozone
  - pH suppression with CO_2 to minimize bromate formation (installed in 2001)
- **Residual disinfectant**
  - Combined chlorine

WATER SUPPLY AND TREATMENT SYSTEM

Delta - H.O. Banks Pumping Plant

- **TOC: 3 mg/L with higher spikes**
- **Bromide ~ 150 µg/L**
  - Highest in November and December
- **Variable alkalinity averages 80mg/L, ranges from 30 to 170 mg/L**
- **Water quality issues are primarily related to the Delta**
- **Seasonal algae growth occurs in both the Delta and Clifton Court Forebay**

Conveyance - South Bay Aqueduct (SBA)

- **Algae growth highest from April through November**
- **Copper sulfate used to control algae growth in aqueduct**
- **Cryptosporidium detected in drainage ditch that feeds into Bethany Reservoir; however being in Bin 1 for LT2ESWTR compliance is anticipated**

Pretreatment

- **Ozone is effective in eliminating T&O issues associated with algae**
- **$FeCl_3$ is effective at achieving TOC and turbidity reductions**
  - $FeCl_3$ doses typically from 14 to 34 mg/L
  - Meeting filtered water turbidity requirements generally results in sufficient TOC removal
  - Alum is not as effective for TOC removal

Filtration - Media Filtration

- **Meeting finished water turbidity requirements provides sufficient TOC removal**
- **ACWD WTP #2 conventional filters run more reliably than ACWD's membrane treatment plant on the same source water quality**

Alternate Supply - Lake Del Valle

- **Higher alkalinity and better water quality than Delta**
- **Used to blend Delta water to address low alkalinity or other problematic water qualities such as taste and odor**

Storage - Lake Del Valle

- **Generally better water quality than Delta water and less algae growth**

Disinfection - Ozone

- **Pre-ozone**
  - Limits THM/HAA problems
  - Bromide peaks in raw water in November through December and results in bromate peaks in treated water
- **Highest DBPs when high bromide and TOC concentrations overlap**

WATER QUALITY IMPROVEMENTS

Source

- **Improving Delta source water quality would provide the best opportunity for better drinking water quality**
- **Would like implementation of methods other than copper sulfate to mitigate algae growth in Clifton Court Forebay**

Conveyance and Storage

- **Communicating with other contractors and DWR to monitor algae growth, controls, and water quality impacts (e.g., sloughed-off algae and copper after copper sulfate addition) during algae growth period**
- **Would like regular maintenance of drainage ditch near Bethany Reservoir**
- **Encouraging implementation of grazing BMPs in Del Valle watershed but minimal other opportunities for water quality improvements exist within the watershed**

Treatment

- **Will increase bromate monitoring with new, more sensitive analysis method**
- **Limit bromate formation by balancing CO_2 addition to lower the pH based on raw water bromide and alkalinity concentrations and pH**
- **Increase intake water quality monitoring when organic carbon concentrations are above 3 mg/L to adjust operations**

131736-002

5. HYPOTHESIS TESTING

This section evaluates the hypotheses proposed as part of this study. The objectives of hypothesis testing were to challenge the current understanding of treating Delta water, identify data and information gaps, and better understand how the WQP can aid in improving drinking water quality and implement ELPH. With respect to water quality constituents, the study hypotheses focused on TOC, bromide, and turbidity because the data sets provided relatively complete coverage of these constituents for the Delta and WTP intakes. The completeness of the data sets also reflects the importance of these constituents to drinking water treatment. Qualitative information obtained from representatives of the study WTPs also supported the hypothesis testing.

As discussed in Section 2.0, these hypotheses consider source water quality and its impact on drinking water treatment. This study evaluated three groups of hypotheses, organized in the same way the conceptual models (Section 4) are: Source (Section 5.1); Storage and Conveyance (Section 5.2) and Treatment (Section 5.3). The discussions below state whether this study's data supported the hypotheses and provide observations relevant to evaluation of the hypotheses. The hypothesis testing and conclusions drawn are for the ten WTP case studies selected for this evaluation and are not necessarily representative of all Delta water users. The water quality data used in this discussion represents both the treatment plants with Sacramento River intakes and those with Delta intakes.

5.1 Source

The ten WTPs included in this study rely on raw water from a variety of locations. Many of the source hypotheses make comparisons regarding water quality at these various locations. For reference, Table 5-1 lists each of the study WTPs, its intake location, and its water sources.

Table 5-1. Summary of Case Study WTPs and Intake Locations and/or Source

Region	WTP	Intake Locations/Source
Upper Watershed	City of Redding Foothill WTP	Sacramento River
	City of Sacramento Sacramento River WTP	Sacramento River
	Delta WTPs	
NBA	City of American Canyon WTP	Barker Slough
Central/South Delta	Contra Costa Water District Bollman WTP	Rock Slough Old River Mallard Slough
	City of Antioch WTP	Rock Slough Old River San Joaquin River
South Bay Aqueduct	Zone 7 Water Agency Patterson Pass WTP	H.O. Banks Pumping Plant Lake Del Valle
	Alameda County Water District WTP # 2	H.O. Banks Pumping Plant Lake Del Valle
California Aqueduct	City of Coalinga WTP	H.O. Banks Pumping Plant Bill Jones (Tracy) Pumping Plant
	Castaic Lake Water Authority Earl Schmidt Filtration Plant	H.O. Banks Pumping Plant Bill Jones (Tracy) Pumping Plant
	Antelope Valley East Kern Quartz Hill WTP	H.O. Banks Pumping Plant Bill Jones (Tracy) Pumping Plant

5.1.1 CALFED ROD Targets

Source Hypothesis 1: *Upper Watershed raw water quality consistently and reliably meets the ROD Delta intake targets of average concentrations of 3 mg/L TOC and 50 µg/L bromide, but the Delta intakes do not.*

The water quality data supports this hypothesis.

The City of Redding Foothill WTP raw water TOC concentration is consistently less than 2 mg/L; bromide is not typically measured at the intake because concentrations are low enough that it is not a treatment concern (Figure 3-6). The City of Sacramento, Sacramento River WTP raw water has variable TOC concentrations, but the average is less than 2 mg/L and the 90th percentile range is less than 3 mg/L (Figure 3-6). Episodic events during the rainy season do result in organic carbon concentrations as high as 4 mg/L (Figure C-1). Bromide concentrations on the Sacramento River are typically less than 50 µg/L (Figure 3-10).

The running annual average TOC concentrations at each of the four primary Delta intakes evaluated in this study (Barker Slough, Banks Pumping Plant, Rock Slough, and Old River) are all typically greater than the ROD target of 3 mg/L. The Old River and Rock Slough running annual average concentrations from 2004 through 2005 were close to 3 mg/L TOC (Figures 3-2 and Appendix C-1 through C-3). Bromide is higher than the ROD intake target of 50 µg/L for Banks Pumping Plant, Rock Slough, and Old River. The running annual average at Barker Slough intake is typically less than 50 µg/L but close to this value.

The hypothesis is correct in that the water on the Sacramento River consistently and reliably meets the ROD intake targets and the water at the Delta intakes evaluated for this study does not consistently and reliably meet the ROD intake targets.

5.1.2 Treatment of Source Waters with Higher TOC, Bromide, and Turbidity

Source - Hypothesis 2: *Better raw water quality allows treatment plants to more cost effectively, reliably, and consistently meet water quality regulations (e.g., Upper Watershed versus Delta).*

Source - Hypothesis 3: *Water quality at each Delta intake is different and therefore has unique water quality challenges related to treatment.*

The water quality data and chemical addition data support Hypotheses 2. Qualitative information obtained from the WTPs further supports Hypotheses 2. Qualitative information obtained from the WTPs supports Hypothesis 3. However, conveyance and storage also affect treatment and therefore the hypothesis was evaluated by intake and region rather than intake alone. Differences in water quality in the four Delta regions do affect treatment and other operations; however, a common theme for the entire set of WTPs is evident when comparing WTPs that treat Delta water with those in the Upper Watershed.

All of the WTPs included in this study consistently meet CDPH drinking water regulations. Some WTP representatives mentioned that meeting DBP regulations remains challenging due to high TOC concentrations. Treatment data and water quality data presented in Section 3.6 demonstrated that WTPs treating Delta water have higher costs and more extensive operational adjustments than Upper Watershed WTPs because their raw water quality is poorer than Upper Watershed water quality. As noted above, the raw water at the Upper Watershed WTPs consistently and reliably meet the ROD intake targets while the water at the Delta intakes does not. The ROD intake Targets were set as a measure of source water quality and thus are indicators that the Upper Watershed water is of higher quality. The data shows that the Upper Watershed WTPs treat water with lower turbidity levels than the Delta WTPs; the Upper Watershed WTPs do have the option to by-pass episodic high turbidity events because they are short lived (a few hours).

As concentrations of bromide and TOC increase, meeting DBP regulations and treating source water becomes more difficult. Table 3-2 presented a comparison of pre-treatment chemical doses alongside intake TOC and turbidity concentrations. All of the WTPs receiving Delta water, with the exception of CLWA Earl Schmidt WTP (discussed further in Section 5.2.1), use significantly higher pre-treatment chemical doses than the Upper Watershed WTPs, due to higher and more variable TOC concentrations and turbidity levels. The chemical doses for most of the WTPs that receive Delta water are close to 50 mg/L, much higher than the 1 mg/L used in the Upper Watershed. This difference in chemical doses is a measure of the cost difference between treating Delta and Upper Watershed water, as discussed in Section 3.6. Compared to their Upper Watershed counterparts, operators at plants receiving Delta water must handle higher constituent concentrations and make more frequent adjustments to accommodate variability in TOC, turbidity, and bromide.

All of the Delta WTPs included in this study have challenges optimizing coagulation due to low and variable raw water alkalinity levels. Figure C-26 through C-28 present TOC, bromide, and turbidity ranges and medians, respectively. The Barker Slough intake has the greatest range and highest media value for TOC and turbidity. Of the Delta intakes, the Rock Slough and Old River intakes have the greatest range and highest median bromide concentrations, which can result in additional difficulty in meeting DBP MCLs for TTHM, HAA5, and bromate. In addition to treatment challenges due to alkalinity, qualitative information gathered from the study WTPs indicates that the WTPs do have differing concerns based on the Delta region from which they receive water. Some of the specific treatment challenges experienced within the different regions used to test Hypothesis 3 include:

- High TOC concentrations in the NBA (Figure C-26). NBA contractors receive higher TOC concentrations than the other WTPs treating Delta water do. City of American Canyon WTP operators make modifications to pre-treatment and coagulant doses based on incoming TOC concentrations. In addition, The City of American Canyon WTP staff feels that the high episodic TOC concentrations are a concern with respect to meeting future DBP regulations. Representatives of many of the other WTPs indicated that percent TOC removal is typically sufficient to meet TOC regulatory requirements when they focus on meeting turbidity removals, and that their operations are dictated more by incoming turbidity concentrations. However, many WTP representatives reported concerns about achieving sufficient TOC removal to minimize DBP formation.
- Blending or switching sources. For the City of Antioch WTP staff, changes in source water in the Central/South Delta due to incoming chloride concentrations requires continual optimization when the source switches at the Central/South Delta plants.
- Algae growth in the Delta and along the SBA and California Aqueduct. The Zone 7 Patterson Pass WTP and AVEK, Quartz Hill WTP representatives reported that algae growth causes disruptions in their WTP processes (filtration and sedimentation/clarification).
- Variability in Delta water quality. ACWD WTP #2 was constructed with ozone, which addresses T&O, but must continually make adjustments to operations due to fluctuations in raw water alkalinity, pH, and bromide. Zone 7 Patterson Pass WTP representatives reported that continual variability in Delta water quality is challenging for pretreatment optimization for their WTPs on SBA.

5.1.3 Blending with Alternative Supplies

Source - Hypothesis 4: *Changes in the quality of Delta water prompt WTPs to switch to or blend Delta water with other water and effectively reduce the reliability of the Delta as a drinking water supply.*

Data obtained during this study does not either fully support or refute this hypothesis. Additional data and information is needed to fully evaluate this hypothesis.

Based on the initial WTP database analysis used to select the WTPs for this study, the majority of WTPs that receive Delta water do not have alternative supplies. WTPs with significant alternative water supplies were not included in this study, to keep the focus of the study on the impact of Delta water on drinking water quality and treatment, and to limit the number of WTPs for this study.

The SBA contractors, ACWD WTP #2 and Zone 7 Patterson Pass use SBA water and receive about 20 percent of their total water supplies from Lake Del Valle. DWR operates both the SBA and Lake Del Valle releases and it is operated more with respect to keeping a full pool during the summer for recreation. However, SBA contractors will submit requests to DWR when the Delta water becomes significantly degraded and mixing Delta water with Del Valle water would be beneficial to treatment.

CCWD operates its intake structures and manages filling Los Vaqueros Reservoir according to salinity concentrations. As a result CCWD is able to effectively store higher quality Delta water for use during times of poorer water quality. However, the difference in Los Vaqueros water quality and other intake water quality can present challenges to City of Antioch treatment when sources are switched. It should also be noted that CCWD is also bounded by other restrictions with respect to pumping, as discussed in the conceptual model and Section 4.0.

In order to fully evaluate this hypothesis it would be necessary to collect water quality data and operational information from WTPs that have greater than 20 percent alternative supplies.

5.2 Storage and Conveyance

The storage and conveyance hypothesis were tested for the WTPs with Delta intakes only (NBA, Central/South Delta, SBA, and California Aqueduct), because the Upper Watershed WTPs receive water from the Sacramento River directly via enclosed pipelines. Each region has differences in conveyance and storage. Depending on residence times in the conveyance and storage structures, water quality can change. The hypotheses for storage and conveyance were developed to look for these changes in water quality.

5.2.1 Attenuation of Water Quality

Storage and Conveyance - Hypothesis 1: *Long residence times within conveyance and storage facilities result in changes to water quality constituents, such as TOC/DOC, bromide, nutrients, algae, turbidity, and pathogens. For more conservative constituents (e.g., bromide and TDS or EC), longer conveyance and storage residence times attenuate the variability seen at Delta intakes. For highly reactive constituents (e.g., nutrients and algae), longer residence times in storage change the water quality characteristics.*

The data gathered during this study supports the hypothesis that long residence times in storage change TOC/DOC, bromide, and turbidity. The data does not support this hypothesis for conveyance. Additional data is necessary to evaluate this hypothesis with respect to nutrients, algae, and pathogens.

The CLWA Earl Schmidt Filtration Plant is the only WTP included in this study that pulls raw water from a storage reservoir with long residence times. The Earl Schmidt Filtration Plant intake water quality data demonstrated that Castaic Lake acted as a buffer for the variability of TOC, turbidity, and bromide, and acted as a sink for TOC and turbidity (Figures 3-16 through 3-18). The Zone 7 Water Agency, Patterson Pass WTP staff has also observed water quality benefits from the 30 MG Patterson Pass Reservoir, which receives water from an overflow weir off of the SBA. Ranges and median turbidity levels and TOC concentrations from 2004 to 2006 were slightly lower at the Patterson Pass WTP intake than at the ACWD WTP # 2, which receives water directly from the SBA a short distance downstream from the Patterson Pass Reservoir (Figures 3-14 and 3-16). The Patterson Pass WTP staff has observed better water quality and less variability at the Patterson Pass WTP than at the other Zone 7 Water Agency WTP, Del Valle WTP, which receives water directly from the SBA without any intermediate storage.

The NBA distribution pipeline and turnout structures are mostly enclosed downstream from Barker Slough intake, and the data available during the study was not sufficient to evaluate changes in water quality through the NBA. Likewise, identifying attenuation of water quality constituents or degradation to water quality from the data set provided by CCWD for the Contra Costa Canal was not possible. A current CCWD project, lining a portion of the Contra Costa Canal to prevent water quality degradation caused by infiltration, suggests that water quality does degrade in the canal, but that the degradation is attributable to factors other than simply the time in transport. The data obtained for this report did not demonstrate any significant changes through the SBA with respect to TOC, turbidity, and bromide (Figures 3-10 through 3-12).

The *California SWP Watershed Sanitary Survey 2006 Update* evaluation found that turbidity increases and becomes more variable along the aqueduct south of San Luis Reservoir and that that there is a “substantial increase” in bromide between Banks Pumping Plant and San Luis Reservoir (SWP Contractors Authority 2007). Algae growth in both the SBA and California Aqueduct has been reported by representatives of the study WTPs and through DWR sampling for MIB and geosmin in conveyance facilities. This information does not support the hypothesis that a longer conveyance residence time attenuates conservative constituents such as bromide, TDS, and EC.

Only one study WTP, the CLWA Earl Schmidt Filtration Plant, consistently received Delta water that had been stored for long residence times. The CLWA Earl Schmidt Filtration Plant was compared to another study WTP that received Delta water via lengthy conveyance, AVEK Quartz Hill WTP. This limited data (based on one applicable WTP) suggests that storage has a greater impact on attenuating water quality constituents and limiting variability than conveyance does. Data from the Zone 7 Patterson Pass WTP intake also demonstrated some water quality improvements as a result of storage time in a small reservoir upstream from the WTP. While storage in well-managed systems can provide attenuation of high concentrations and a reduction in variability for some water quality constituents, systems not managed for optimum water quality can result in degradation of water quality. Often storage reservoirs are managed for multiple purposes, these other restrictions can result in less than optimal water quality. Algae growth in conveyance and storage reservoirs along the California Aqueduct has been reported to be a significant problem for some systems. In summary, storage can effectively improve water quality but storage and conveyance systems need to be well managed to prevent potential water quality degradation.

The data in this study indicates that conveyance degrades water quality with respect to some constituents and at specific locations, as discussed above.

5.2.2 Algae and Taste and Odor

Storage and Conveyance - Hypothesis 2: *All plants receiving Delta water have T&O issues associated with Delta water, but the nature and extent of their T&O problems are dependent on intake location and their conveyance and storage infrastructure.*

The T&O information collected for this study does not support this hypothesis. Overall, not all WTPs that treat Delta water receive T&O complaints.

Section 3.8 described the data evaluation activities necessary to evaluate this hypothesis. SWP and Contra Costa Canal system MIB and geosmin data, indicators of algae growth, show that algae growth occurs both in the Delta and in the conveyance facilities. The causes of algae growth in those facilities are both the presence of nutrients in Delta water and the conditions present in the conveyance structures (discussed in Section 3.5). Indicators of algae growth or nutrient data at the WTP intakes were not available to link algae growth and T&O complaints directly. In evaluating this hypothesis, the study team considered the following evidence:

- The *California SWP Watershed Sanitary Survey 2006 Update* noted that while there is algae growth in the Barker Slough Watershed and the Napa Turnout Reservoir, NBA customers do not typically make T&O complaints. City of American Canyon has not documented T&O complaints associated with algae and does not treat its water with ozone.
- Algae growth and MIB and geosmin have been identified in both the Contra Costa Canal and the SBA, but the WTPs that include ozonation typically do not receive T&O complaints.
- The study WTPs on the California Aqueduct, CLWA Earl Schmidt Filtration Plant and AVEK Quartz Hill WTP, are wholesalers, so T&O customer complain information was not available from them.

While many of the WTPs treating Delta water do not have a significant number of T&O complaints associated with algae growth, this is not clear evidence that algae growth in the Delta or along conveyance structures is not currently problematic. The information presented in Section 4.0 with the conceptual models identified a number of issues associated with algae growth in the Delta.

It should also be noted that operation of ozone systems that treats T&O causing compounds is more expensive than chlorine disinfection.

5.2.3 Delta Variability

Storage and Conveyance - Hypothesis 3: *Treatment plants receiving water directly from the Delta (e.g., via the SBA) have costs and operational challenges beyond those of plants that receive Delta water with longer residence times in storage and conveyance that provide a buffering capacity.*

The data and qualitative information collected for this study neither supports nor refutes this hypothesis. This could be due to data limitations, limitations of the data analysis, and/or the construction of the hypothesis.

TOC, bromide, and turbidity data presented in Section 3.4 indicate that the variability within the SBA and at ACWD WTP #2 (Figures 3-13 through 3-15) may be greater than within the Central/South Delta (Figures 3-10 through 3-12) and the California Aqueduct (Figures C-12 through C-14). In addition, the NBA water quality is highly variable and has higher episodic peaks with respect to TOC and turbidity than the SBA. However, the qualitative information obtained from the WTPs and presented in Section 4 indicates that all of the WTPs, except CLWA Earl Schmidt Filtration Plant, are challenged by the variability of Delta water quality in some respect, regardless of their intake location within the conveyance structure. Some of the issues associated with water quality variability are described below.

- The City of American Canyon WTP increases its alum dose based upon incoming TOC concentrations and must purchase differing concentrations/pHs of pre-mixed acidified alum dependent on the alkalinity of the incoming water. The episodic high TOCs are a concern with respect to meeting DBP regulations. Meeting turbidity filtration requirements is also a challenge for the City of American Canyon WTP with its conventional WTP during episodic high turbidity events.
- City of Antioch WTP staff members reported that when they change supplies (and switch between their independent intake, Contra Costa Canal water direct from the Delta intakes, and Los Vaqueros Reservoir) they have difficulties in operating their pre-treatment systems.
- The Zone 7 Patterson Pass staff reported that optimizing pre-treatment is challenging due to the variability of incoming pH, alkalinity, TOC, and turbidity. The Patterson Reservoir provides some attenuation to the variability at the Paterson Pass plant compared to Zone 7's Del Valle WTP, which experiences more variability and operational challenges because it does not have an intermediate reservoir.

The CLWA Earl Schmidt Filtration Plant is the only WTP treating Delta water that did not have significant variability in the source water causing treatment challenges (Figures 3-16 through 3-18). As a result of long storage times in the reservoirs on the West Branch of the California Aqueduct, there is significant attenuation of variability in TOC, turbidity, and bromide in Castaic Lake. The CLWA staff did report that when Castaic Lake is not kept at a full pool the WTP receives water more directly from the California Aqueduct (i.e., with a shorter residence time in Castaic Lake) and the WTP's raw water quality is more variable.

One of the intents of this hypothesis was to evaluate the difference in water quality at WTP intakes that are closer to the Delta intakes, (i.e., the SBA), compared to those with longer conveyance residence times and with storage, (the California Aqueduct). However, the water quality data is insufficient to compare the changes in variability and water quality due to conveyance residence times for the two aqueducts. From a qualitative perspective, representatives of the SBA WTPs, Zone 7 Patterson Pass and ACWD WTP #2, did explain that continued issues with variability in many raw water quality constituents is a continual struggle and changes in water quality can happen very rapidly because they receive water so quickly from the Delta.

Additional, related discussion points are included under Storage and Conveyance Hypothesis 1, Section 5.2.1.

5.3 Treatment

The hypotheses related to treatment look at both the impact of source water quality on finished water quality and the ability of filtration and disinfection processes to meet WTP goals and regulations. The treatment hypotheses also compared the difference in meeting DBP regulations in the Upper Watershed and Delta WTPs.

5.3.1 Disinfection By-Product Formation

Treatment - Hypothesis 1: *Higher raw water TOC concentrations due to source water quality, conveyance, and local watershed inputs lead to increased DBP formation.*

Treatment - Hypothesis 2: *Plants employing alternative disinfectant technologies:*

i. *Have lower DBP concentrations and/or meet maximum contaminant levels (MCLs) more reliably;*
ii. *Achieve higher log removals; and*
iii. *Are better prepared to meet future regulations (e.g. lower DBP MCLs).*

The data obtained for this study neither fully supports nor refutes these hypotheses. This is due to both data limitations and the complexity in the relationship between drinking water treatment and source water quality.

Figure 3-20 and 3-21 and Appendix C-20 through C-25 presented TTHM and HAA5 concentrations by quarter for 2006 for the WTPs that provided DBP data. Figure 5-1 summarizes study data relevant to the evaluation of this hypothesis.

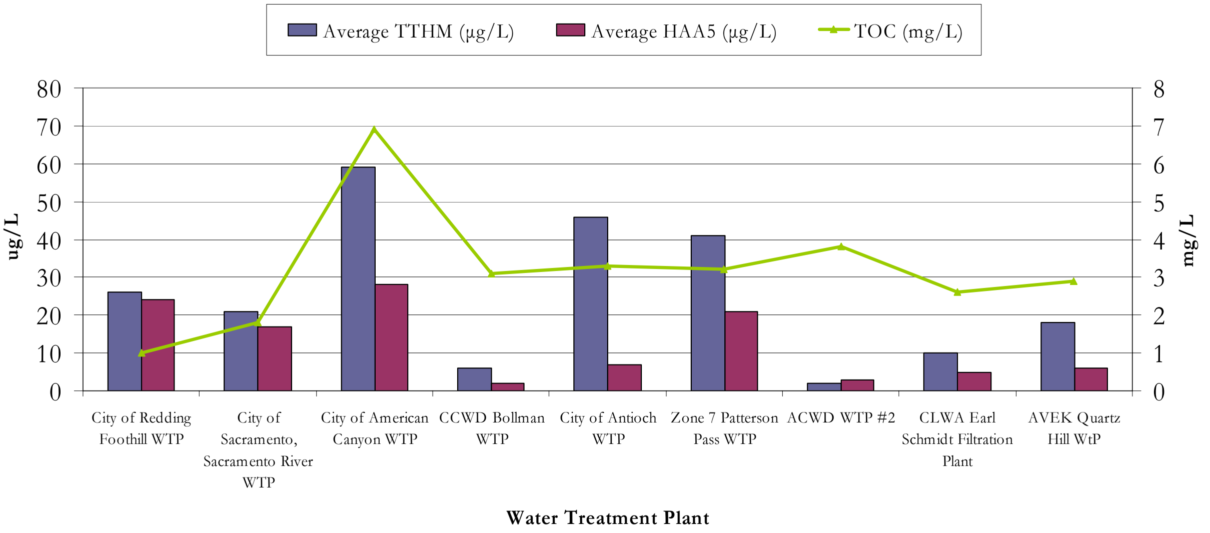


Figure 5-1. Average TTHM, HAA5, and TOC Concentrations from 2004 to 2006 at Selected WTPs Participating in the Study.

The following observations are useful in evaluating Treatment Hypothesis 1:

- Figure 5-1 shows the City of Redding, Foothill WTP and City of Sacramento, Sacramento River WTP have low DBP concentrations and typically treat water with low TOC concentrations. However, the AVEK Quartz Hill WTP, which also uses chlorine disinfection, has TTHM and HAA5 concentrations that are as low as those at Upper Watershed WTPs but the average TOC concentration is higher.
- The City of American Canyon WTP and City of Antoich WTP also both use chlorine as their primary disinfectant. Compared to Upper Watershed WTPs, the TOC concentrations at these plants are higher and TTHM and HAA5 concentrations are higher.

The data does not entirely support the hypothesis that higher TOC concentrations alone result in high DBP formation and demonstrates that DBP precursor removal aids in limiting DBP formation at WTPs that use chlorine as their primary disinfectant. This is partially due to the limited data set but also due to difference in DBP sample location and treatment processes.

The following observations are useful in evaluating Treatment Hypothesis 2.i:

- The City of Redding, Foothill and City of Sacramento, Sacramento River WTPs have very low TTHM and HAA5 concentrations using free chlorine as a primary disinfectant. Other Delta WTPs also using free chlorine, the City of Antioch WTP and City of American Canyon WTP, have higher TTHM and HAA5 concentrations than the Upper Watershed WTPs but still meet DBP MCLs with chlorine disinfection.
- CCWD Bollman, ACWD WTP #2, CLWA Earl Schmidt Filtration Plant, and ACWD WTP #2 all use ozone as a primary disinfectant and have the lowest TTHM and HAA5 concentrations of the WTPs included in this study.

This information supports the hypothesis that WTPs practicing alternative technologies have lower DBPs and are able to meet DBP MCLs more reliably. If these WTPs can continue to achieve these low DBP concentrations, they will be more likely to be able to continually meet THM and HAA regulations in the future (Treatment Hypothesis 2.iii).

All the WTPs included in this study meet log removal requirements. Hypothesis 2.ii was not evaluated during this study because all WTPs reported achievement of sufficient log removal while meeting DBP MCLs.

Data regarding bromate (a DBP of ozone) concentrations was not obtained during this study. Representatives of all WTPs disinfecting with ozone did, however, report challenges with bromate minimization strategies and concerns about bromate formation, because of the high bromide concentrations in Delta water. While WTPs using ozone, the only alternative disinfectant evaluated in this study, are able to reliably meet THM and HAA regulations, the use of ozone results in a trade off with challenges in managing another DBP, bromate.

5.3.2 Effectiveness of Conventional Filtration

Treatment Hypothesis 3: *Current conventional filtration processes in use in California provide sufficient filtration/removal of organic carbon in Delta water.*

The data and qualitative information obtained in this study supports this hypothesis. The WTPs practicing conventional treatment are able to meet regulations and have modified or upgraded processes to meet many of the challenges associated with treating Delta water; however, current operating practices frequently come at a high cost, treating Delta water remains challenging, and WTPs can always benefit from new technologies. While TOC removal is challenging, WTPs treating primarily Delta water are able to meet required TOC percent removal and meet DBP MCLs.

Specific water quality compliance information is not presented in this report as all of the WTPs meet CDPH regulations.

Delta WTP representatives reported the following particular challenges related to TOC with conventional treatment.

- Achieving enhanced coagulation or obtaining adequate TOC removal due to low and variable alkalinities remains challenging for all study WTPs using Delta water. For SBA contractors, this is further complicated by variations in pH. Alkalinity and pH affect coagulation significantly.
- The City of American Canyon has a challenge due in part to extremely high TOC concentrations, but also due to low alkalinities.

In addition to TOC removal, Zone 7 Patterson Pass WTP experiences shortened filter runs as a result of algae growth in the Delta and SBA.

In summary, the challenge in treating Delta water lies in optimizing pre-treatment. With optimal pre-treatment, WTPs are able to effectively treat Delta water with conventional filtration.

5.3.3 Effectiveness of Membrane Filtration

***Treatment Hypothesis 4:** Compared with conventional filtration, membrane filtration achieves as good or better finished water quality (pathogens, TOC, and turbidity).*

There was insufficient data to evaluate this hypothesis. City of American Canyon, ACWD, and Zone 7 staff provided qualitative information related to this hypothesis. The ACWD, Mission San Jose WTP was not included in this detailed study; however, the staff members provided qualitative information on the operation of this membrane WTP.

Both ACWD and Zone 7, which run membrane processes as well as conventional processes, have found the operation of their membrane processes challenging and have reported numerous operational upsets and membrane fouling caused by poor Delta water quality. Representatives of both of these WTPs prefer the operation of their conventional processes. In contrast, the City of American Canyon is able to achieve consistent and reliable turbidity removal with less operator attention using its membrane plant than on its conventional plant.

All three membrane WTPs have different membranes and process trains. Differences in equipment and upstream treatment processes affect water quality and operations significantly. To fully test this hypothesis, an analysis of side by side raw water, post pre-treatment, filtrate data and more comprehensive operation data is necessary.

6. CONCLUSIONS AND RECOMMENDATIONS

As part of the CALFED WQP Stage 1 Final Assessment, the WQP conducted a study of drinking water quality from the Delta intakes through WTP intakes. This section presents the conclusions of the systematic study, which the WQP conducted with assistance from Reclamation, CDPH, a small working group of the CALFED Water Quality Subcommittee, and their consultants, Brown and Caldwell. The results of this study, presented in earlier sections, demonstrate linkages between water quality in the Delta and treatment of the water at WTPs. The study team drew several key conclusions from the data (Section 6.1), and based on them, developed recommendations regarding the development of quantitative drinking water performance measures (Section 6.3) and regarding next steps for the WQP (Section 6.4).

6.1 Study Conclusions

Below are the key study conclusions from the analysis of water quality data, consideration of information obtained from WTP staff, and hypotheses testing presented in Sections 3 through 5. The conclusions are presented by system component - source, conveyance and storage, and treatment.

6.1.1 Source

- Many of the water quality challenges experienced at the case study WTPs originate with Delta intake water quality. Delta intake water has TOC, turbidity, and bromide concentrations that are higher and more variable, and that require more extensive treatment than the Upper Watershed (WTPs on the Sacramento River in this study) raw water sources.
- Water at the Upper Watershed WTPs in this study comes closer to meeting the ROD intake targets than water from the Delta. Water at the Upper Watershed WTP intakes consistently meets CALFED ROD bromide and TOC intake targets while the water at the Delta intakes does not. The differences in source water quality affects treatment and operation in the case study WTPs. Achieving water quality at the Delta intakes that is similar to Sacramento River water quality, through conveyance and/or source improvement projects, would significantly increase the ability of WTPs to meet treated water quality objectives less expensively and more reliability.

6.1.2 Conveyance and Storage

- Algae growth in the Delta and along conveyance and storage structures results in operational upsets, presents challenges with respect to pre-treatment optimization and T&O, and is not fully addressed by current mitigation methods. Algae mitigation is a growing concern due to increased limitations on copper sulfate use.
- Storage time between Delta intakes and WTP intakes can attenuate high concentrations of undesirable constituents and buffer the variability of water quality from the Delta but must be carefully monitored and/or managed to avoid degradation of water quality.

6.1.3 Treatment

- Treatment issues associated with TOC concentrations in the Delta are compounded by low and variable alkalinity, which makes achieving optimal TOC removal and optimizing pre-treatment difficult.

- While treatment plants are able to meet TOC percent removal regulatory requirements, they are not always able to meet the agency/WTP TOC removal objectives to minimize DBP formation.
- The treatment challenges associated with Delta water quality depend on which Delta intake a WTP uses, and upon the conveyance used. Specific regional problems include:
  - High TOC in the NBA;
  - Algae growth and resultant changes in water quality along the SBA; and
  - Continual changes in source water quality, with corresponding changes in WTP intake water quality that affect treatment differently in each region.
- Most treatment plants treating Delta water are able to consistently meet DBP MCLs; however, DBPs continue to be a challenge when WTPs treat raw water having high TOC concentrations. TOC removal and the optimization of disinfection processes are also challenging when treating Delta water.
- For WTPs that have switched to ozone, limiting bromate formation remains a challenge; however, most of the study WTP operators prefer to use ozone for T&O benefits and THM/HAA minimization.

6.1.4 New Findings

In addition to confirming many of the historic beliefs and assumptions on Delta drinking water quality, this study developed new information regarding the treatment of Delta water and offered fresh perspectives, as follows.

- The cost difference between treating Delta water and treating Upper Watershed water can be roughly quantified and evaluated by comparing pre-treatment chemical concentrations associated with WTP intake TOC and turbidity concentrations.
- Challenges posed by algae growth are becoming more complicated, as a result of more prevalent year-round growth, which causes operational challenges beyond T&O issues. Regulatory restrictions on mitigation measures (i.e., copper sulfate usage) are exacerbating the problem.
- This study clarified the following issues, highlighting the complexity associated with balancing TOC removal and DBP minimization.
  - Meeting TOC percent removal and DBP regulations may not be sufficient to meet the challenges posed by future DBP regulations,
  - Treating and removing the high TOC concentrations in Delta water is challenging because of the Delta water quality matrix, necessitating continued research on Delta specific optimization strategies for TOC removal and DBP minimization.
  - Episodic changes in the water quality matrix can compound TOC removal issues.

6.2 Providing Context for ELPH

One of the purposes of this study was to help the WQP develop a better understanding of the ROD objective of achieving an "equivalent level of public health protection (ELPH) using a cost effective combination of alternative source waters, source control, and treatment technologies." The Conceptual Model Framework, upon which the individual WTP conceptual models were based, helps to outline the components of ELPH. The conceptual models present a visualization of boundary conditions and constraints. While the information is presented for individual WTPs, many of the potential areas in which the WQP could aid in achieving the ELPH objective are regional or statewide in nature.

Development of the conceptual models brought to light the following ways in which the WQP could assist in meeting ELPH objectives when water quality targets at the source are not being met.

- Investigate the potential for additional storage for the WTPs that do not have intermediate storage between the Delta and their WTP intakes.
- Research, develop, and implement new storage practices to maintain and/or improve drinking water quality
- Research, develop, and implement additional algae mitigation strategies.
- Research, develop, and implement new Delta specific TOC removal strategies.

The conceptual models provide visual tools that show examples of system infrastructure and highlight locations where water quality degradation may occur. They provide a framework that depicts the water quality linkages from source to tap and support critical thinking regarding how best to balance management decisions and select preferred alternatives for meeting ELPH objectives.

6.3 Performance Measure Development

Using the Conceptual Model Framework, the study team developed a System Water Quality Conceptual Model (Appendix E). The System Water Quality Conceptual Model diagrams and explains the areas and processes in the system where water quality may be affected by infrastructure or the natural environment, and presents a visual context for how key water quality constituents may change through the system. It also shows key data gathering locations within the system. Where possible, the study team gathered data for the constituents of concern at these locations, as presented in Section 3.0. Through review of data in the context provided by the System Water Quality Conceptual Model, the study team developed recommendations regarding performance measures that would help to evaluate water quality improvements in the near term. Section 6.3.1 describes this recommended set of currently achievable performance measures, and Section 6.3.2 describes an "ideal" set of performance measures that could determine whether ELPH and other specific water quality objectives are being met over the long term.

6.3.1 Recommended Performance Measures

In order to develop practical quantitative drinking water performance measures beyond those embodied in the ROD targets, it is necessary to determine which water quality constituents are most relevant to drinking water quality. As a start, the fact that WTPs measure (and adjust treatment according to) certain constituents is a good indicator that those constituents have a high level of relevance. In addition, for performance measures to be useful, the constituents need to be monitored at a sufficient frequency for analysis through the system. Measurement and evaluation of the selected constituents need to be conducted such that it is informative to the WQP regarding changes in water quality. Section 6.3.1.1 describes the recommended water quality constituents to be to be included in performance measures and Section 6.3.2 recommends a process by which these constituents can be used for performance measures.

6.3.1.1 Performance Measure Water Quality Parameters

Based on the data and information obtained during this study, performance measures for evaluation of water quality improvements should be developed for two tiers of parameters.

Tier 1 Parameters are direct indicators of WTP source water improvement. These are key drinking water quality constituents that are measured at the Delta intakes, through conveyance and storage, and at the WTP intakes at a daily or higher frequency. These parameters can be used to investigate improvement or degradation of water quality, changes in variability, and decreases in episodic high constituent concentrations at the Delta source. Because these parameters are also measured within conveyance and at the WTPs, they are good measures for evaluating changes in water quality through the system, both improvements and degradation. For Tier 1 parameters, evaluations should examine variability and typical parameter concentrations for improvements in water quality.

- **TOC.** TOC can be linked directly to the evaluation of DBP formation. There is currently sufficient baseline information from the intakes to the WTPs on TOC, which is monitored frequently, daily for most plants. Due to inconsistency in TOC and DOC measurements at the Delta intakes, within conveyance, and at WTP intakes, either TOC or DOC should be selected at the outset. Further, one analytical method should be designated at the outset of performance measurement implementation.
- **EC/TDS/Chloride**. All of these parameters are used as measures of salinity in the Delta and conveyance systems but at different frequencies depending on location. Salinity measurements are important because bromide (a salinity constituent measured as part of EC and TDS) concentrations have significant impacts on DBP formation and WTP operation. Bromide is typically not evaluated at as high of a frequency as EC, TDS, and chloride are at the Delta intakes, through conveyance, and at the WTP intakes. One of these measures of salinity should be selected to evaluate changes in salinity as a surrogate for bromide.
- **Turbidity.** While turbidity was not identified previously as a constituent of concern, it is a critical water quality parameter for drinking water treatment. Historically, turbidity was used as an indicator for the potential for pathogens to be present in source water and as a measure of input from storm water or other sources into a watershed. Sufficient baseline information exists for turbidity levels from the intakes to the WTPs. WTPs monitor turbidity with on-line monitors, and many WTPs treating Delta water make operational adjustments according to incoming turbidity concentrations.

Tier 2 Parameters are indicators of drinking water quality improvement but would not necessarily be direct measures of Delta source water quality improvements. These parameters are as important as the Tier 1 parameters; however, they are not measured as frequently and are influenced significantly by water quality management strategies within conveyance, storage, and drinking water treatment. Measurement of these parameters for performance measures are to be done at the WTPs.

- **Pathogens and Pathogen Indicators.** Pathogen data for the Delta intakes, at storage and conveyance locations, and at the WTP intakes is limited. WTP staff members typically measure pathogen and pathogen indicator microorganisms weekly to monthly, depending on the microorganism. Due to the complexity of factors influencing pathogen and pathogen indicator decay, evaluation of pathogen and pathogen indicators as a performance measure should be conducted only for the WTP intakes.
- **DBP.** DBP concentrations for individual WTPs help identify the impacts of Delta source water quality and demonstrate a WTP's ability to meet its objectives. Performance measures should include speciated DBP concentrations, where appropriate, at the individual WTPs and at the location closest to the finished water outlet of each WTP.
- **T&O associated with Algae.** Most WTP agencies measure neither nutrients nor surrogate measures for algae (chlorophyll-a, MIB, and geosmin) at their intakes; however, the agencies do track T&O complaints and the cause to which those complaints are attributed. Performance measures should include requirements for tracking and evaluating the numbers and causes of T&O complaints, to provide indicators of the success of algae mitigation for drinking water treatment. This can be augmented by information available on algae growth in the Delta and through conveyance; however, this information is not consistent enough to inform entirely on drinking water quality.

At this stage, it is not recommended that specific targets be developed for Tier 2 parameters, however, the WQP should continue to take steps to minimize pathogens, reduce DBP concentrations, and address algae growth to reduce the associated number of T&O and operational issues to the extent possible.

6.3.1.2 Analysis of Performance Measures

It is recommended that the WQP produce an annual report on drinking water quality as indicated by the Tier 1 and 2 parameters. As discussed above, Tier 1 parameters would be used to measure changes in water quality through the system, and Tier 2 would measure changes in drinking water quality at the WTPs. The evaluation would assess whether changes in the variability of water quality and changes in constituent concentrations occur.

To limit the initial effort, it is recommended that five to six WTPs be solicited as an initial set of WTPs from the four Delta intake regions to provide data for both Tier 1 and Tier 2 parameters. Using the WTPs in this study would provide a head start, in that this report presented some of this initial information. As the effort grows, more WTPs can be included into the annual report. Participation of CCWD and one of its WTPs would provide particularly useful Central/South Delta information, because CCWD collects data at locations along the entire route of water from its Delta intakes to its WTPs. Intake and conveyance water quality data is available through the DWR's Water Data Library and California Data Exchange Center for the other Delta intake regions. To limit the data collection and evaluation effort for WTPs, a standardized data collection spreadsheet and database should be developed and employed to compile the data and conduct basic statistical evaluations.

As part of a yearly evaluation of the Tier 1 and 2 parameters, the System Water Quality Conceptual Model can be further developed and augmented to identify and explain the changes in water quality through the system.

6.3.2 Ideal Set of Performance Measures

The ideal set of drinking water quality constituents for performance measures, measured from the Delta intakes to the WTP intakes and at the WTP outlets, contains the same constituents as the recommended set discussed above. For consistency, and to provide additional valuable information, the set of parameters would be augmented as described below.

6.3.2.1 Water Quality Parameters

- **TOC/DOC and UV254**. Ideally, TOC would be measured on a daily basis and with the same analytical method throughout the system. In addition to TOC measurements, DOC and UV254 measurements would be included in the ideal set, to allow for a better characterization of organic carbon. These additions would provide enhanced information on the changes in DBP formation potential through the system.
- **Chloride/Bromide/Iodide**. Salinity monitoring methods are not consistent throughout the system. Rather than using more indirect measures, it would be more beneficial to measure bromide, chloride, and iodide consistently and at a regularly frequency - perhaps daily - throughout the system. This is particularly important as the public health concern over idodated and bromated THM and HAAs grows. Directly monitoring bromide and chloride are more useful for identifying salinity challenges and concerns than monitoring for EC or TDS alone.
- **Turbidity**. Turbidity can be monitored continuously with simple on-line analyzers, throughout the system. These turbidity measurements could provide a measure of daily variability for WTPs, which are often operated according to incoming turbidity values.
- **Alkalinity.** Alkalinity measurements in the Delta and at other locations within the system are needed to provide a better understanding of seasonal and monthly changes in alkalinity. Historically, alkalinity has not been monitored consistently within the SWP conveyance system.

- **Nutrients, Algae Counts and Algae By-products**. Reports of year round algae growth and associated T&O indicate that year round, weekly monitoring of algae and algae by-products is merited. When higher levels of algae growth occur, algae counts and measurements for algae by-products should be conducted more than weekly. Additional nutrient monitoring on a weekly basis would help in understanding the nutrient thresholds at which problems occur in the Delta system.
- **Pathogens/Indicator Microorganisms.** Daily-to-weekly measurements to augment WTP intake monitoring can provide information about Delta pathogen concentrations and how they change through the system. Currently, little is known about pathogens and indicator microorganism throughout the system.
- **DBP**. Sampling should be conducted at the location nearest to the outlet of each WTP for both regulated and non-regulated THMs and HAAs on a weekly basis. Concerns regarding idodated and brominated DBPs are growing industry wide. Understanding the nature of their occurrence at Delta WTPs, which use source water with high concentrations of iodide and bromide DBP precursors, could be important in meeting future regulations.

Monitoring for these sets of parameters throughout the system at the above-recommend frequency would be expensive; development of this ideal set of performance measures did not consider costs, but outline a long-term objective.

6.3.2.2 Frequency and Locations

For the ideal set of water quality performance measures all of the water quality constituents would need to be measured frequently, at a number of key locations in the system. In addition to the Delta and WTP intakes, other key locations would be: downstream from significant storage facilities; downstream from other locations that could improve or degrade water quality; and after long residence times in conveyance. The frequency of monitoring at all locations should be consistent within the parameter group and should be sufficient to evaluate the water quality constituents on a seasonal and weekly basis. The analysis and frequency of monitoring should be at a daily level at the WTP intakes to identify changes in variability and concentration at the WTP level. Daily monitoring at the WTP would provide signals for initiating additional water quality monitoring and would help to identify potential problems within the system that may need to be monitored.

6.3.2.3 Analysis

As recommended above, analysis would continue on a yearly basis for the ideal set of performance measures, in order to develop an annual report. The evaluation would include an investigation of changes in variability and median constituent concentrations at sampling locations as well as at the WTP intakes. At the Delta intakes, WTP intakes, and some key locations in conveyance and storage facilities, seasonal and weekly variability should be analyzed. As the database and analysis grows, numeric targets for reductions in variability and concentration can be set.

To assist participating WTPs, a user friendly database would need to be developed such that the WTPs can download data to the database directly.

6.4 Recommendations for WQP Stage II

The results of this water quality analysis, conceptual model development and hypothesis testing suggest that, to assist in improving drinking water quality, the WQP should pursue actions for reducing both the variability in water quality at the Delta intakes and the episodic high constituent concentrations, and develop strategies for storage and conveyance to dampen variability between the intakes and the WTPs. The study team developed the specific recommendations below for the WQP for Stage II actions (i.e., next steps).

6.4.1 Source

- Continue improving and/or maintaining Delta intake water quality. Particularly to variability for TOC, bromide, and turbidity.
- Continue to investigate projects (such as the Through-Delta facility) that could permit more direct access to Upper Watershed water for those WTPs currently treating Delta water.
- Fund research to develop alternatives to copper sulfate for algae mitigation at Clifton Court Forebay and other locations in the Delta as necessary.
- Approach drinking water quality and treatment challenges at a regional level to develop more site-specific solutions that meet local needs.

6.4.2 Conveyance and Storage

- Fund research to develop alternatives to copper sulfate for algae mitigation in conveyance channels and reservoirs
- Investigate/support enclosing sections of the conveyance channels that continually have significant algae growth.
- Investigate storage options for WTPs that currently do not have storage.
- Investigate alternatives to limit water quality degradation in Barker Slough or proceed with projects to re-locate the NBA intake.

6.4.3 Treatment

- To increase the level and availability of knowledge and experience with organic carbon removal, conduct detailed assessments of WTPs that achieve good organic carbon removal while treating water that is difficult to coagulate and that is high in organic carbon. Provide this information in a useable format to Delta WTPs.
- Evaluate the trade-offs between membrane treatment and conventional treatment with the help of agencies that currently operate both. This evaluation should consider the membrane technology used, influent water quality, and membrane and media filtrate.
- Provide direct outreach to disadvantaged communities with small WTPs that use Delta water to identify specific opportunities to improve drinking water quality at the level of these small WTPs statewide.

7. LIMITATIONS

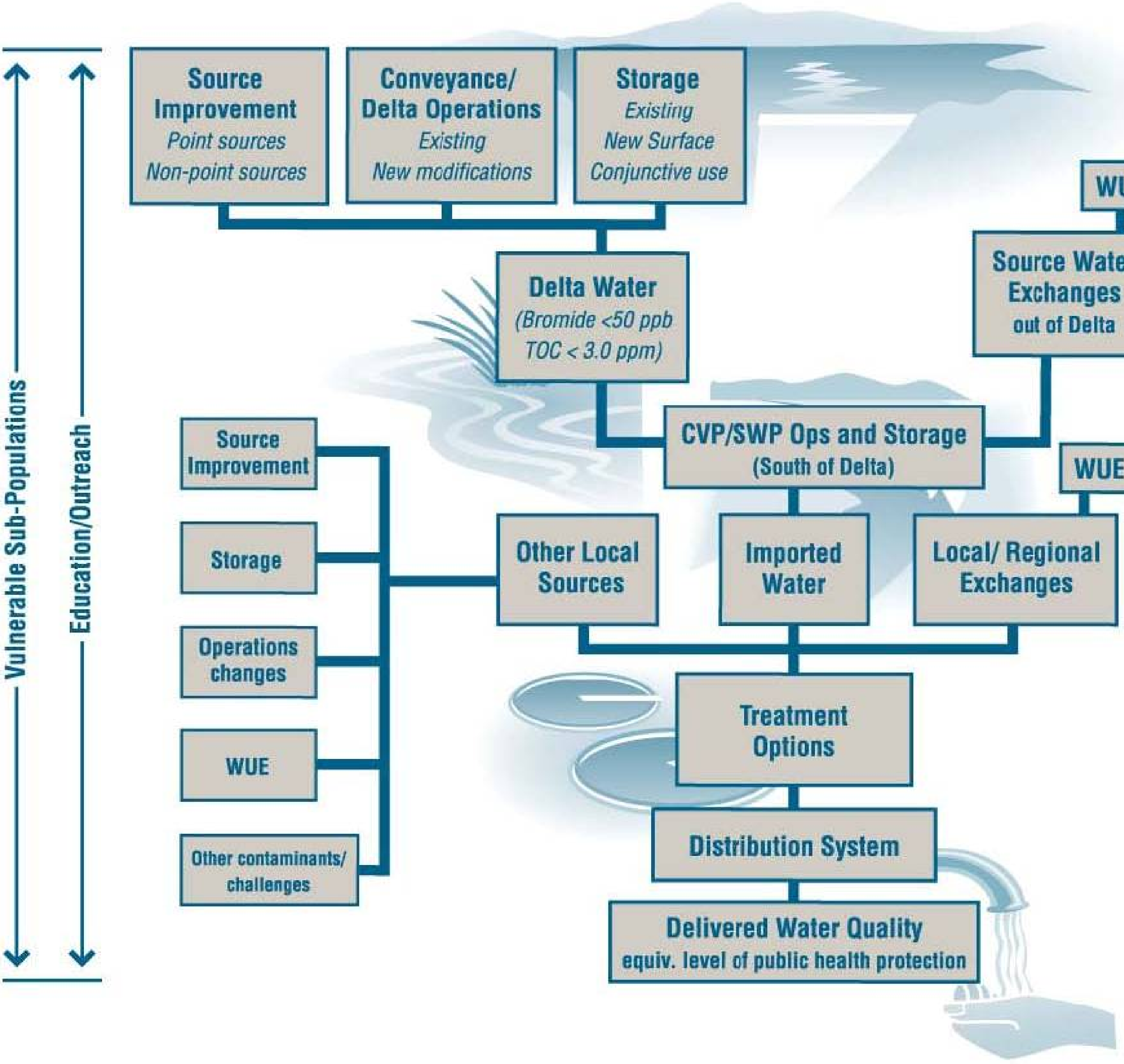
Report Limitations

This document was prepared solely for CALFED Water Quality Program and United States Department of the Interior Bureau of Reclamation in accordance with professional standards at the time the services were performed and in accordance with the contract between United States Department of the Interior Bureau of Reclamation and Brown and Caldwell dated, October 23, 2006 and CALFED Water Quality Program and Brown and Caldwell dated, May 2007. This document is governed by the specific scope of work authorized by both the CALFED Water Quality Program and United States Department of the Interior Bureau of Reclamation; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by CALFED Water Quality Program and United States Department of the Interior Bureau of Reclamation and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

APPENDIX A

ELPH Diagram

Equivalent Level of Public Health Protection (ELPH)



APPENDIX B

Approach to the Detailed Study

BROWN AND CALDWELL

Technical Memorandum

201 North Civic Drive, Suite 115
Walnut Creek, California 94596
Main Office Phone Number: (925) 937-9010

Prepared for: CALFED Water Quality Program

Project Title: Stage 1 Final Assessment; Tap Water Improvement

Project No: 131736-200-003

Technical Memorandum No. 3

Subject: Approach to the Detailed Study of Delta Drinking Water Quality

Date: June 11, 2007

To: Lisa Holm, P.E., Water Quality Program Manager

From: Sarahann M. Dow, Ph.D., Brown and Caldwell

Copy to: Claire Jacquemin, USBR

Prepared by: Emily A Moshier

Emily Moshier, Staff Engineer

Reviewed by: Sarahann M Dow

Sarahann Dow, Project Engineer

Limitations:

This document was prepared solely for the United States Bureau of Reclamation ((USBR) in accordance with professional standards at the time the services were performed and in accordance with the contract between Brown and Caldwell and URS Group, Inc. dated October 23, 2006. This document is governed by the specific scope of work authorized by USBR; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by USBR and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

1. INTRODUCTION

The CALFED Water Quality Program (WQP) is in the process of preparing the Stage 1 Final Assessment. As part of the Stage 1 Assessment, the WQP is taking a systematic look at drinking water quality. The CALFED WQP is seeking to better understand the CALFED Record of Decision (ROD) goal of "equivalent level of health protection (ELPH) using a cost effective combination of alternative source waters, source control and treatment technologies" and how to best implement this. The ELPH objective recognizes the connections among source water quality protection and public health protection, the importance of multiple barriers, and the ultimate retention of the Delta as a drinking water source. This study will look at water quality from the Delta Intakes through treatment as a "system" and will expand on the ELPH framework to evaluate drinking water quality from the Delta Intakes through storage, conveyance, and treatment. This effort will build off of lessons learned while preparing the Initial Assessment and the "Issues with Delta Drinking Water Treatment" study. The initial work completed for the "Issues with Delta Drinking Water Treatment" was an informative qualitative survey. The detailed study will attempt to quantify the issues identified during this initial effort and expand upon them. The information gathered in this detailed study, both qualitative and quantitative, will inform the CALFED WQP on the need for future actions to improve drinking water quality. The detailed study will develop quantitative goals for "drinking water treatment" for Stage 2 and to support crucial decisions being made in 2007 and 2008 as part of the Delta Vision Process.

One of the objectives of this detailed study is to develop a performance measure system that captures water quality from the Delta Intakes through to treatment. At the outset, these performance measures may be more qualitative in nature with the hope of being quantitative as the program progresses. The detailed study will specifically look at total organic carbon (TOC)/ disinfection by-product (DBP) formation, bromide and total dissolved solids (TDS), nutrients and algae, and pathogens as potential water quality parameters from which performance measures may be developed. The detailed study will look for linkages and relationships between Delta source water quality and finished water quality to help identify what effects improvements at the source can have on treatment success.

Other detailed study objectives include:

- Provide feedback to legislature and implementing agencies
- Guide future funding and identification of future resource allocation including Stage 2 CALFED actions
- Identify water quality and treatment challenges and options to address them
- Quantify issues and challenges in treating Delta water
- Communicate challenges and opportunities through drinking water conceptual models
- Identify where in the system improvements are best focused
- Capture range of (and quantify) existing conditions
- Identify the key indicators of source water degradation to finished water quality
- Help refine ELPH and how to achieve it

In order to complete this detailed study, the CALFED WQP and two of its implementing agencies, the United States Bureau of Reclamation (USBR) and California Department of Health Services (CA DHS), will ask for the participation of up to 10 water treatment plants (WTPs). This technical memorandum describes the approach for the detailed study of WTPs receiving Delta water and the selection of WTPs. This effort, in coordination with the Central Valley Drinking Water Policy and the CA DHS, began with the identification of 57 representative WTPs that either use Delta water as a source or are within the upstream tributaries in the Central Valley. CA DHS then provided some of its collected data to the CALFED WQP in order to develop a database of general treatment parameters, raw water quality data, and treated water quality data for the 57 WTPs. The general treatment parameters were then confirmed or corrected by CA DHS District Engineers and additional WTP characteristics were collected through a survey of utilities (60% response rate). This limited data set was analyzed to determine the range of treatment and water quality characteristics within the CALFED solution area and areas within the tributaries to the Delta. Results from the database analysis informed the selection of 10 WTPs for the detailed study and are presented in this technical memorandum. A separate technical memorandum, currently under preparation, will document in greater detail the development of the WTP database, its limitations, and the analysis of its contents.

The detailed evaluation of 10 WTPs is meant to develop a more quantitative understanding of the role of Delta water quality in drinking water treatment and finished water quality. The CALFED WQP is interested in capturing the state of drinking water quality knowledge throughout the CALFED solution area, including identification of problem areas in order to prioritize potential solutions. Through the detailed study regional drinking water quality conceptual models and individual models for each of the case studies will be developed to organize and present the information obtained from the case studies. The “Drinking Water Quality Conceptual Model” (DWQCM) and the “System Water Quality Conceptual Model” (SWQCM) templates are attached to this technical memorandum and further described below.

2. DETAILED STUDY APPROACH AND INVOLVEMENT

This section describes the approach to the detailed study and an initial framework for the level of effort from the participating WTPs. CA DHS District Engineers, where possible, will be engaged in the communication and collection of information from the WTPs.

2.1 Study Hypotheses

Study hypotheses are postulated to clarify the quantitative study objectives and to help identify the data collection and analyses objectives. Study hypotheses are categorized by source, conveyance and storage, and treatment process (disinfection and filtration). The hypotheses, data collection, and analytical approach may evolve over the course of the study, based on interim findings.

A. Source

The origin of source water plays a large role in its water quality, influenced by hydrology, upstream land use and water infrastructure, and, in the Delta, by hydrodynamics of the Estuary. The CALFED WQP has a separate effort underway to synthesize information on these watershed factors. In order to better assess the critical factors within the watershed, the CALFED WQP must also understand the specific source water concerns of treatment plants. Within this study, the CALFED WQP is interested in both the differences in tributary and Delta water quality and in differences between the different Delta drinking water intakes.

Hypotheses:

1. Upper Watershed raw water quality consistently and reliably meets the ROD Delta intake targets of average concentrations of 3 mg/L total organic carbon (TOC) and 50 μg/L bromide, but the Delta intakes do not.
2. Better raw water quality allows treatment plants to more cost effectively, reliably, and consistently meet water quality regulations (e.g. Upper Watershed versus Delta).
3. Water quality at each Delta intake is different and therefore has different water quality challenges related to treatment.
4. Changes in water quality conditions in the Delta cause WTPs to switch to or blend with other sources of water, reducing the reliability of the Delta as a drinking water supply. (We will not be testing this

hypothesis during this initial phase of the detailed study due to the complexity of assessing the impact and benefits of alternative supplies on finished water quality.)

Data Collection and Analysis:

1. Collect upper watershed intake TOC and bromide data (daily). Compare raw water TOC and bromide concentrations at upper watershed and Delta intakes to ROD targets. Conduct comparison at both the frequency of concern for WTPs (daily) and the CALFED WQP targets set in the CALFED ROD (running annual average).
2. Compare average cost per gallon (or other similar operating cost measurement) to treat water from the Upper Watershed to Delta WTPs.
3. Compare water quality data at each Delta intake: annual running averages and daily/monthly averages of TOC, dissolved organic carbon (DOC), total dissolved solids (TDS) or electrical conductance (EC), bromide, total nitrogen, total phosphorus, turbidity and alkalinity.

B. Conveyance and Storage

Water in California is often transported great distances and stored in large or small reservoirs or lakes prior to reaching a treatment plant. The study will evaluate the role of conveyance and storage for a number of drinking water quality parameters, by creating regional conceptual models that identify key infrastructure and representative data collection points. One way the study will evaluate this role is to compare WTP intake water quality between plants receiving Delta water directly and those with intermediate reservoir storage. The CALFED WQP is also exploring building off the Department of Water Resources (DWR) State Water Project (SWP) Sanitary Survey to examine the change in raw water quality due to conveyance and storage infrastructure and the primary parameters influencing such change.

Hypotheses:

1. Longer residence time within conveyance structures results in changes to the water quality parameters TOC/DOC, bromide, nutrients, algae, turbidity and pathogens.
2. For more conservative constituents, longer storage residence times attenuate the variability seen at Delta intakes (e.g. bromide and TDS or EC). For highly reactive constituents, longer residence times in storage change the water quality characteristics (e.g. nutrients and algae).
3. All plants receiving Delta water have taste and odor issues associated with Delta water, however the nature and extent is dependent on intake location and conveyance and storage infrastructure.
4. Treatment plants receiving water directly from the Delta have additional costs and operational challenges treating Delta water (e.g. South Bay Aqueduct).

Data Collection and Analysis

1. Compare TOC/DOC, bromide, nutrients, algae, turbidity, and pathogen concentration (monthly, daily) ranges at WTP intakes to Delta intake locations to determine magnitude and timescale of changes in variability. Compare data to the CALFED ROD intake goals of 50 μg/L bromide and 3 mg/L TOC. Examine nutrient and algae data availability and speciation and collect information from treatment plants on the frequency and timing (season, month) of algae growth episodes requiring treatment. Identify what prompts changes in source water operations and/or treatment (e.g. increases in constituent concentration, operational trigger, and or customer complaint level).
2. Gather and compare water quality data from intakes, key points in the conveyance systems, and at the WTP intakes. Use the SWP Sanitary Survey and information collected for that effort for treatment plants on the SWP system. Compare water quality data to the CALFED WQP goals. For treatment plants with raw water storage not on the SWP system, work with WTP to obtain water quality data and characterize the impact of storage on their intake water quality.

3. Compare chlorophyll-a and/or algae cell counts at WTP intakes and Delta intakes. Compare systems with minimal or small storage reservoirs to systems with larger storage reservoirs along the California Aqueduct to evaluate the influence of reservoir storage on algae growth. Gather customer complaint information to identify degree to which algae growth in conveyance impacts finished water quality.
4. Compare intake water quality at plants without intermediate storage to plants receiving Delta water with intermediate storage (e.g. South Bay Aqueduct versus CA Aqueduct plants). Identify differences in water quality variability. Compare yearly costs of operation per gallon.

C. Treatment

The goal of this study is to begin to quantify how Delta water quality influences the ability of treatment plants to meet current and future regulations, as well as local objectives. CALFED recognizes that treated water quality is driven by a number of factors, such as supply, economics, and customer expectations, many of which are far beyond the scope of the CALFED WQP or its state and federal implementing agencies. However, the CALFED WQP is seeking to understand its role in treated water quality, build a strategy towards water quality, prioritize actions, and develop quantitative performance measures for the state's role in improving source (specifically Delta) water quality. The selection of treatment plants for this study was prioritized by those plants that use Delta water as their primary supply. In addition to this study, CALFED is evaluating the results and transferability of CALFED-funded alternative treatment technology studies.

Disinfection: Use of ozone as opposed to chlorine changes the focus of source water concern from TOC to bromide and the formation of DBPs from total tri-halomethanes (TTHMs) and halo acetic-acids (HAAs) to bromate. The study disinfection hypotheses are intended to evaluate the effectiveness of ozone and potential benefits or degradation to finished water quality.

Filtration: The filtration study hypotheses are intended to evaluate the benefits of conventional and membrane filtration organic carbon removal and overall reduction in DBP formation. Filtration is also an important step in pathogen removal. Finished water turbidity will be used to evaluate pathogen removal.

Hypotheses:

1. Higher TOC concentrations due to source water quality, conveyance, and local watershed inputs lead to increased DBP formation.
2. Plants employing alternative disinfectant technologies:
   i. Have lower DBP concentrations and/or meet maximum contaminant levels (MCLs) more reliably
   ii. Achieve higher log removals
   iii. Are better prepared to meet future regulations (e.g. lower DBP MCLs)
3. Current conventional filtration processes in use in California provide sufficient filtration/removal of organic carbon in Delta water.
4. Membranes achieve as good or better finished water quality (pathogens, TOC, and turbidity) as conventional filtration.

Data Collection and Analysis:

1. Collect TOC, DOC, and bromide data at WTP intakes (daily) and TTHM, HAA and bromate data from finished water (all available) for the years 2004 through 2006. Compare intake WTP water quality to other key system locations, and examine how Delta water quality influences treated water quality.
2. Ask WTP for details on their disinfection processes, their drivers of disinfection use, and the log removal credits achieved. Compare the data collected in (1) and compare results based on different disinfection schemes to assess hypotheses (i) – (iii).

3. and 4. Collect TOC, DOC, turbidity, and pathogens/indicator microorganism data from WTP intakes, after pre-treatment, and finished water quality (daily). Compare organic carbon and turbidity removals for conventional and membrane filtration.

2.2 Conceptual Models

The "Drinking Water Quality Conceptual Model" framework (DWQCM), Attachment 1, was developed as a tool for evaluating the Delta drinking water system, its boundary conditions and constraints, and the potential opportunities to improve water quality at different places within the system. The DWQCM will be the framework to complete conceptual models for each region and treatment plant. The objective in developing the regional conceptual models is to produce a visual schematic of the large infrastructure in each region, to identify the roles this infrastructure plays in each treatment plants raw water quality, and to illustrate the shared infrastructure in each region. These illustrations, once populated with related water quality analyses, will help the CALFED WQP better describe drinking water, focus priorities for Delta water quality, and highlight regional priorities for water quality improvement in Stage 2 of the CALFED program. The model divides each regional Delta drinking water system into three phases: source, conveyance and storage, and treatment, with a primary focus on evaluating water quality changes through the system. Individual WTP conceptual models will be developed for the treatment portion of the DWQCM.

A System Water Quality Conceptual Model (SWQCM), Attachment 2, was developed to investigate the potential changes in water quality by constituent as water moves through the three phases. The SWQCM is a detailed look at the Water Supply and Treatment System section of the DWQCM. The SWQCM focuses on TOC/DOC and DBP formation, as well as bromide/TDS, nutrients and algae, and pathogens. The SWQCM identifies and explains the areas and processes in the system where water quality may be affected and helps target the information collection process. Information to be collected from different points in the system is identified in italics on the SWQCM.

Upon completion of the detailed study data collection, the regional DWQCM conceptual model frameworks will be updated to emphasize the key outcomes of the detailed study.

2.3 Information Collection

In addition to the hypothesis testing, a list of questions and information has been developed to guide information collection with the WTPs based on the DWQCM and SWQCM (Attachment 3). The intent of this information collection outline is to obtain both qualitative and quantitative information through the system that impacts delivered Delta water quality, with a focus on Delta constituents of concern (TOC/DOC and DBP formation, as well as bromide/TDS, nutrients and algae, and pathogens). The information collection outline will remain dynamic as additional issues surface. This outline will be submitted to the WTPs prior to the visit to obtain as much water quality data and documents to support information discussed. Water quality data from 2004 - 2006 will be of primary interest, unless there has been a major treatment upgrade within that time, in which case data after the upgrade will be of primary interest.

2.4 Contact and Communication with WTPs

The following outline describes the planned contact and communication with the WTPs.

1. **Invite recommended (or alternate) plants to participate.** The WTPs recommended for inclusion in the study will be invited to participate with an introductory phone call. The project objectives and anticipated level of effort from the WTPs will be described.
2. **Distribute letter, detailed study approach, and information collection outline.** A follow up letter will be sent to each treatment plant describing the detailed study. Attached to the letter will be an outline of the desired information including discussion topics and data requests and this technical memorandum. The WTPs will be asked to determine their ability to participate in the study and provide the requested information.
3. **Schedule visit.** After the WTPs have agreed to participate in the study, a visit will be scheduled between the WTP representatives, DHS District Engineers, CALFED, and Brown and Caldwell staff. Visits will be scheduled to allow representatives from DHS and CALFED to be present to the extent possible.
4. **Meet with WTPs.** The meetings will take place at the WTP offices. Brown and Caldwell will gather the initial set of water quality data and information.
5. **Request follow up information.** After reviewing the initial data set and notes from the qualitative discussions, Brown and Caldwell will contact the WTPs with any follow-up information requests. Follow-up data requests may include information needed to maintain a similar level of breadth and detail between the WTPs studied.
6. **Review of draft report.** In order to accurately represent the WTPs, upon completion of the draft report and individual WTP conceptual models all participants will be provided an opportunity to review the report and comment.

3. TREATMENT PLANT SELECTION

Figure 1 describes the process for selecting the five WTPs.

The selection process will identify treatment plants based on three factors;

1. Raw water source and conveyance system,
2. Treatment process and community demographics, and
3. Treated water quality.

Subsequent sections describe the selection of the treatment plants according to Factor 1 and 2. There is limited treated water quality information in the DHS database to inform selection of treatment plants: however, regional selection of treatment plants provides for representative distribution based on raw water quality.

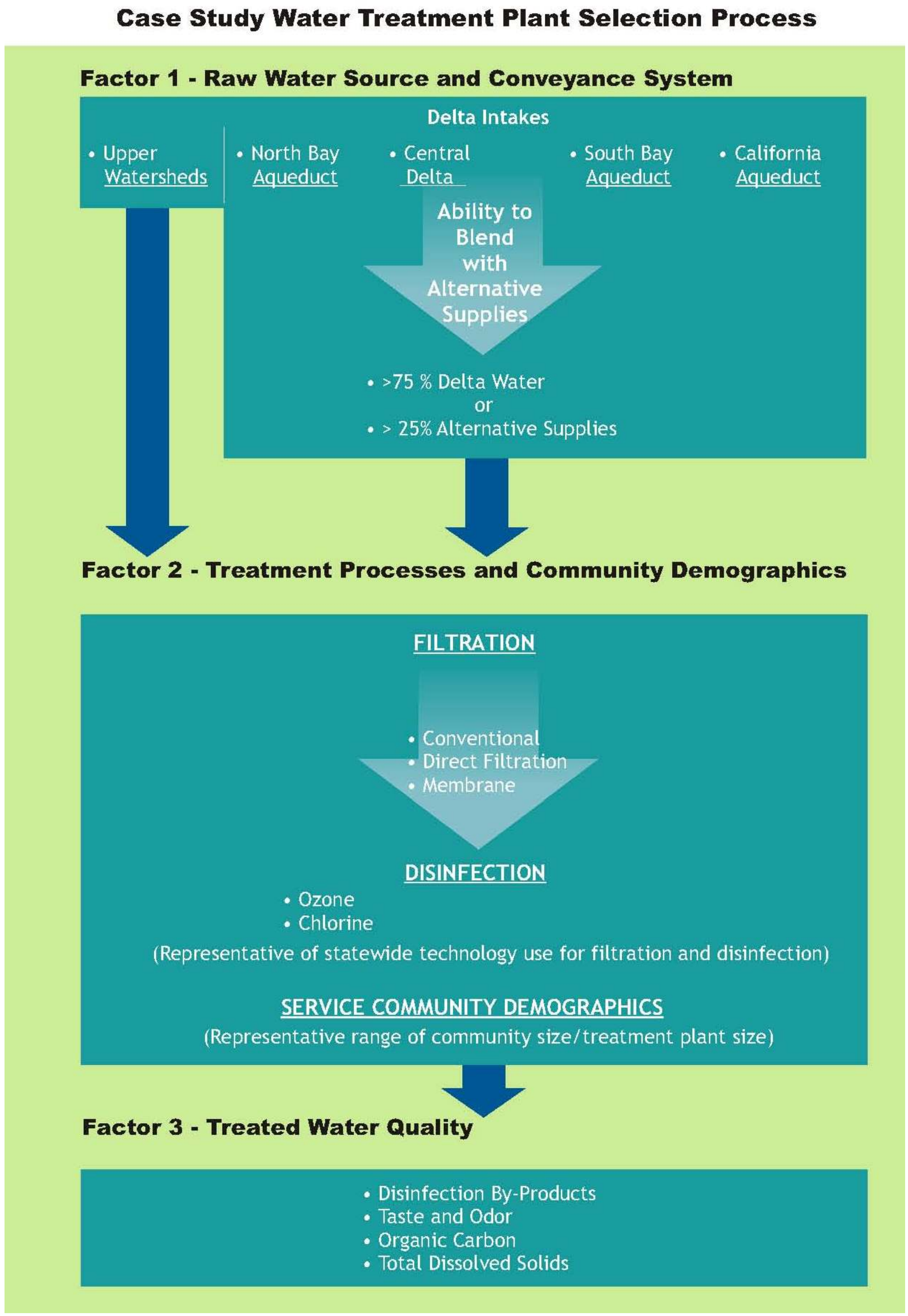


Figure 1. Case Study Water Treatment Plant Selection Process

3.1 Factor 1—Raw Water Source and Conveyance System

Within this factor treatment plants are grouped by where they receive their raw (Delta-related) water source, their conveyance system, and the availability of alternative supplies.

Treatment plants in the DHS database represent five water quality regions;

- **Upper Watershed**, which includes treatment plants receiving water either directly or through a reservoir on the Sacramento and San Joaquin Rivers and their tributaries.
- **North Bay Aqueduct** (NBA) treatment plants receive water from the North Delta via the Barker Slough pumping plant.
- **Central/South Delta** treatment plants receive water from a Delta intake other than through Clifton Court Forebay.
- **South Bay Aqueduct** receives water directly from Clifton Court Forebay with minimal storage residence time along the aqueduct.
- **California Aqueduct** plants receive water pumped from Clifton Court Forebay into the California Aqueduct via San Luis Reservoir and represent the majority of treatment plants in the SWP system.

The regional divisions were carried through when evaluating the different treatment technologies below.

Figure 2 categorizes the WTPs by percent Delta water used within each of the regions. Alternative supplies will not be looked at for the Upper Watershed treatment plant selection because the Upper Watershed case study is being conducted as a comparison to the other treatment plants and most of the treatment plants have a single supply source. Most of the treatment plants responding to the previously distributed survey treat between 80 to 100 percent Delta water and have limited alternative supplies. The Delta is the focus of the CALFED WQP therefore, evaluation of alternative supplies is a less important factor. A few treatment plants in the NBA region and the California Aqueduct (CA Aqueduct) region identified the availability of alternative supplies. A treatment plant in the NBA region and CA Aqueduct with alternative supplies may be selected.

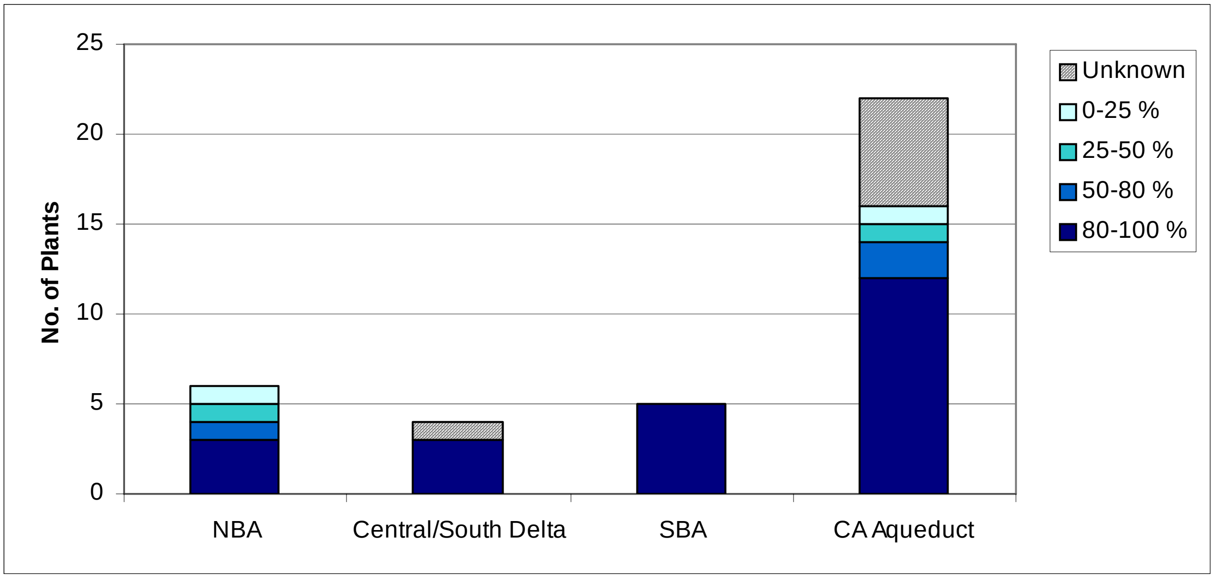


Figure 2. Percent Delta Water Used by Region

Note: "Upper Watershed" category not included in graphic since alternative supplies is not a specific category for evaluation of the Upper Watershed treatment plant. "Unknown" are treatment plants that did not return questionnaires for percent Delta water used confirmation.

3.2 Factor 2—Treatment Process and Community Demographics

Of the treatment plants within the DHS database, the majority of treatment plants throughout California practice conventional filtration (Figure 3). A few treatment plants receiving Delta water practice membrane treatment or direct filtration. Of the 18 treatment plants in the Upper Watershed thirteen treatment plants practice conventional filtration.

Based on the distribution of filtration technology the majority of the treatment plants selected for the detailed case studies will be conventional. The Upper Watershed case study is being conducted to compare the Delta WTP to treatment in the Upper Watershed. Therefore, the Upper Watershed treatment plant should be consistent with the overall statewide and Delta treatment distribution and not unique. As membranes are an emerging technology of interest a limited number of membrane treatment plants receiving Delta water may be selected for evaluation.

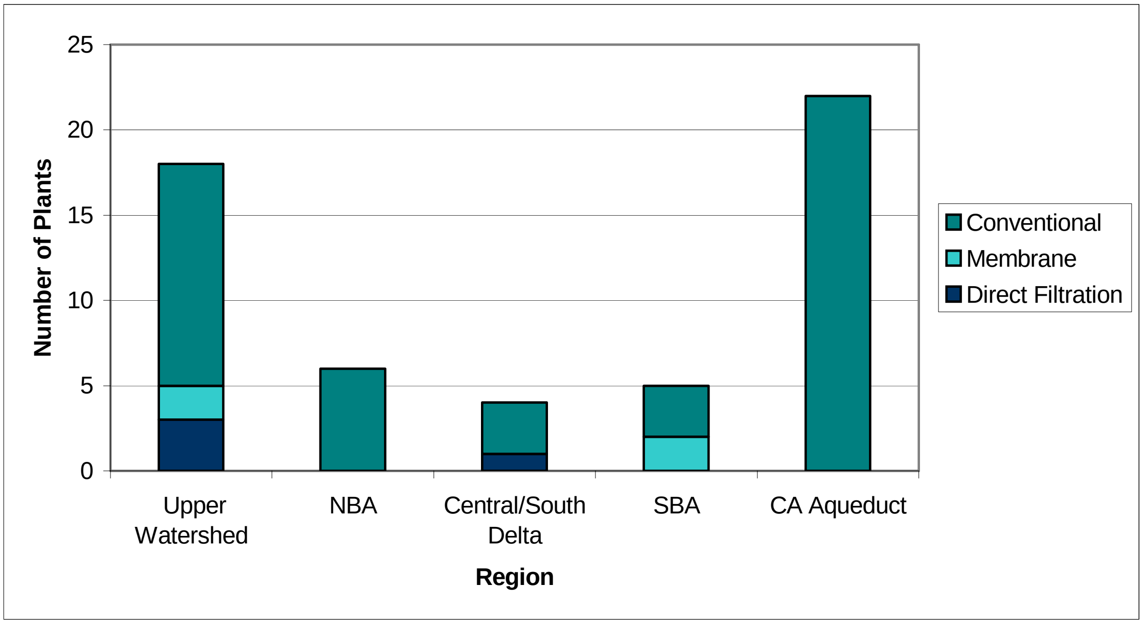


Figure 3. Regional Distribution of Filtration

Note: NBA—American Canyon is listed as a conventional plant but also recently started operating a parallel membrane plant.

The proposed type of filtration technology by region for selection is:

- **Upper Watershed** – Conventional
- **NBA** – Conventional
- **Central/South Delta** – Conventional
- **SBA** – Conventional and Membrane
- **CA Aqueduct** – Conventional

Evaluating disinfection practices will be an important part of the case studies because of the necessary balance in water treatment between the formation of DBPs and protection against pathogenic microorganisms. This evaluation does not include distribution system disinfection, only primary disinfection. Impacts to water quality within the distribution system will be addressed only in a qualitative manner if a WTP identifies it as a primary water quality concern. The distribution system is generally considered out of the scope of the CALFED WQP. Evaluation of water quality impacts in the distribution system is also highly complex and varied.

Figure 4 illustrates the distribution of treatment plants using ozone and only chlorine based on region. The database does not reflect future conditions, so plants currently being converted to ozone are not represented. Of the treatment plants included in the database, 76 percent of the treatment plants statewide and 70 percent of the treatment plants receiving Delta water (i.e. treatment plants not within the Upper Watershed) use chlorine as their primary disinfectant.

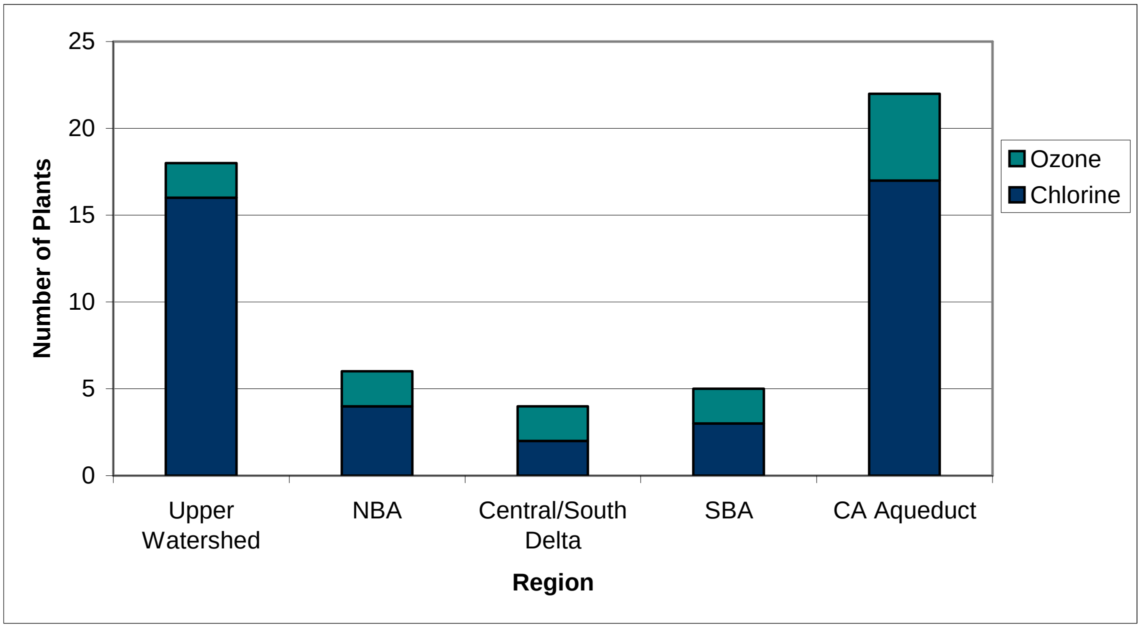


Figure 4. Disinfection Technology Distribution by Region

Based on the statewide distribution of disinfection, the treatment plant within each of the regions will include the following filtration and disinfection technology:

- **Upper Watershed** – Conventional/Chlorine
- **NBA** – Conventional/ Chlorine
- **Central/South Delta** – Conventional/ Chlorine and Ozone
- **SBA** – Conventional or Membrane/ Chlorine and Ozone
- **CA Aqueduct** – Conventional/ Chlorine and Ozone

Overall seven treatment plants using chlorine and three treatment plants using ozone will be selected.

The first cut on evaluating treatment plants based on community demographics was done by treatment plant size. However, plant size is not directly indicative of community demographics or available resources. For example, large agencies with smaller treatment plants may have extensive agency resources. To compensate for this, plant size statistics were evaluated with the support of qualitative knowledge of treatment plants receiving Delta water.

Information on treatment plant size was not confirmed for treatment plants that did not return the distributed questionnaires. Based on the available information, treatment plant size is evenly distributed in the size ranges of less than 15 mgd, 15 – 75 mgd, and greater than 80 mgd (Figure 5). There is a wide range in treatment plant size along the California Aqueduct. Therefore a small treatment plant, less than 15 mgd, and a mid-sized treatment plant from the California Aqueduct will be included in the detailed case studies. Since the Upper Watershed cases are included as a comparison to the Delta-dependent treatment plants, mid-sized treatment plants will be selected. Treatment plant size will not be a priority in the selection of the case study treatment plant from the NBA and SBA regions because there is an even distribution between small and medium treatment plants and the range in size is small relative to the California Aqueduct.

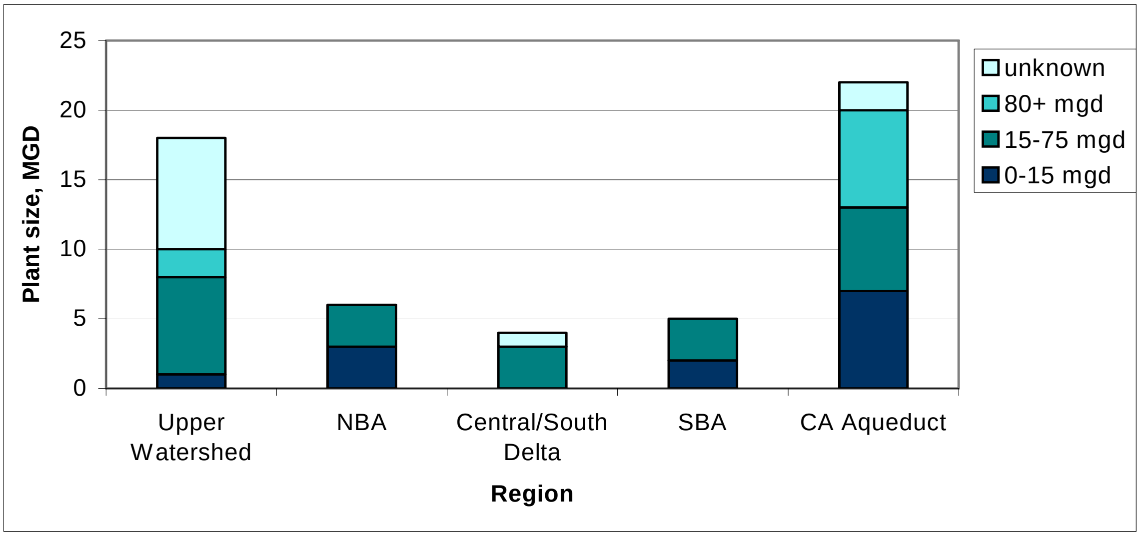


Figure 5. Plant Treatment Plan Size by Region

Note: "Unknown" are treatment plants that did not return questionnaires for size confirmation..

3.3 Selected Treatment Plants

Based on the selected distribution of filtration and disinfection technologies and treatment plant size, the treatment plant list was narrowed to the following treatment plants within each of the regions. Certain treatment plants were selected within one region to maintain the balance of treatment technologies throughout the regions. In order to streamline the case studies, treatment plants with a high percentage of alternative supplies were not selected. This is supported by the database, where the majority of the treatment plants treat 80 percent or greater Delta water.

- **Upper Watershed** – Conventional/Chlorine /15 – 75 mgd
    - City of Redding
    - City of Sacramento – Sacramento River WTP
    - East Bay MUD Lafayette WTP (Mokelumme Aqueduct) – alternate

The City of Redding and City of Sacramento are both conventional treatment plants that practice chlorine disinfection. It is anticipated that the water quality at the City of Redding treatment plant is of much higher quality than the City of Sacramento because it is closer to the watershed source.

- **NBA** – Conventional/Chlorine
    - American Canyon – Conventional and Membrane/Chlorine
    - City of Fairfield – Conventional/Chlorine - alternate

American Canyon provides an opportunity to evaluate constraints and opportunities to improve water quality with two filtration technologies side by side. City of Fairfield is proposed as an alternate because they use less than 80 percent Delta water and would represent one of the treatment plants using alternative supplies.

- **Central/South Delta** – Conventional/ Chlorine and Ozone
    - Contra Costa Water District – Bollman WTP – Conventional/Ozone
    - City of Antioch – Conventional/Chlorine

Both the Contra Costa Water District and the City of Antioch are entirely dependent on the Delta, and their plant intake water quality most closely resembles their Delta intake water quality. They offer a unique comparison, because the Contra Costa Water District has an intermediate reservoir to improve its water quality and because the plants treat similar water with different disinfection technologies.

- **SBA** – Conventional or Membrane/ Chlorine and Ozone/Medium Size Treatment Plants
  - Zone 7 Water Agency – Patterson Pass – Membrane and Conventional /Chlorine
  - Alameda County Water District (ACWD) WTP # 2 - Conventional/Ozone

Zone 7 Water Agency – Patterson Pass was selected because of the opportunity to evaluate treatment of Delta water with both conventional and membrane treatment side by side. Patterson Pass WTP was also selected to maintain a balance of treatment plants practicing different disinfection technologies. ACWD WTP # 2 was selected as an example of conventional treatment with ozone disinfection.

- **CA Aqueduct** – Conventional/ Chlorine and Ozone – 1 small, medium and large WTP.
  - Small Treatment Plant
    - City of Coalinga – Conventional/Chlorine
    - City of Avenal – Conventional – Chlorine - alternate
  - Large Treatment Plant
    - Antelope Valley East Kern (AVEK) – Quartz Hill WTP – Conventional/Chlorine
  - Midrange Size
    - Castaic Lake Water Authority (CLWA) – Earl Schmidt WTP – Conventional/Ozone
  - Potential Alternates:
    - MWD of Southern California – Jensen WTP – Conventional/Ozone - alternate
    - MWD of Southern California – Diemer, Skinner, or Weymouth – Conventional/Chlorine – Alternative supplies – Colorado River

The City of Coalinga was selected because they are a small community along the CA Aqueduct not associated with a large agency. In addition, the majority of small treatment plants in the Central Valley practice conventional treatment with chlorine disinfection, similar to the City of Coalinga. Both the City of Coalinga and City of Avenal participated in the "Issues with Delta Drinking Water Treatment" survey report.

AVEK Quartz Hill WTP and the CLWA Earl Schmidt WTP were selected to conduct case studies on a treatment plant on both the east and west branches of the CA Aqueduct. MWD's Diemer, Skinner, or Weymouth plants were identified as alternates because they receive 20% or more of their water from the Colorado River and are currently in the process of switching to ozone disinfection.

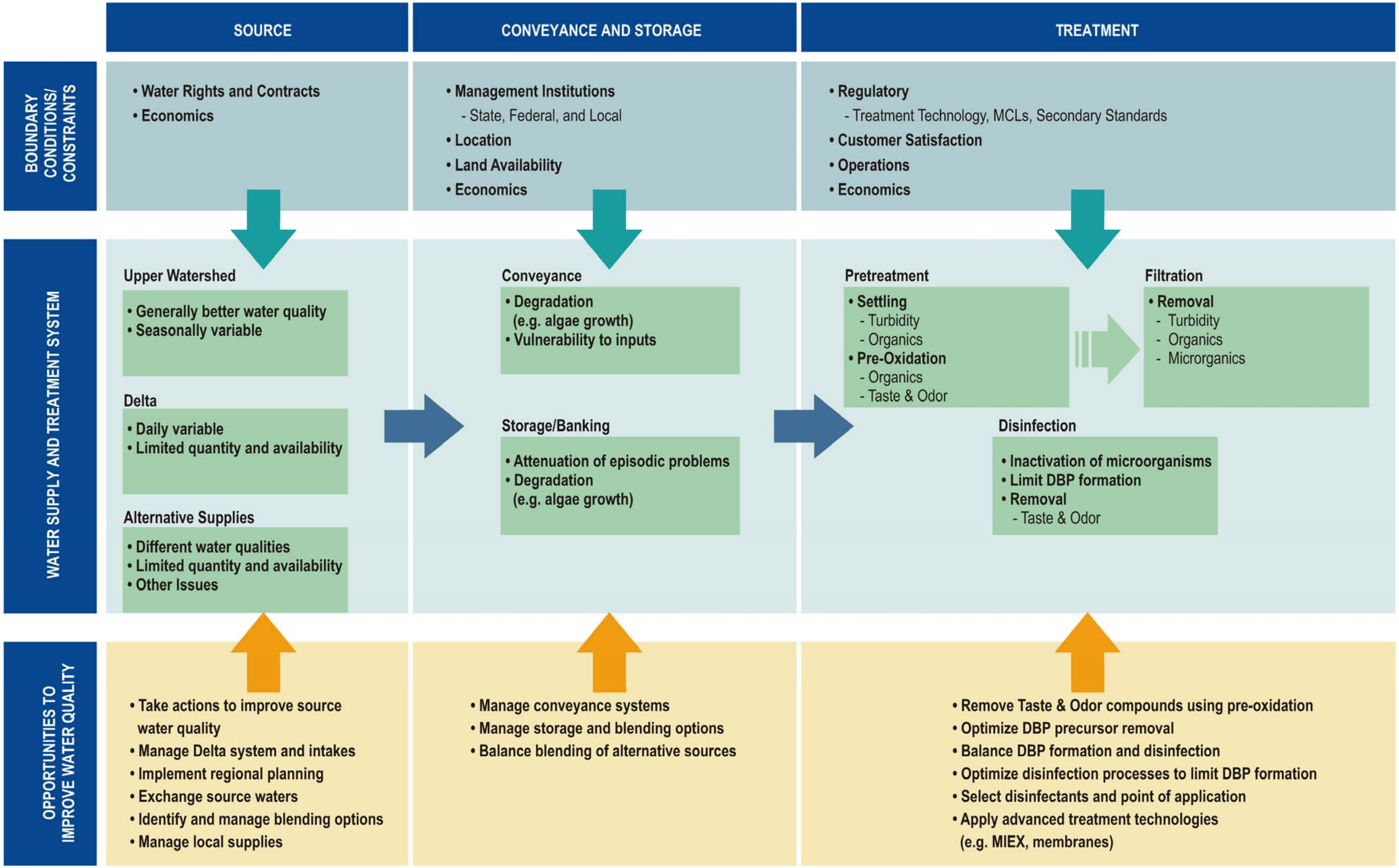
ATTACHMENTS

Drinking Water Quality Conceptual Model

System Water Quality Conceptual Model

Information Collection Outline

DRINKING WATER QUALITY CONCEPTUAL MODEL



BOUNDARY CONDITIONS/ CONSTRAINTS

SOURCE

- Water Rights and Contracts
- Economics

CONVEYANCE AND STORAGE

- Management Institutions
  - State, Federal, and Local
- Location
- Land Availability
- Economics

TREATMENT

- Regulatory
  - Treatment Technology, MCLs, Secondary Standards
- Customer Satisfaction
- Operations
- Economics

WATER SUPPLY AND TREATMENT SYSTEM

SOURCE

Upper Watershed

- Generally better water quality
- Seasonally variable

Delta

- Daily variable
- Limited quantity and availability

Alternative Supplies

- Different water qualities
- Limited quantity and availability
- Other Issues

CONVEYANCE AND STORAGE

Conveyance

- Degradation (e.g. algae growth)
- Vulnerability to inputs

Storage/Banking

- Attenuation of episodic problems
- Degradation (e.g. algae growth)

TREATMENT

Pretreatment

- Settling
  - Turbidity
  - Organics
- Pre-Oxidation
  - Organics
  - Taste & Odor

Filtration

- Removal
  - Turbidity
  - Organics
  - Microrganics

Disinfection

- Inactivation of microorganisms
- Limit DBP formation
- Removal
  - Taste & Odor

OPPORTUNITIES TO IMPROVE WATER QUALITY

SOURCE

- Take actions to improve source water quality
- Manage Delta system and intakes
- Implement regional planning
- Exchange source waters
- Identify and manage blending options
- Manage local supplies

CONVEYANCE AND STORAGE

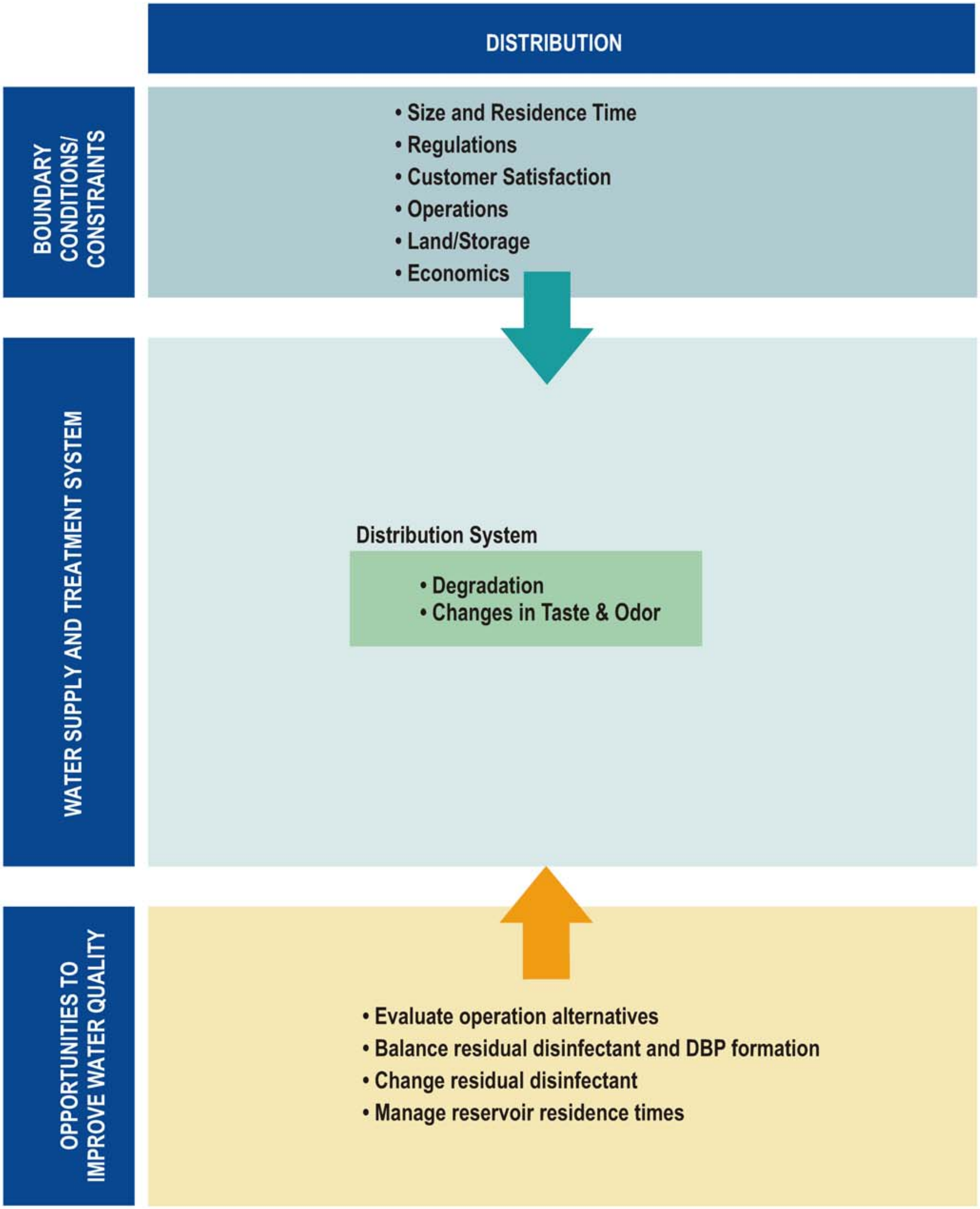
- Manage conveyance systems
- Manage storage and blending options
- Balance blending of alternative sources

TREATMENT

- Remove Taste & Odor compounds using pre-oxidation
- Optimize DBP precursor removal
- Balance DBP formation and disinfection
- Optimize disinfection processes to limit DBP formation
- Select disinfectants and point of application
- Apply advanced treatment technologies (e.g. MIEX, membranes)

DRAFT - Version 1-3/15/07

DRINKING WATER QUALITY CONCEPTUAL MODEL



DISTRIBUTION

BOUNDARY CONDITIONS/ CONSTRAINTS

- Size and Residence Time
- Regulations
- Customer Satisfaction
- Operations
- Land/Storage
- Economics

WATER SUPPLY AND TREATMENT SYSTEM

Distribution System

- Degradation
- Changes in Taste & Odor

OPPORTUNITIES TO IMPROVE WATER QUALITY

- Evaluate operation alternatives
- Balance residual disinfectant and DBP formation
- Change residual disinfectant
- Manage reservoir residence times

DRAFT - Version 1-3/15/07

SYSTEM WATER QUALITY CONCEPTUAL MODEL

WATER SUPPLY AND TREATMENT SYSTEM	SOURCE	CONVEYANCE AND STORAGE	TREATMENT: Filtration	TREATMENT: Disinfection	
TOC	• Interaction with Cl_2 forms regulated DBPs during disinfection • TOC removal requirement in treatment based on concentration • *TOC and DOC concentrations*	• Change in concentration and/or nature of TOC due to alternative sources, conveyance, and storage • *TOC and DOC concentrations*	• Removal of TOC during conventional treatment • Membranes do not remove TOC • *TOC concentration*	• Interaction with Cl_2 forms regulated DBPs during disinfection • Change in TOC • *CT target/requirement* • *TTHM and HAA5 concentrations by species*	DBPs
Bromide / TDS	• Interaction of bromide and ozone forms bromate during disinfection • Usability • USEPA secondary standard for TDS is 500mg/L • *Bromide and TDS concentrations*	• Change in concentrations due to alternative sources, conveyance, and storage - Dilution or increase - Attenuation • *Bromide and TDS concentrations*	• Minimal to no change in concentration through conventional treatment	• Interaction of Bromide and ozone forms bromate during disinfection • Taste and usability impacts • *CT target/requirement* • *Bromate and TDS concentrations* • *Customer complaints*	Bromate
Nutrients/ Algae	• Increased nutrients increase algae growth • Nitrate/Nitrite MCL • Algae produces mal taste and odors • *Nutrient and chlorophyll a concentrations, algae counts*	• Residence time, temperature, light exposure and depth may impact algae growth • Control/management practices • *Nutrient and chlorophyll a concentrations, algae counts*	• Removal of algae and T & O • Algae can clog filters and impact treatment operation	• Oxidation of algae by-products and improved T & O • *Customer complaints* • *Nitrate/Nitrite concentations*	Taste and Odor
Pathogens/ Indicator Organisms	• Source concentrations inform treatment requirements • *Total/Fecal, Giardia, E. coli, HPC, Cryptosporidium concentrations*	• Increased light and temperature can inactivate some pathogens • Inputs along conveyance • Watershed inputs • *Total/Fecal, Giardia, E. coli, HPC, Cryptosporidium concentrations*	• Receive log removal credit for pretreatment and filtration (limits necessary disinfection) • *Log removal achieved/target*	• *Log removal achieved/target* • *CT* • *Total/Fecal, Giardia, E. coli, Cryptosporidium concentrations, HPC*	Pathogens / Indicator Organisms

DRAFT - Version 4-17-07

Items in italics are information to be collected.

SYSTEM WATER QUALITY CONCEPTUAL MODEL

DISTRIBUTION SYSTEM

WATER SUPPLY AND TREATMENT SYSTEM

TOC/ DBPs	• **Additional DBP formation** • **Decrease in Cl_2 residual concentration due to TOC** • **Bio-film formation** ***• TTHM and HAA5 concentrations***
TDS	• **Taste** ***• Customer complaints***
Taste and Odor	***• Customer complaints***
Pathogens / Indicator Organisms	• **Regrowth** • **Bio-film formation** ***• Total/Fecal, HPC***

DRAFT - Version 5-9-07

Items in italics are information to be collected.

APPENDIX C

Supplemental Water Quality Data

SUPPLEMENTAL WATER QUALITY DATA

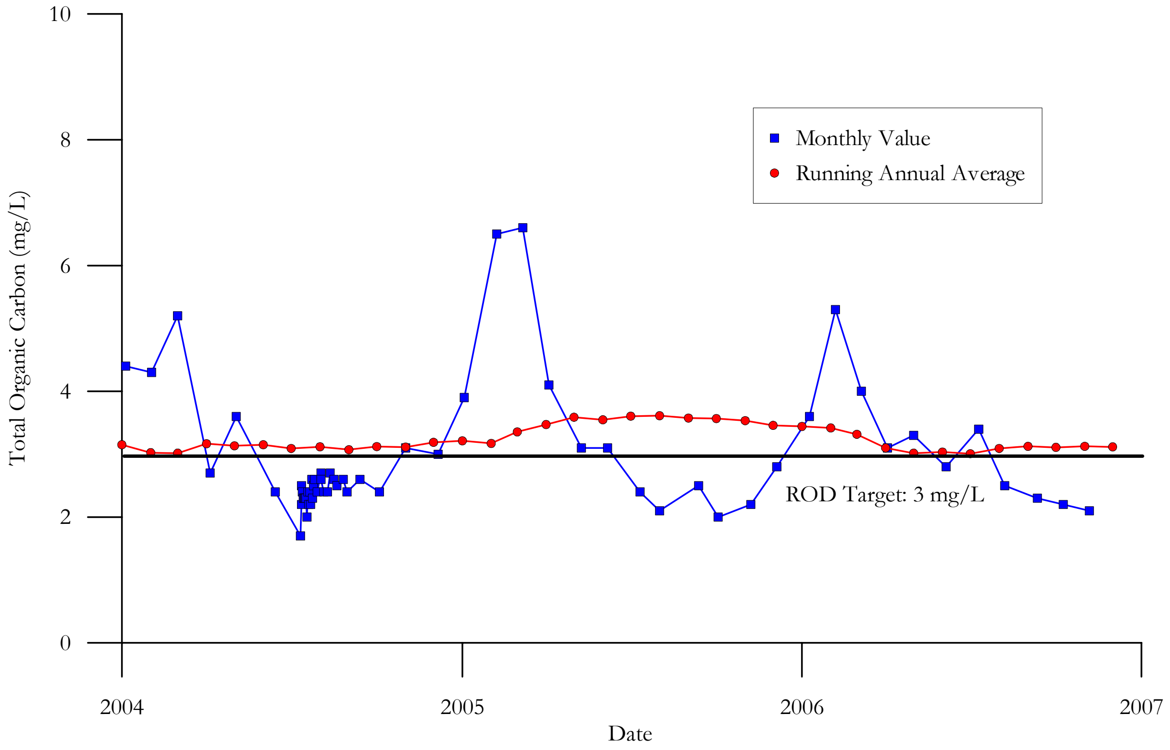


Figure C-1. TOC Running Annual Average and Discrete Concentrations for Old River Pumping Plant 2004 - 2006

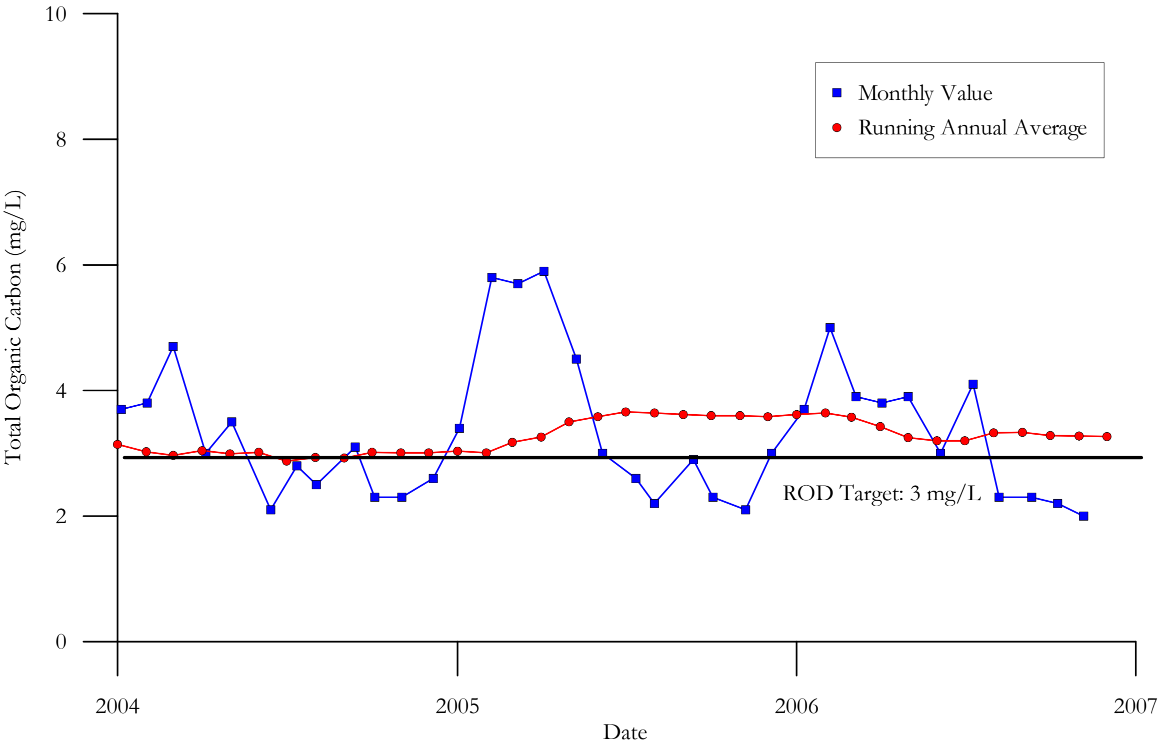


Figure C-2. TOC Running Annual Average and Discrete Concentrations for Rock Slough Pumping Plant 2004 - 2006

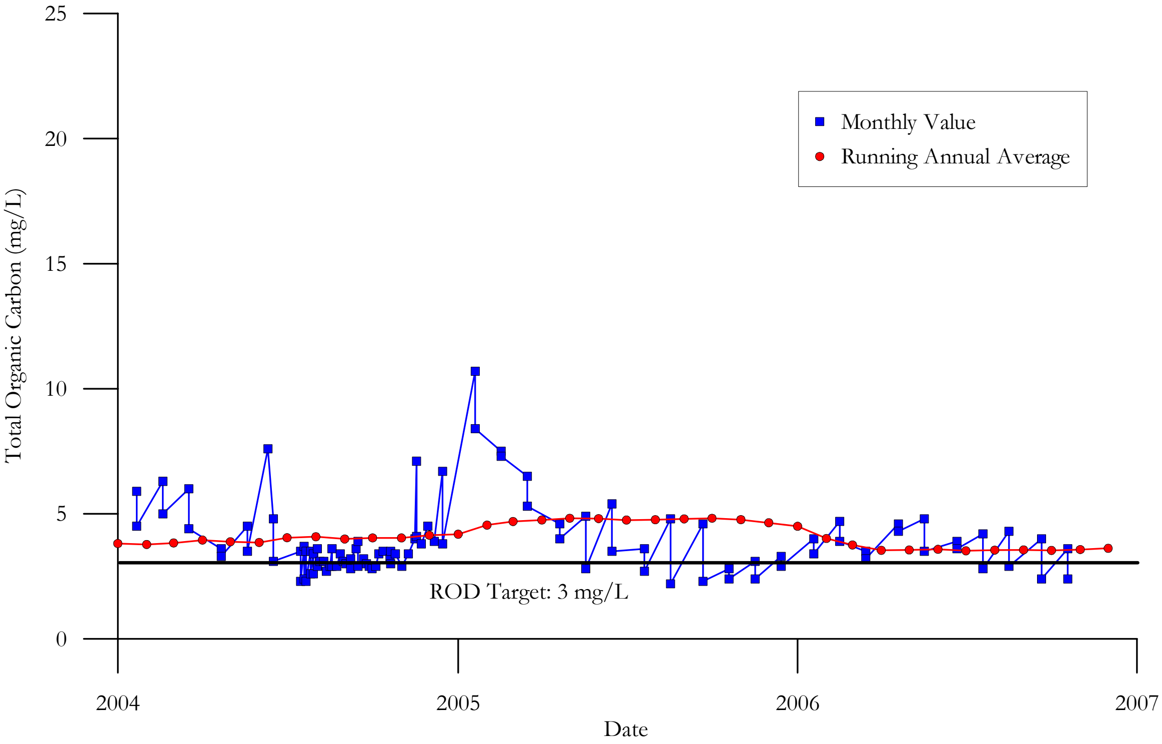


Figure C-3. TOC Running Annual Average and Discrete Concentrations for Banks Pumping Plant 2004 - 2006

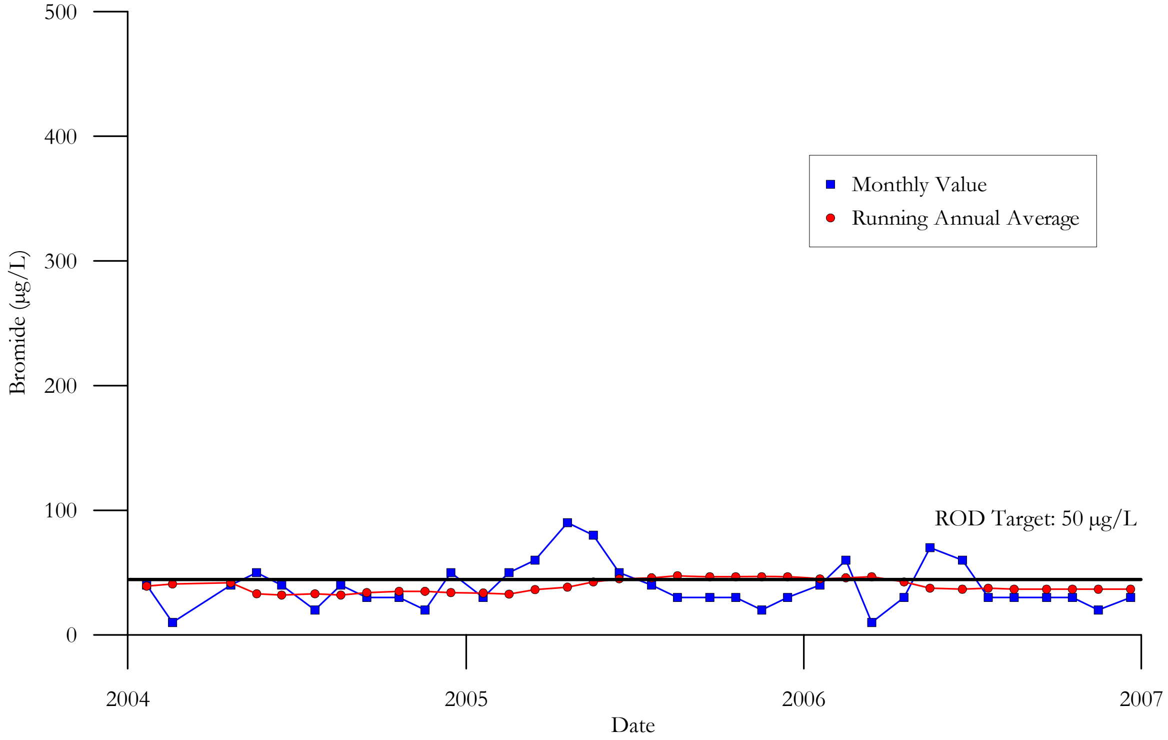


Figure C-4. Bromide Running Annual Average and Discrete Concentrations for Barker Slough Pumping Plant 2004 - 2006

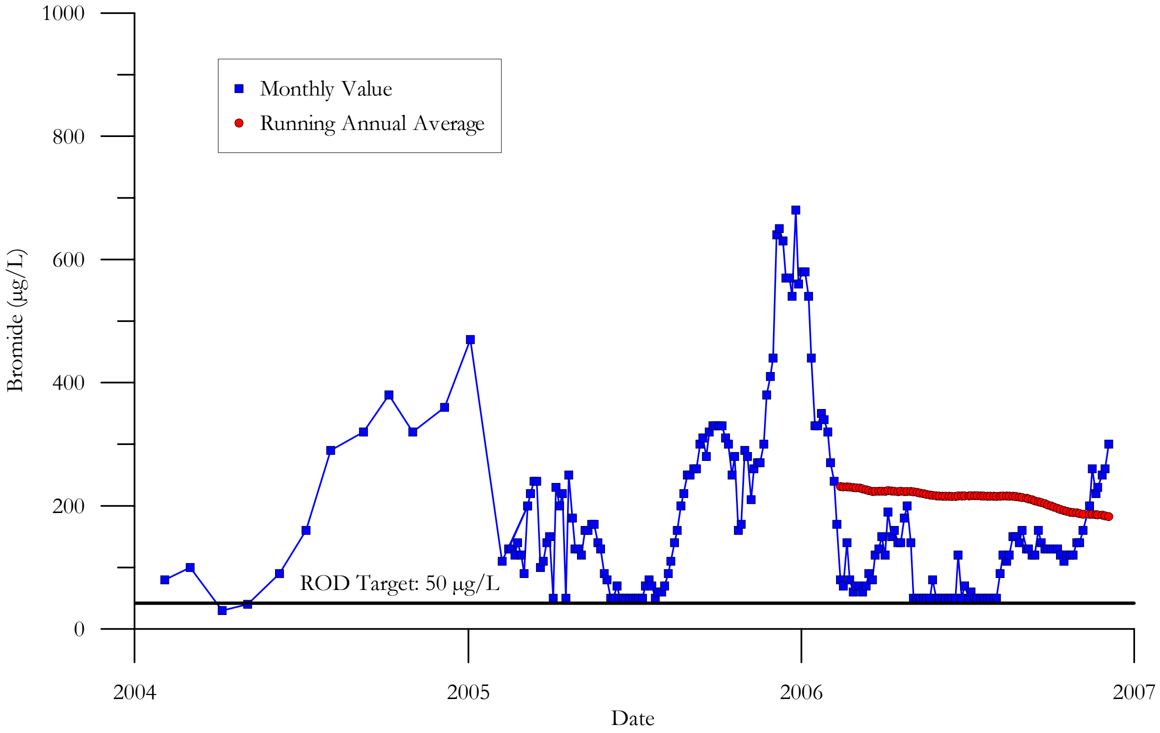


Figure C-5. Bromide Running Annual Average and Discrete Concentrations for Rock Slough Pumping Plant Bromide 2004 - 2006

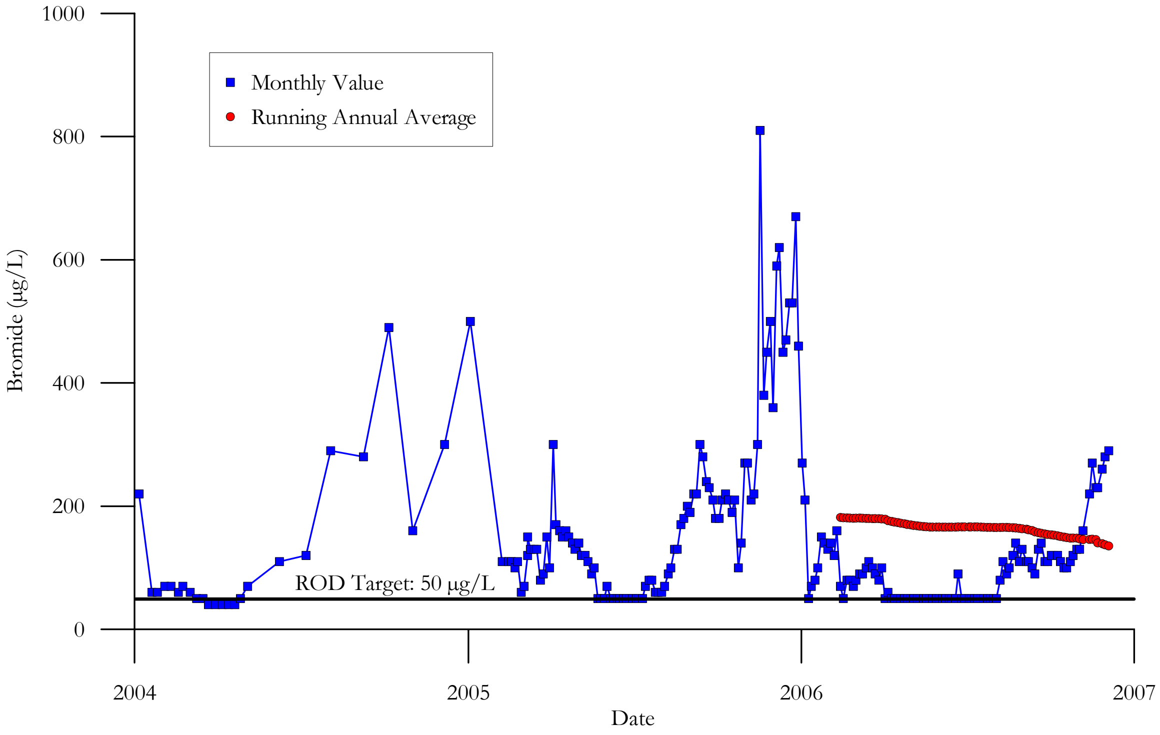


Figure C-6. Bromide Running Annual Average and Discrete Concentrations for Old River 2004 – 2006

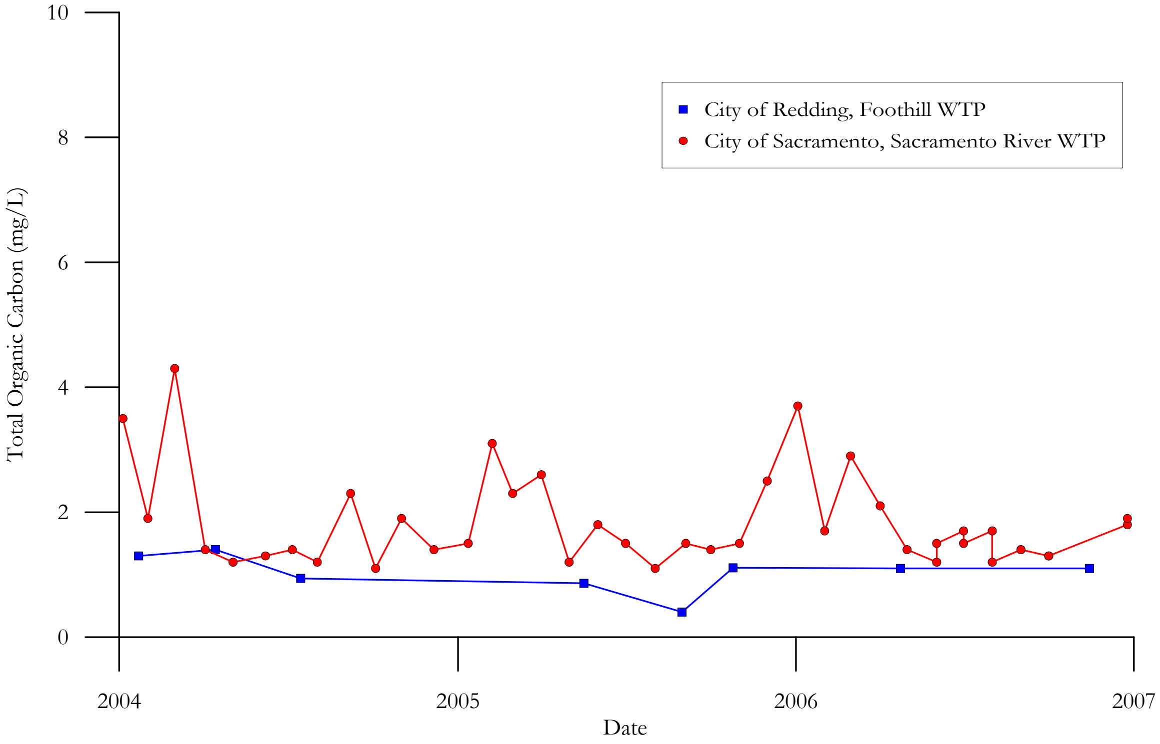


Figure C-7. Intake Values for Total Organic Carbon for the City of Sacramento, Sacramento River WTP and City of Redding Foothill WTP 2004 - 2006

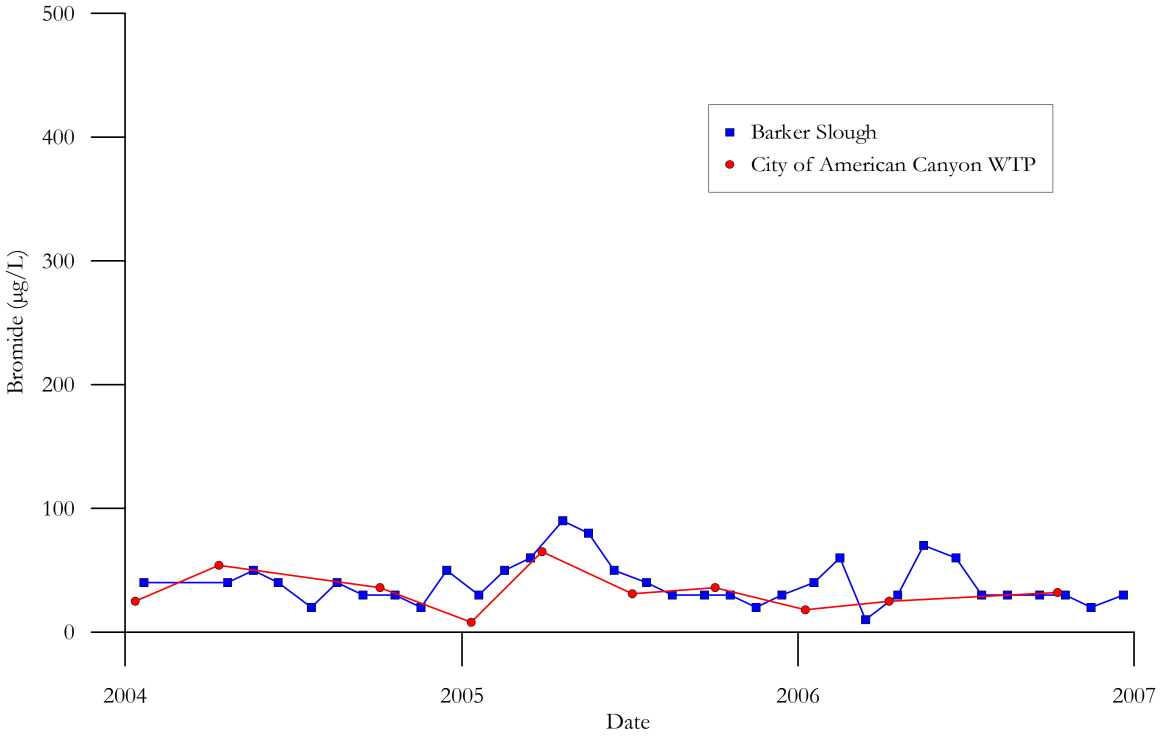


Figure C-8. Bromide Values for Barker Slough Pumping Plant and City of American Canyon WTP Intake 2004 - 2006

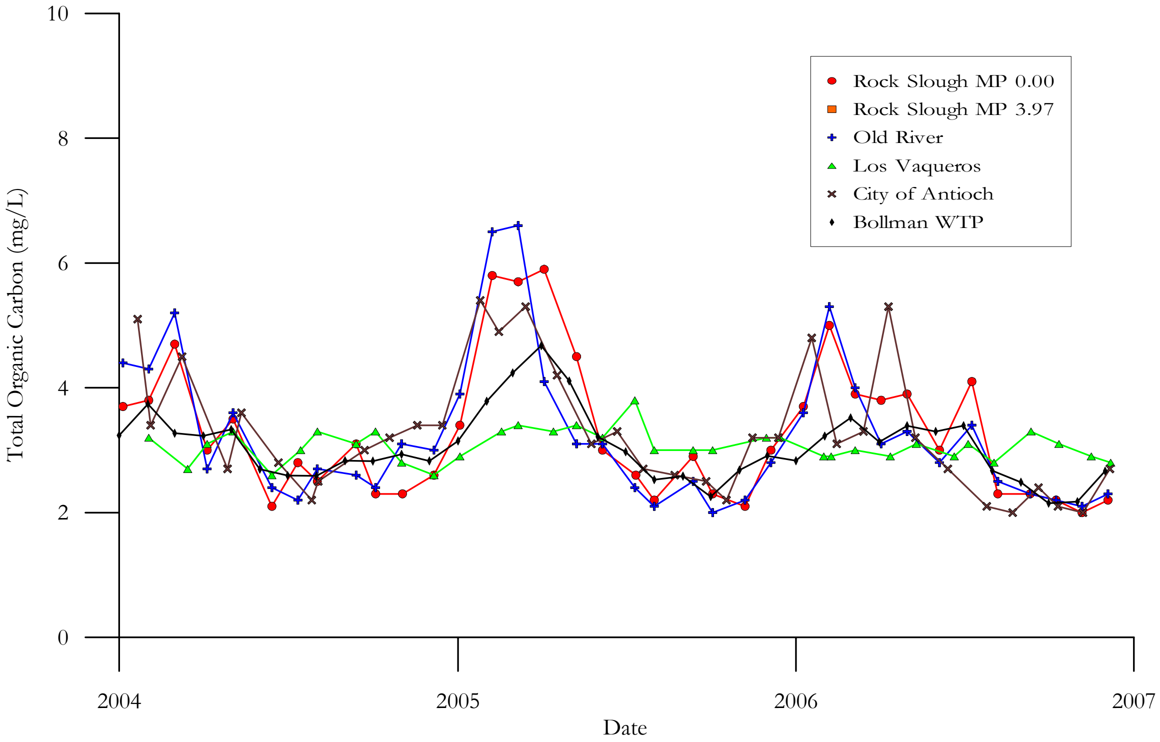


Figure C-9. Total Organic Carbon Monthly Values for Rock Slough MP 0.00, Rock Slough MP 3.97, Old River Pumping Plant, Los Vaqueros, City of Antioch WTP Intake, Bollman WTP Intake 2004 - 2006

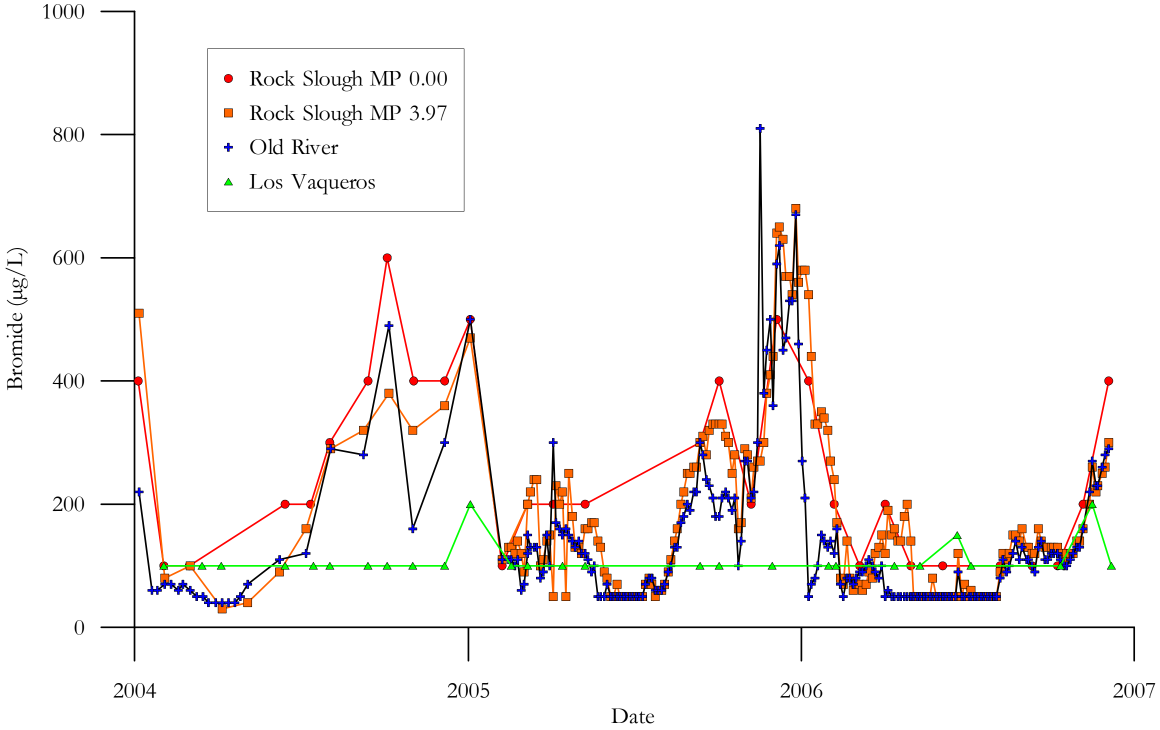


Figure C-10. Bromide Values for Rock Slough MP 0.00, Rock Slough MP 3.97, Old River Pumping Plant, Los Vaqueros 2004 - 2006

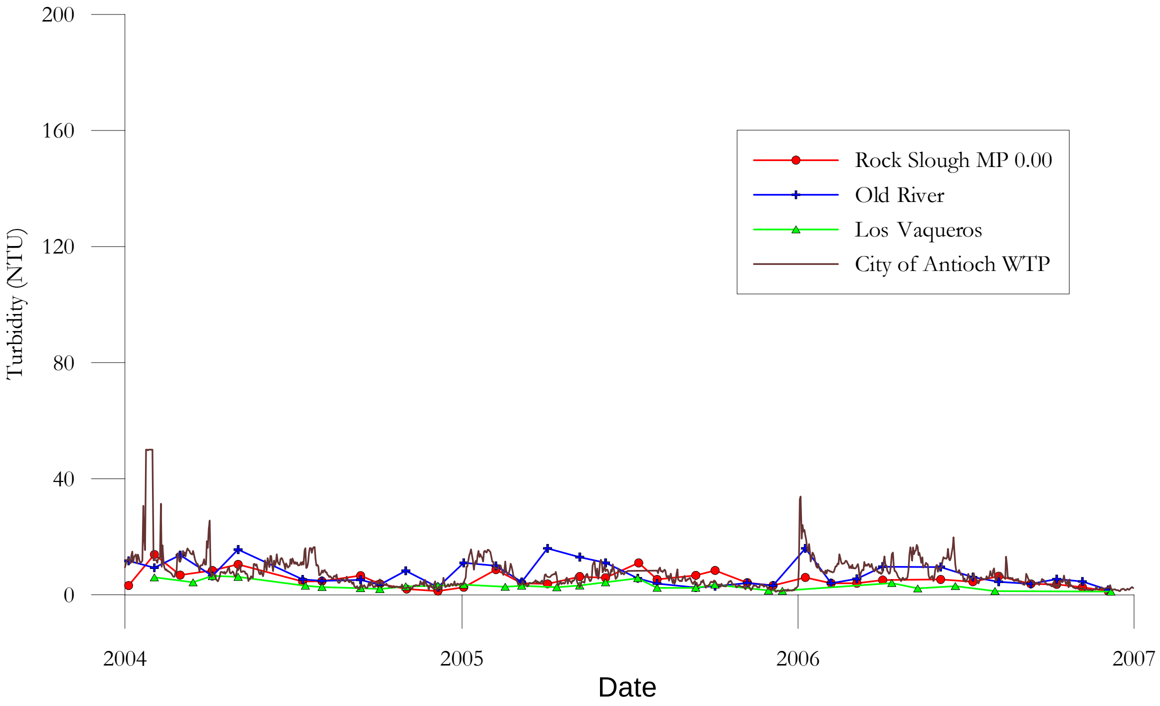


Figure C-11. Turbidity Values for Rock Slough MP 0.00, Old River Pumping Plant, Los Vaqueros, City of Antioch WTP Intake 2004 - 2006

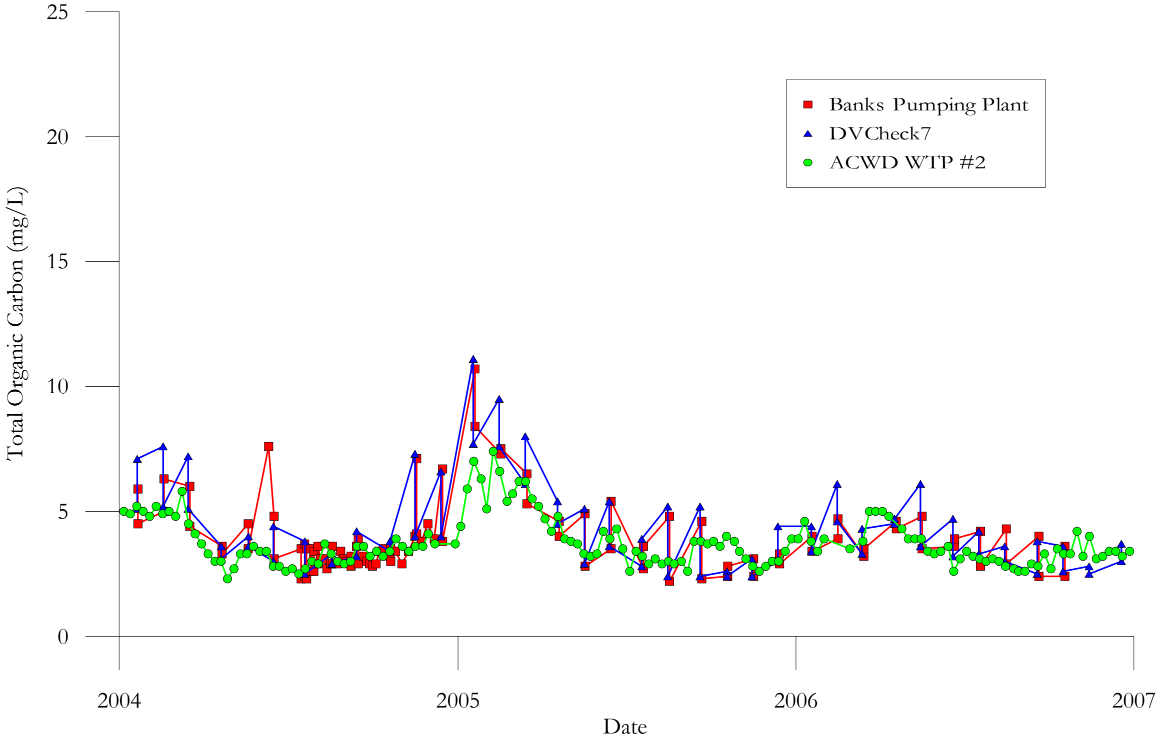


Figure C-12. Total Organic Carbon Values for Banks Pumping Plant, DVCheck7, and ACWD WTP #2 Intake 2004 - 2006

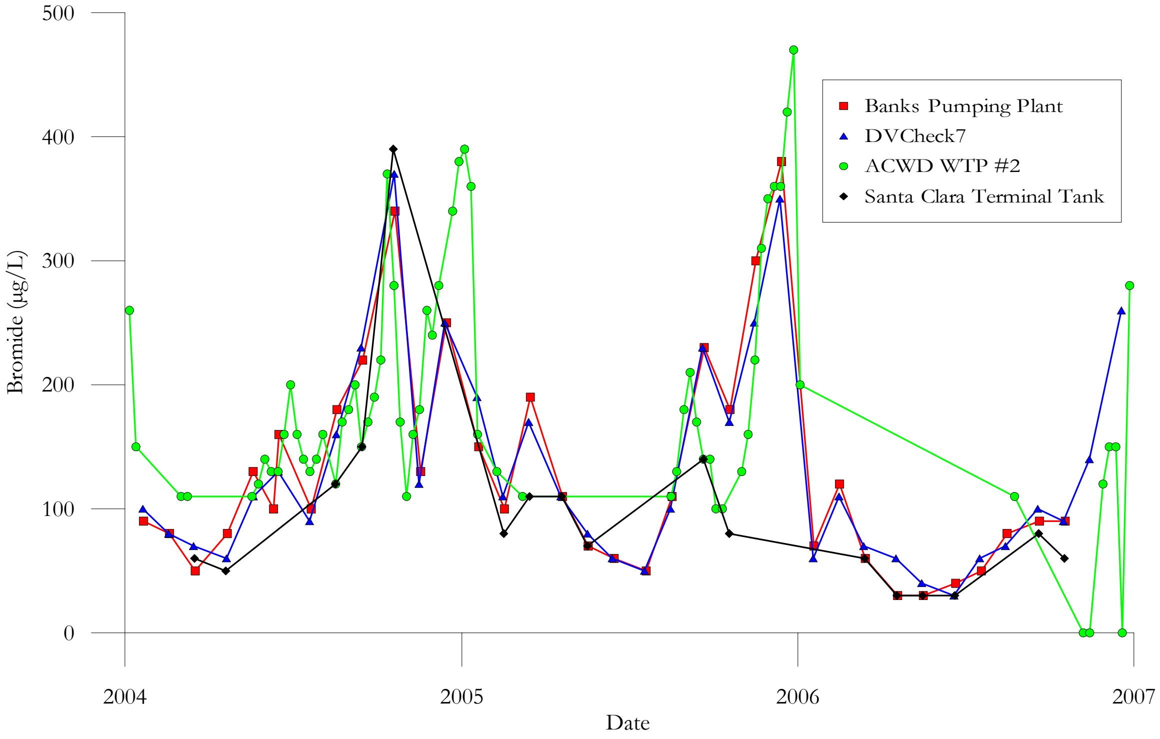


Figure C-13. Bromide Values for Banks Pumping Plant, DVCheck7, ACWD WTP #2 Intake, and the Santa Clara Terminal Tank 2004 - 2006

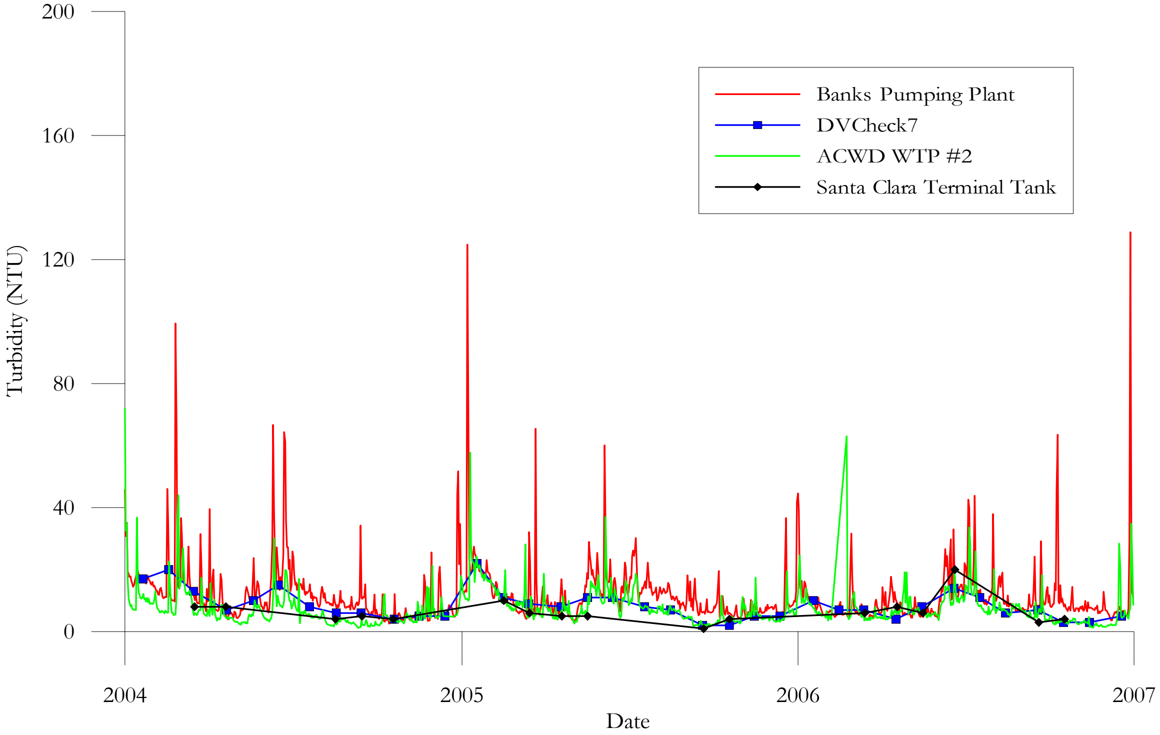


Figure C-14. Turbidity Values for Banks Pumping Plant, DVCheck7, ACWD WTP #2 Intake, and Santa Clara Terminal Tank 2004 - 2006

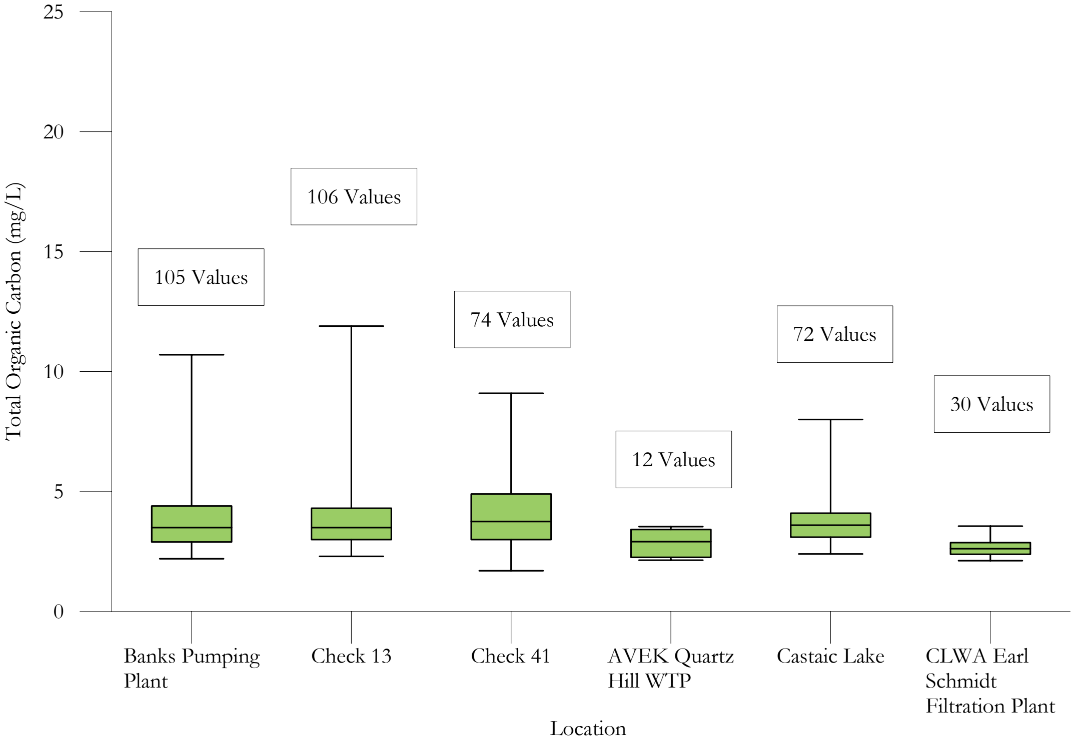


Figure C-15. Total Organic Carbon Ranges and Medians for Banks Pumping Plant, Check 13, Check 41, AVEK Quartz Hill WTP Intake, Castaic Lake, and CLWA Earl Schmidt Filtration Plant Intake 2004 - 2006

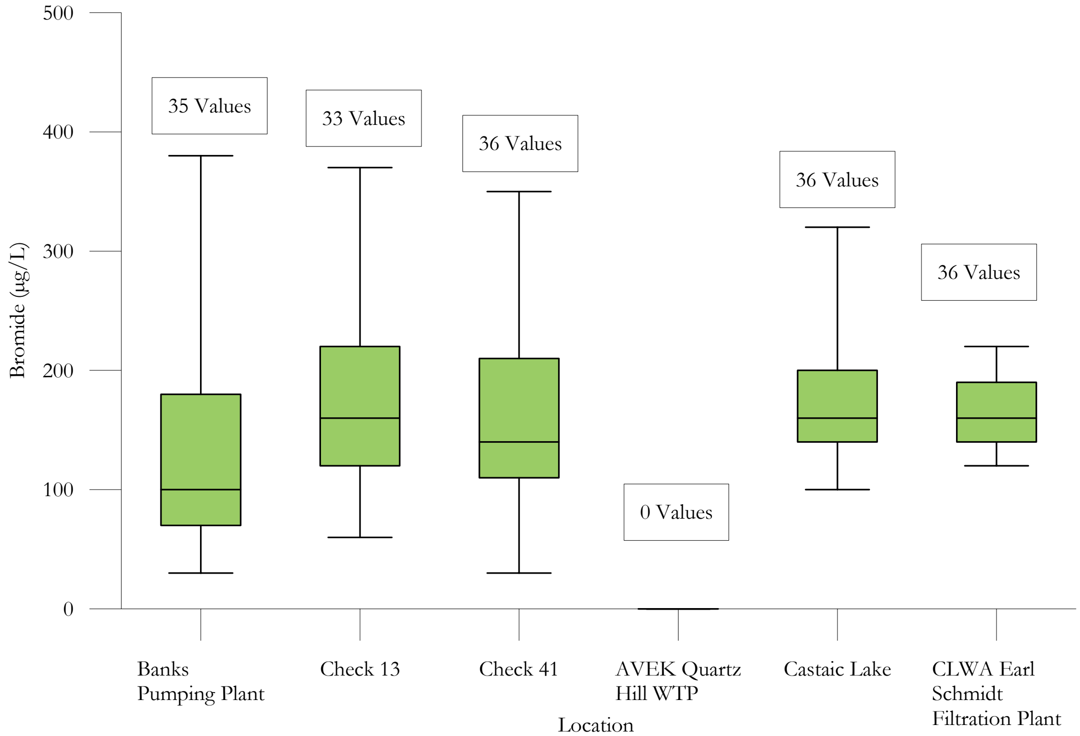


Figure C-16. Bromide Ranges and Medians for Banks Pumping Plant, Check 13, Check 41, AVEK Quartz Hill WTP Intake, Castaic Lake, and CLWA Earl Schmidt Filtration Plant Intake 2004 - 2006

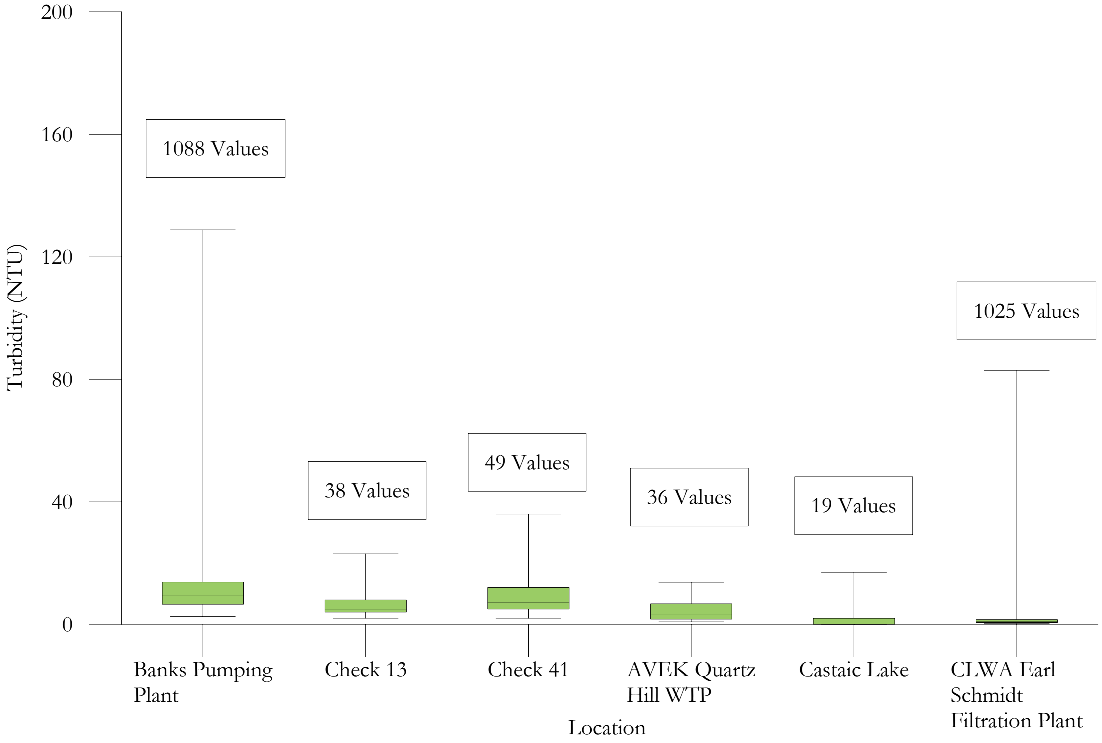


Figure C-17. Turbidity Ranges and Medians for Banks Pumping Plant, Check 13, Check 41, AVEK Quartz Hill WTP Intake, Castaic Lake, and CLWA Earl Schmidt Filtration Plant Intake 2004 – 2006

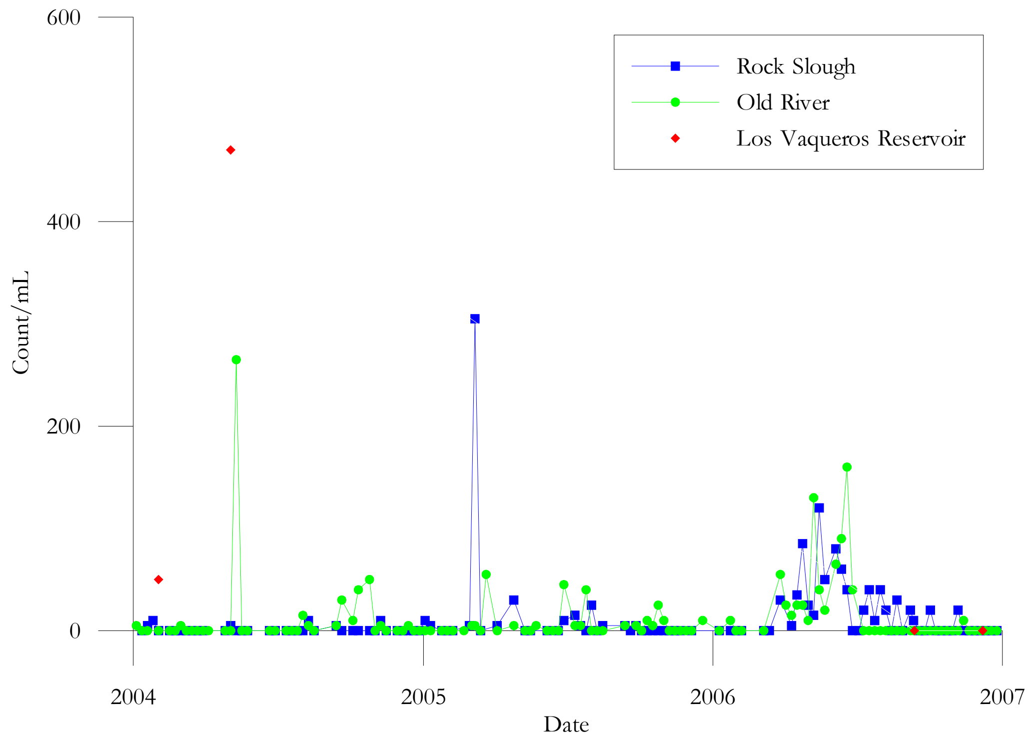


Figure C-18. Bluegreen Algae Cell Counts at Rock Slough and Old River Intakes and Los Vaqueros Reservoir 2004 – 2006

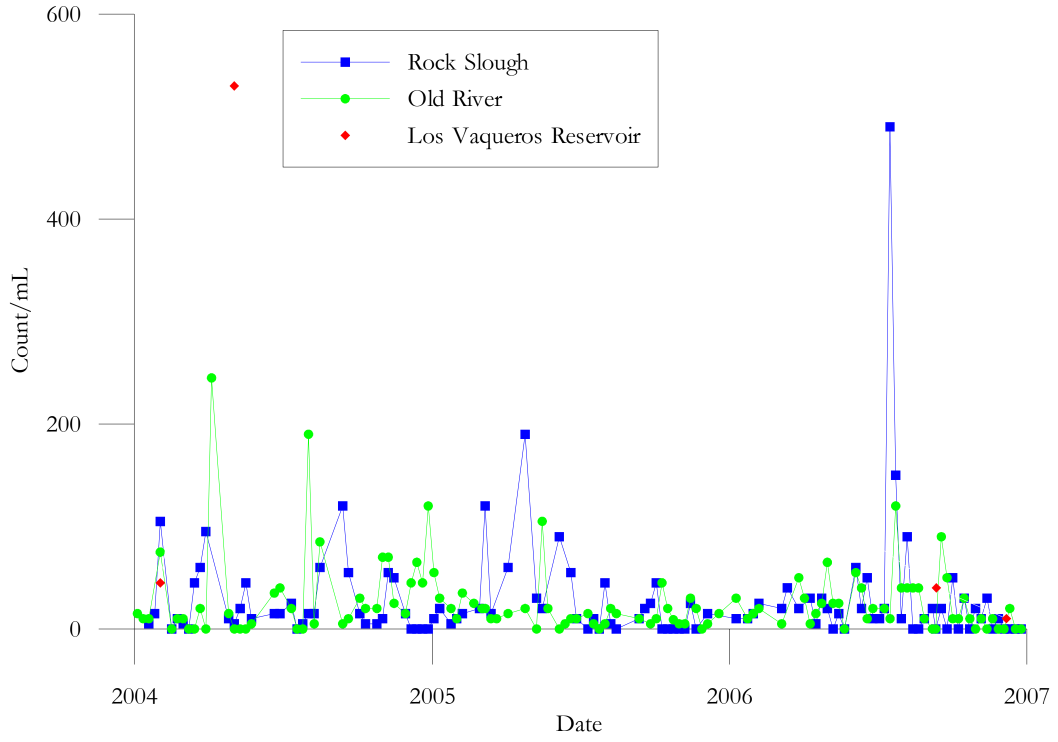


Figure C-19. Green Algae Cell Counts at Rock Slough and Old River Intakes and Los Vaqueros Reservoir 2004 – 2006

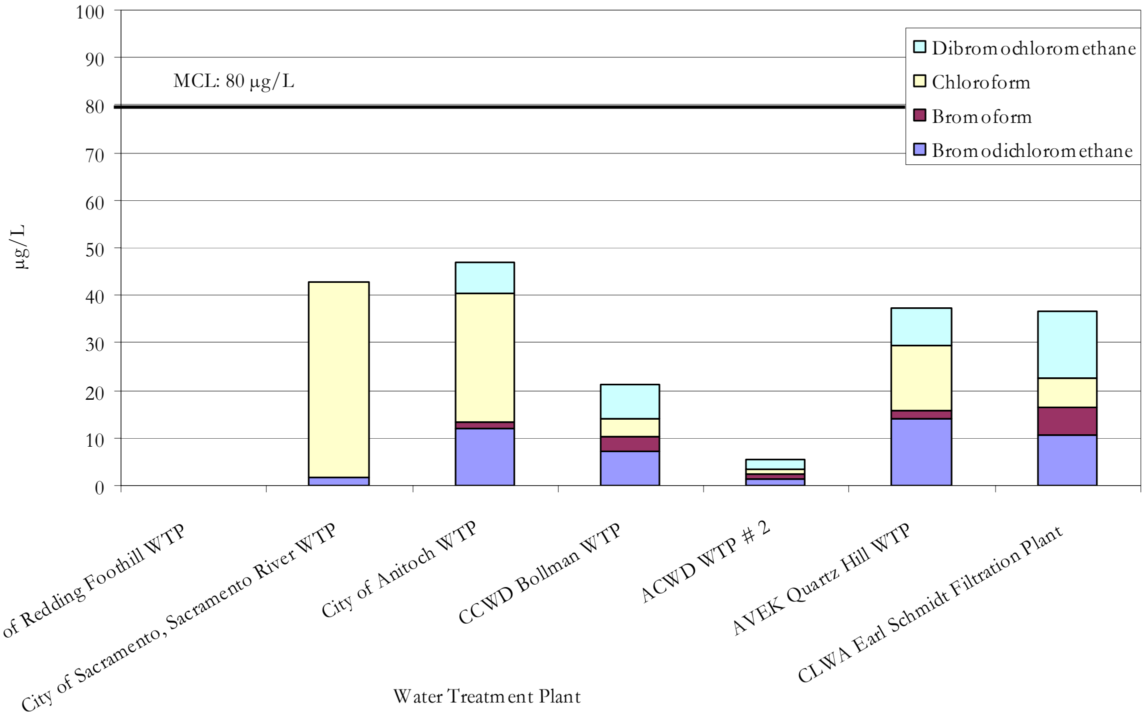


Figure C-20. THM Speciation for Study WTPs First Quarter, January – March, 2006

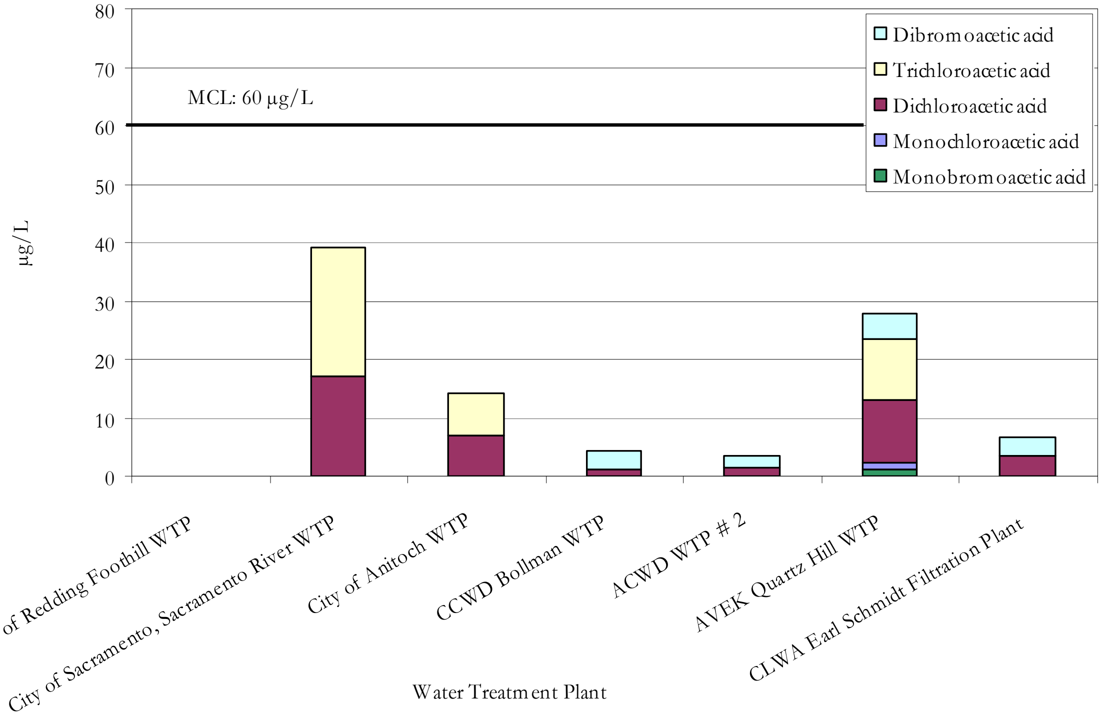


Figure C-21. HAA Speciation for Study WTPs First Quarter, January – March, 2006

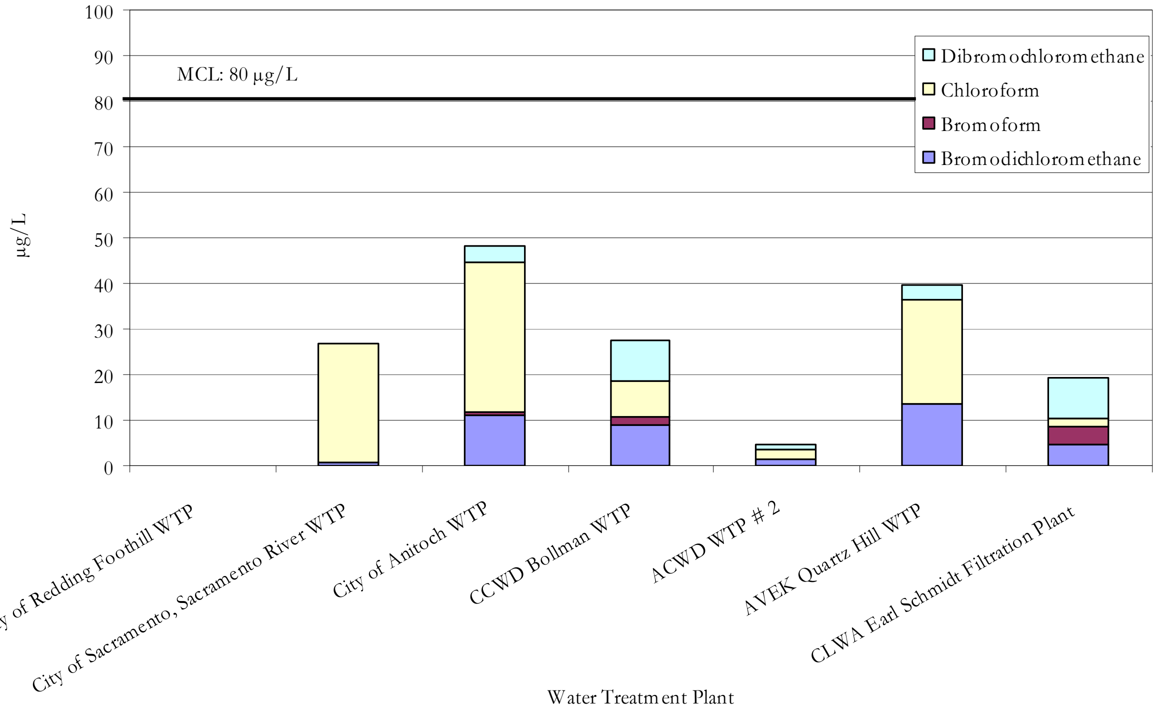


Figure C-22. THM Speciation for Study WTPs Second Quarter, April - June, 2006

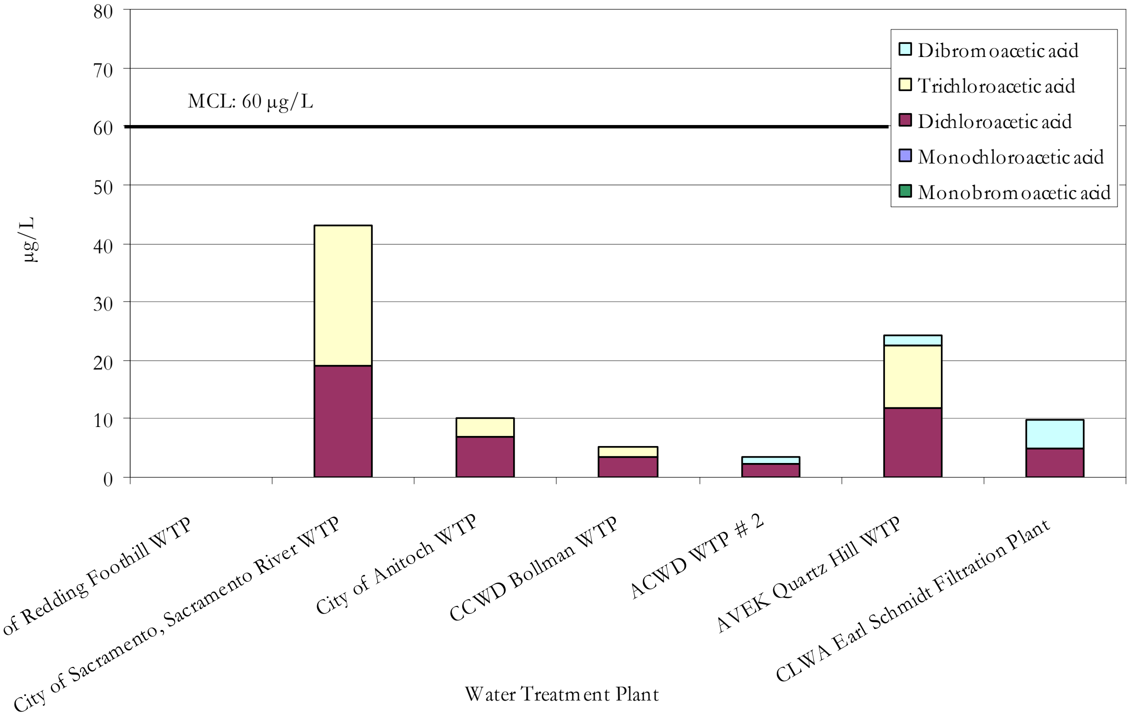


Figure C-23. HAA Speciation for Study WTPs Second Quarter, April - June, 2006

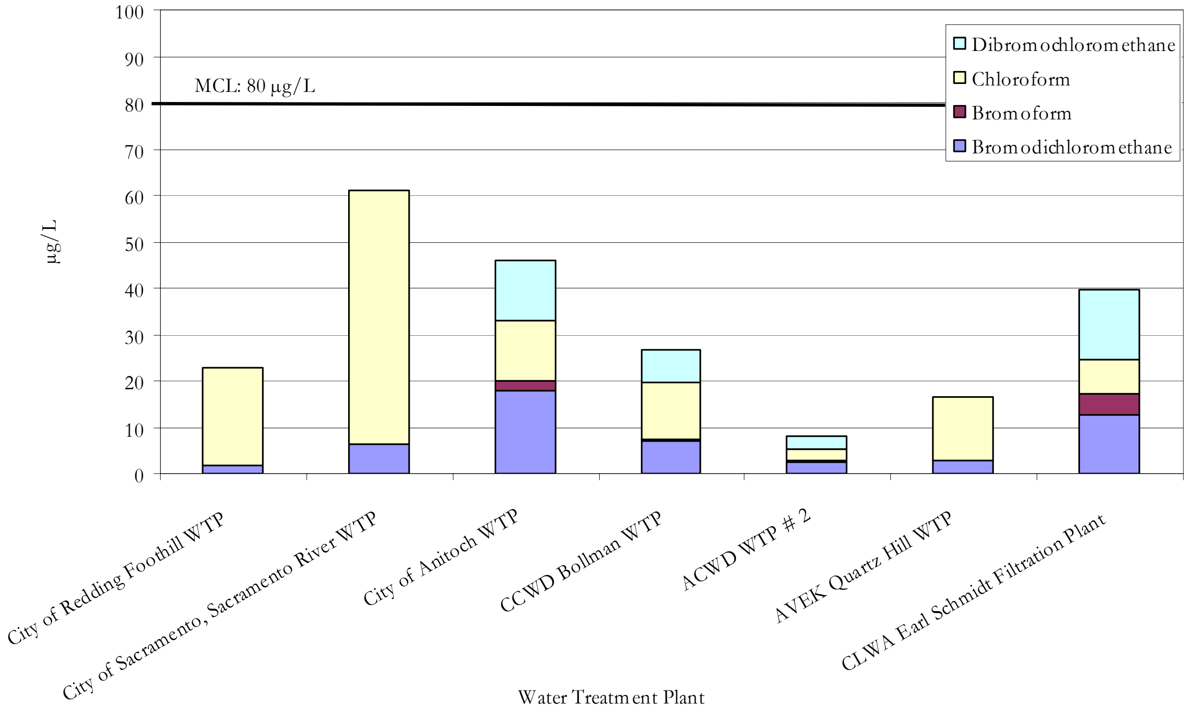


Figure C-24. THM Speciation for Study WTPs Third Quarter, July – September, 2006

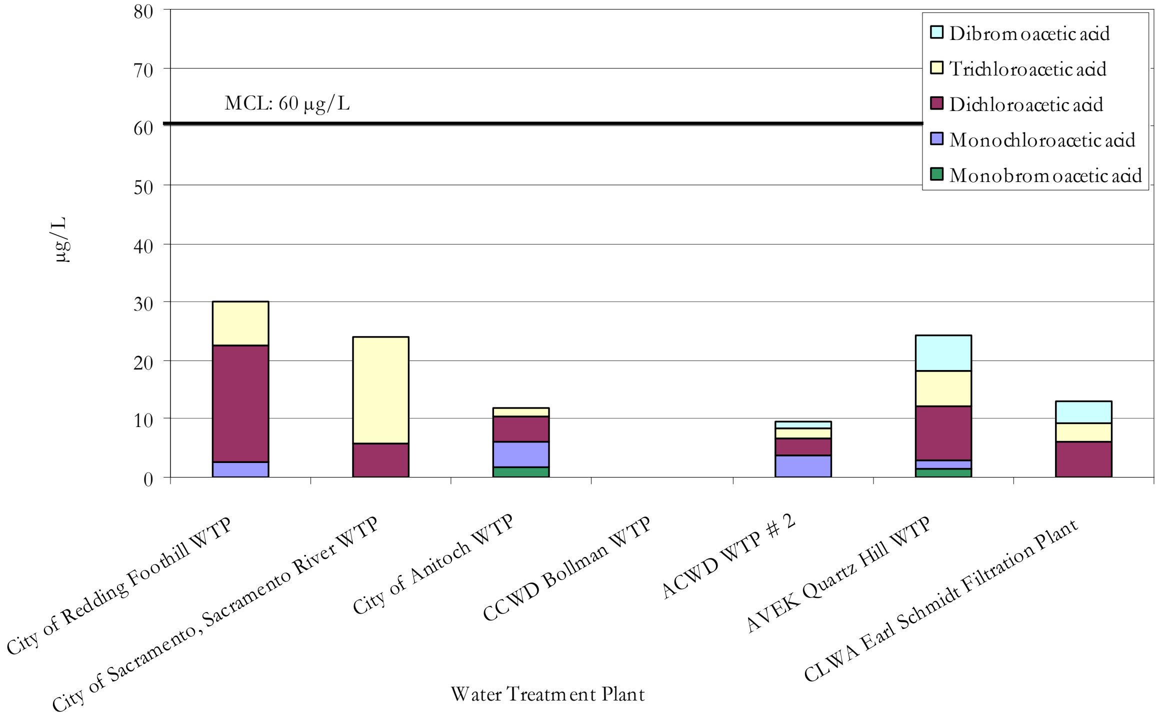


Figure C-25. HAA Speciation for Study WTPs Third Quarter, July – September, 2006

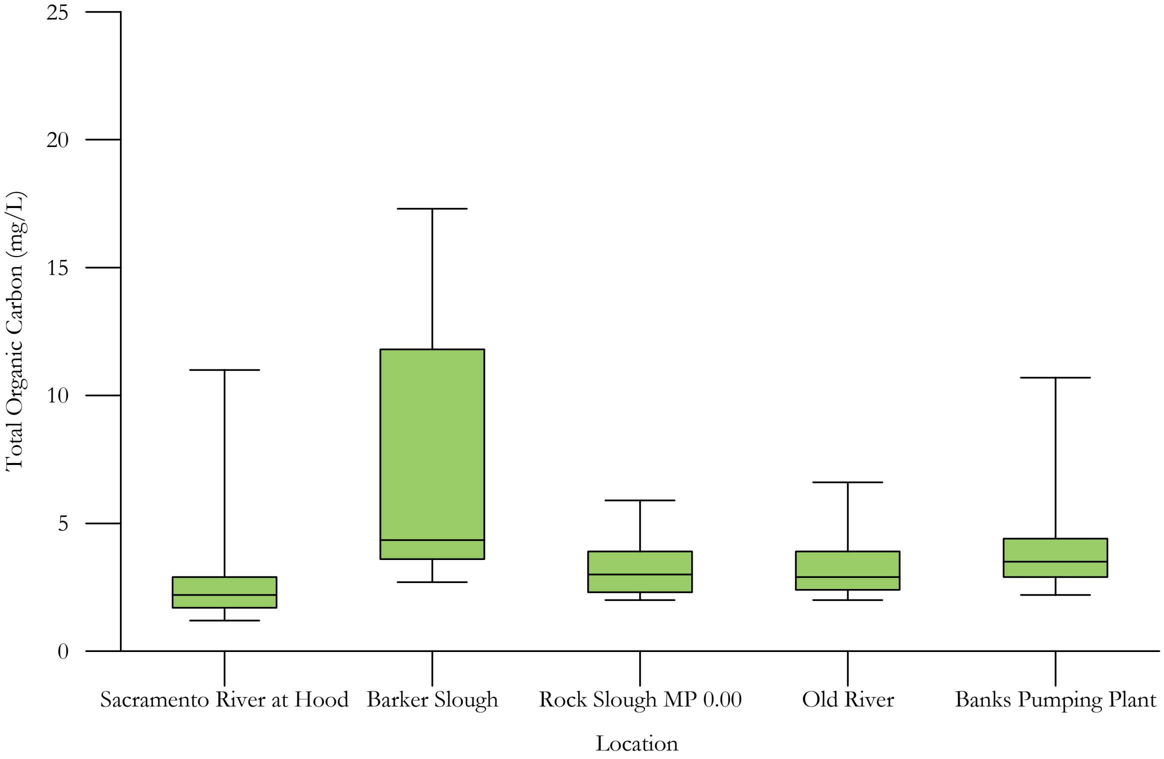


Figure C-26. TOC Range and Medians for Delta intakes 2004 – 2006

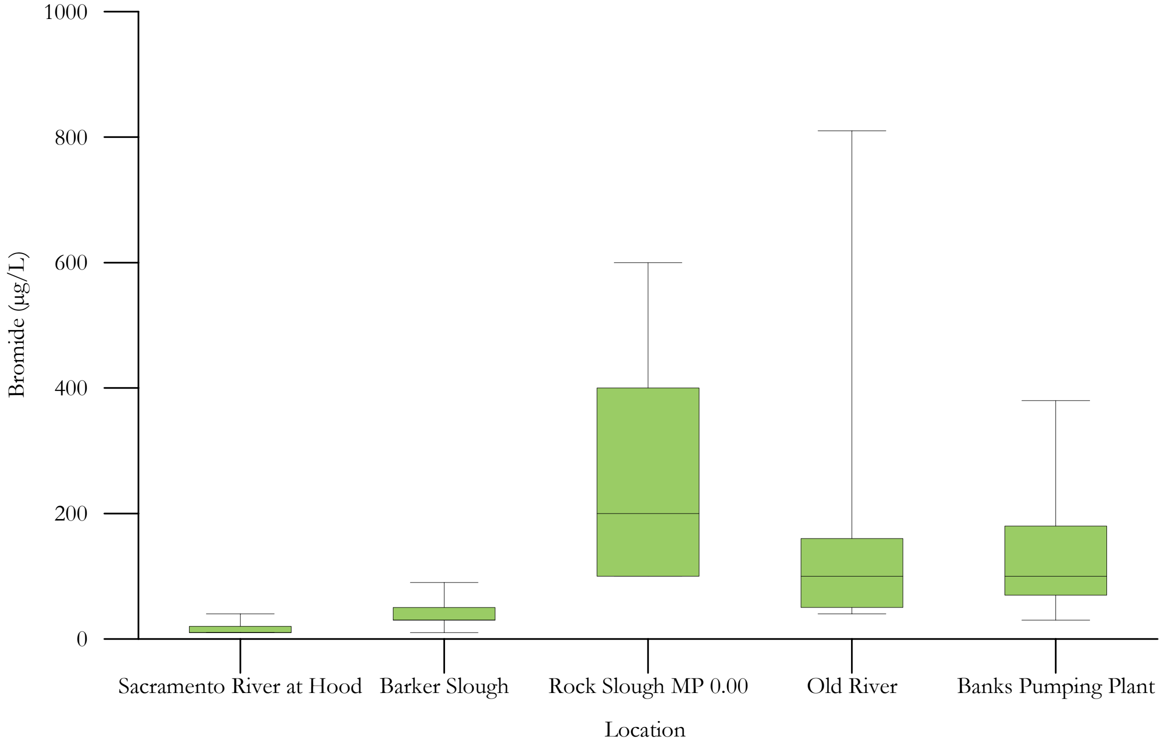


Figure C-27. Bromide Range and Medians for Delta intakes 2004 – 2006

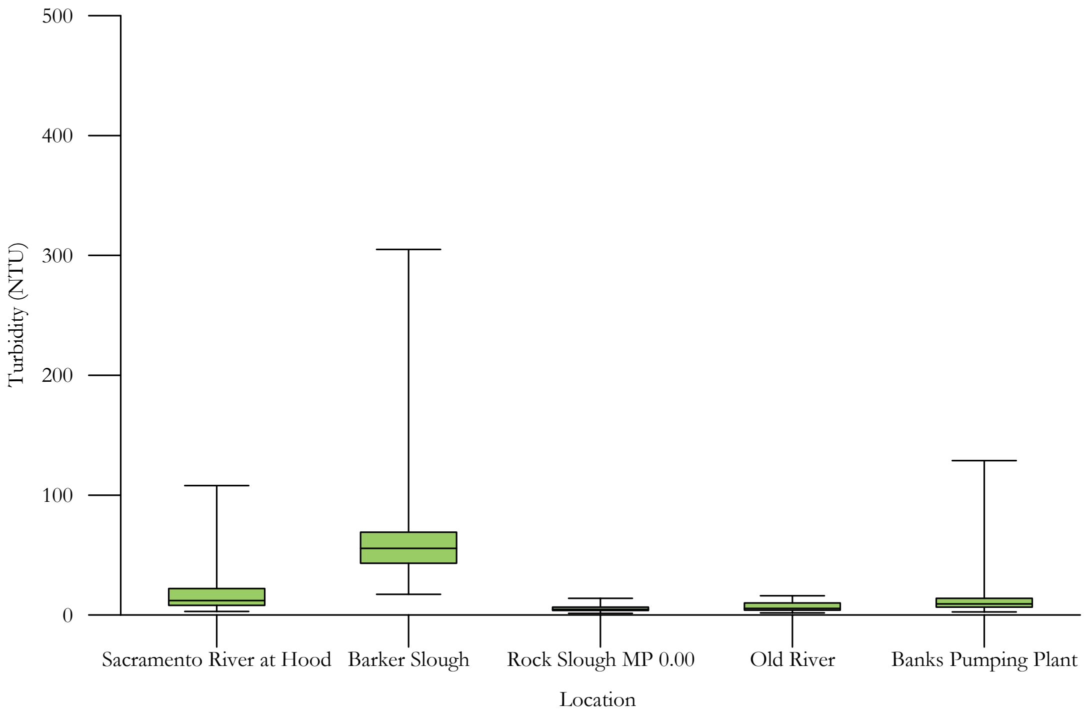


Figure C-28. Turbidity Range and Medians for Delta intakes 2004 – 2006

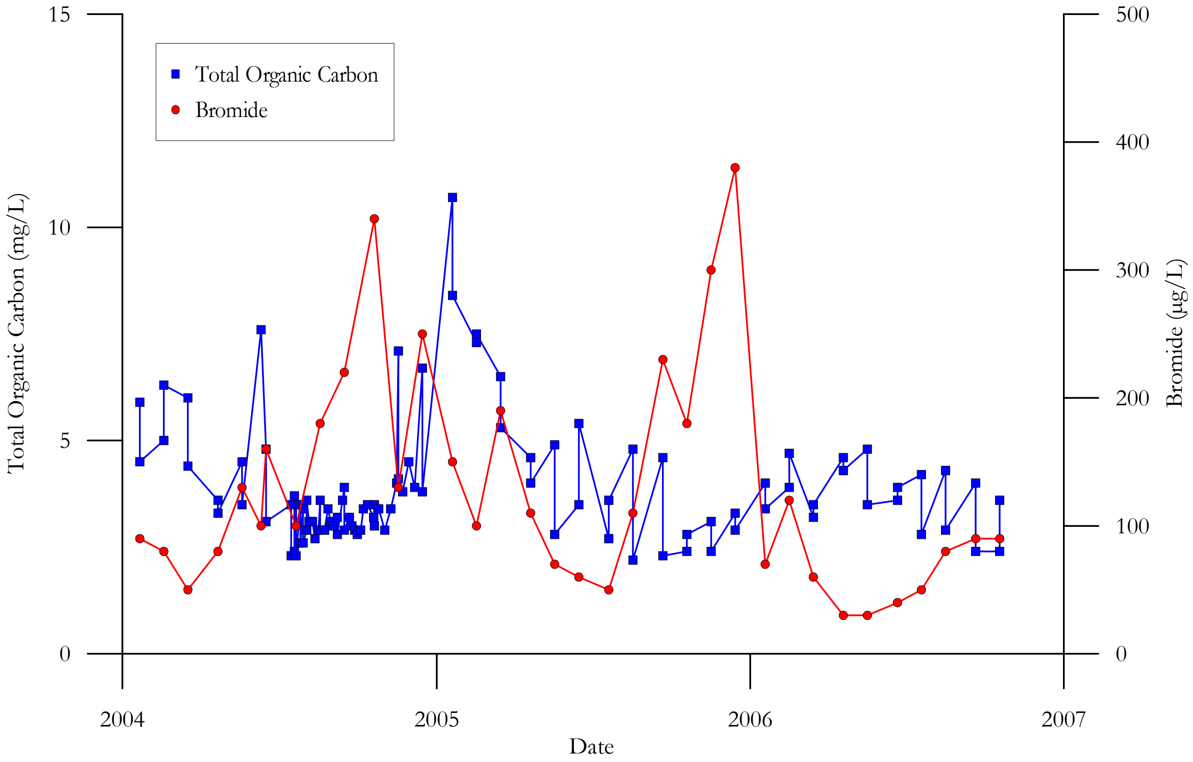


Figure C-29. TOC and Bromide Concentrations at H.O. Banks Pumping Plant

APPENDIX D

WTP Conceptual Models and Meeting Summaries

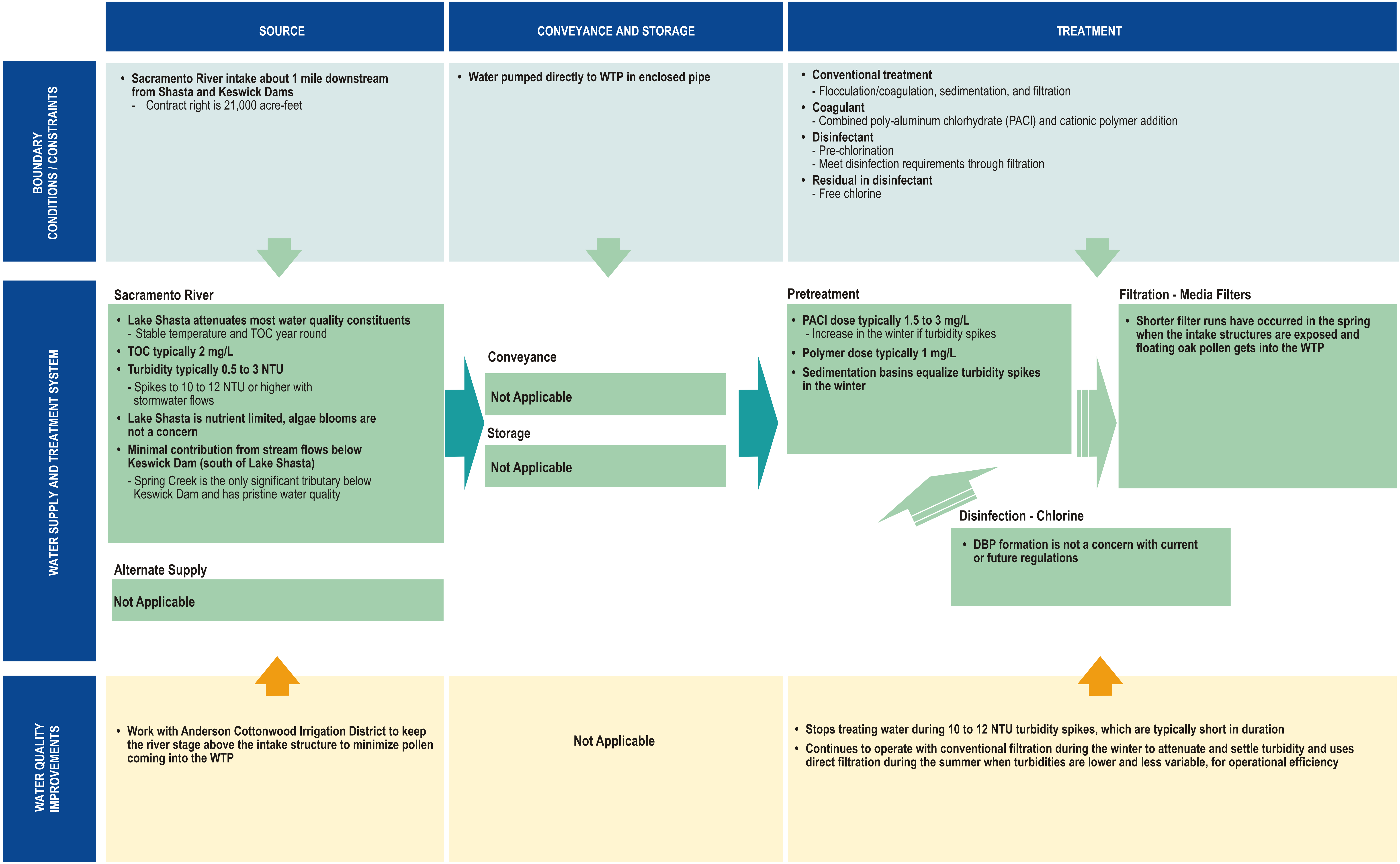
Conceptual Models:

- Upper Watershed – City of Redding, Foothill WTP
- Upper Watershed – City of Sacramento River, Sacramento WTP
- North Bay Aqueduct – City of American Canyon WTP
- Central/South Delta – Contra Costa Water District, Bollman WTP
- Central/South Delta – City of Antioch WTP
- South Bay Aqueduct – Zone 7 Water Agency, Patterson Pass WTP
- California Aqueduct – City of Coalinga WTP
- California Aqueduct, West Branch – Castaic Lake Water Authority, Earl Schmidt Filtration Plant
- California Aqueduct, East Branch – Antelope Valley East Kern WTP, Quartz Hill WTP

Meeting Summaries:

- City of Redding, Foothill Water Treatment Plant, Redding, CA
- City of Sacramento, Sacramento River Water Treatment Plant, Sacramento, CA
- Contra Costa Water District Bollman Water Treatment Plant, Concord, CA
- City of Antioch Water Treatment Plant, Antioch, CA
- Zone 7 Water Agency Patterson Pass Water Treatment Plant
- Alameda County Water District Water Treatment Plant #2, Fremont, CA
- Castaic Lake Water Agency Earl Schmidt Filtration Plant, Castaic, CA
- Antelope Valley East Kern Quartz Hill Water Treatment Plant, Palmdale, CA

UPPER WATERSHED - CITY OF REDDING, FOOTHILL WTP CONCEPTUAL MODEL



SOURCE | CONVEYANCE AND STORAGE | TREATMENT

BOUNDARY CONDITIONS / CONSTRAINTS

SOURCE

- **Sacramento River intake about 1 mile downstream from Shasta and Keswick Dams**
  - Contract right is 21,000 acre-feet

CONVEYANCE AND STORAGE

- **Water pumped directly to WTP in enclosed pipe**

TREATMENT

- **Conventional treatment**
  - Flocculation/coagulation, sedimentation, and filtration
- **Coagulant**
  - Combined poly-aluminum chlorhydrate (PACl) and cationic polymer addition
- **Disinfectant**
  - Pre-chlorination
  - Meet disinfection requirements through filtration
- **Residual in disinfectant**
  - Free chlorine

WATER SUPPLY AND TREATMENT SYSTEM

Sacramento River

- **Lake Shasta attenuates most water quality constituents**
  - Stable temperature and TOC year round
- **TOC typically 2 mg/L**
- **Turbidity typically 0.5 to 3 NTU**
  - Spikes to 10 to 12 NTU or higher with stormwater flows
- **Lake Shasta is nutrient limited, algae blooms are not a concern**
- **Minimal contribution from stream flows below Keswick Dam (south of Lake Shasta)**
  - Spring Creek is the only significant tributary below Keswick Dam and has pristine water quality

Alternate Supply

Not Applicable

Conveyance

Not Applicable

Storage

Not Applicable

Pretreatment

- **PACl dose typically 1.5 to 3 mg/L**
  - Increase in the winter if turbidity spikes
- **Polymer dose typically 1 mg/L**
- **Sedimentation basins equalize turbidity spikes in the winter**

Filtration - Media Filters

- **Shorter filter runs have occurred in the spring when the intake structures are exposed and floating oak pollen gets into the WTP**

Disinfection - Chlorine

- **DBP formation is not a concern with current or future regulations**

WATER QUALITY IMPROVEMENTS

SOURCE

- **Work with Anderson Cottonwood Irrigation District to keep the river stage above the intake structure to minimize pollen coming into the WTP**

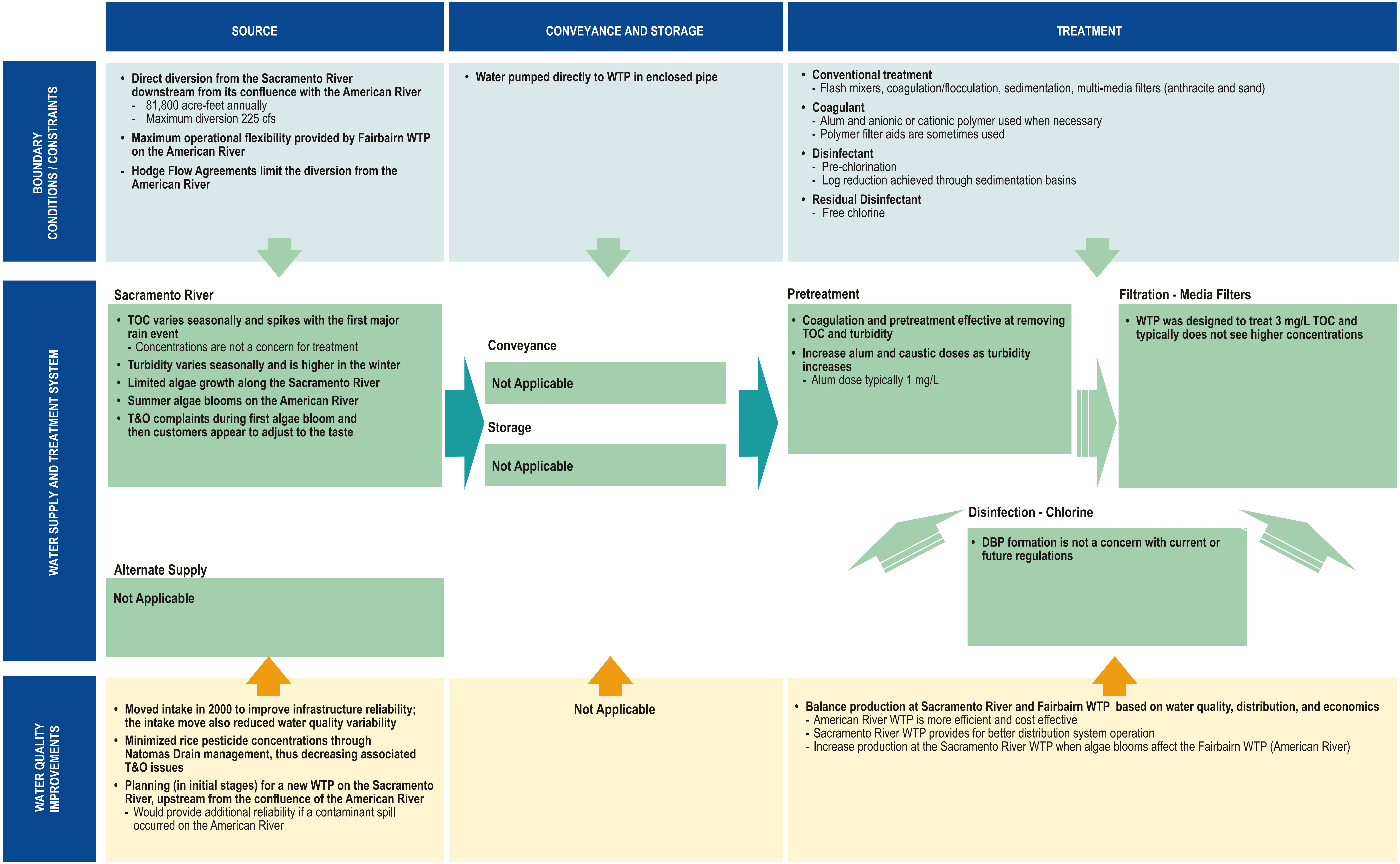
CONVEYANCE AND STORAGE

Not Applicable

TREATMENT

- **Stops treating water during 10 to 12 NTU turbidity spikes, which are typically short in duration**
- **Continues to operate with conventional filtration during the winter to attenuate and settle turbidity and uses direct filtration during the summer when turbidities are lower and less variable, for operational efficiency**

UPPER WATERSHED - CITY OF SACRAMENTO, SACRAMENTO RIVER WTP CONCEPTUAL MODEL



SOURCE

CONVEYANCE AND STORAGE

TREATMENT

BOUNDARY CONDITIONS / CONSTRAINTS

Source

- **Direct diversion from the Sacramento River downstream from its confluence with the American River**
  - 81,800 acre-feet annually
  - Maximum diversion 225 cfs
- **Maximum operational flexibility provided by Fairbairn WTP on the American River**
- **Hodge Flow Agreements limit the diversion from the American River**

Conveyance and Storage

- **Water pumped directly to WTP in enclosed pipe**

Treatment

- **Conventional treatment**
  - Flash mixers, coagulation/flocculation, sedimentation, multi-media filters (anthracite and sand)
- **Coagulant**
  - Alum and anionic or cationic polymer used when necessary
  - Polymer filter aids are sometimes used
- **Disinfectant**
  - Pre-chlorination
  - Log reduction achieved through sedimentation basins
- **Residual Disinfectant**
  - Free chlorine

WATER SUPPLY AND TREATMENT SYSTEM

Sacramento River

- **TOC varies seasonally and spikes with the first major rain event**
  - Concentrations are not a concern for treatment
- **Turbidity varies seasonally and is higher in the winter**
- **Limited algae growth along the Sacramento River**
- **Summer algae blooms on the American River**
- **T&O complaints during first algae bloom and then customers appear to adjust to the taste**

Alternate Supply

Not Applicable

Conveyance

Not Applicable

Storage

Not Applicable

Pretreatment

- **Coagulation and pretreatment effective at removing TOC and turbidity**
- **Increase alum and caustic doses as turbidity increases**
  - Alum dose typically 1 mg/L

Filtration - Media Filters

- **WTP was designed to treat 3 mg/L TOC and typically does not see higher concentrations**

Disinfection - Chlorine

- **DBP formation is not a concern with current or future regulations**

WATER QUALITY IMPROVEMENTS

Source

- **Moved intake in 2000 to improve infrastructure reliability; the intake move also reduced water quality variability**
- **Minimized rice pesticide concentrations through Natomas Drain management, thus decreasing associated T&O issues**
- **Planning (in initial stages) for a new WTP on the Sacramento River, upstream from the confluence of the American River**
  - Would provide additional reliability if a contaminant spill occurred on the American River

Conveyance and Storage

Not Applicable

Treatment

- **Balance production at Sacramento River and Fairbairn WTP based on water quality, distribution, and economics**
  - American River WTP is more efficient and cost effective
  - Sacramento River WTP provides for better distribution system operation
  - Increase production at the Sacramento River WTP when algae blooms affect the Fairbairn WTP (American River)

NORTH BAY AQUEDUCT - CITY OF AMERICAN CANYON WTP CONCEPTUAL MODEL

BOUNDARY CONDITIONS / CONSTRAINTS

SOURCE

- **Barker Slough Pumping Plant**
  - Primarily Sacramento River water via Barker Slough
- **SWP water**
  - Quantity is limited due to contract agreements
- **Purchase treated water to augment supply**
  - Primarily from City of Napa in the summer
  - Occasionally from Vallejo; however, more expensive

CONVEYANCE AND STORAGE

- **North Bay Aqueduct (NBA)**
  - Underground pipeline
- **Napa Turnout Reservoir**
  - Open, lined tank
  - Shared with City of Napa
  - 22 acre-feet tank
  - Very short residence time
- **Tank at WTP site**
  - Storage capacity 7mg
  - Very short residence time

TREATMENT

Parallel treatment plants

1) Conventional 5 mgd

- Rapid mix, flocculation and tube settlers for sedimentation
- Multi-media filters
- Use non-ionic polymer filter aid (0.2 mg/L)

2) Membrane 5 mgd

- Rapid mix with submerged membrane in sedimentation tank
- ZeeWeed 500 Ultra-filtration membranes

Both treatment plants

- **Coagulant**
  - Alum
- **Disinfectant**
  - Post-chlorination
- **Residual disinfectant**
  - Free chlorine

WATER SUPPLY AND TREATMENT SYSTEM

Barker Slough Pumping Plant

- **Sacramento River**
  - TOC < 2 mg/L in dry season and 4 to 6 mg/L in wet season
- **Barker Slough Watershed**
  - Watershed contributions increase concentrations and seasonal variability of TOC, turbidity, and iron
  - Median TOC is 4.5 mg/L; winter episodic highs range from 14 to 24 mg/L
  - Turbidity is highly variable
  - Bromide - 100µg/L to 500 µg/L
  - Alkalinity drops to 40 to 60 mg/L with rain events

Conveyance - North Bay Aqueduct

- **No observed impacts to water quality**
- **WTP site storage tank**
  - Most iron is oxidized and settles
  - Some algae growth occurs in tank but typically no T&O complaints

Pretreatment

- **Water with high TOC and turbidity and low alkalinity is difficult to coagulate**
- **Depress pH with acidified alum critical for removing TOC and meeting DBP MCLs**
- **TOC is the driver for chemical addition**
  - Alum dose typically 50 to 120 mg/L

Filtration - Media and Membrane Filtration

- **Consistently meets SWTR TOC removal requirements but meeting DBP MCLs remains difficult**
- **Turbidity removal with membrane treatment is reliable, while the conventional filters have more challenging operational requirements**
- **Automated membrane treatment plant requires significantly less operator attention than the conventional media filters**

Disinfection - Post chlorination

- **Pre-chlorination not practiced because it results in DBP concentrations above the MCL**
- **Meeting DBP MCLs was not problematic during 2007 because TOC concentrations were low in the NBA due to dry weather**
- **Meeting Stage 2 D/DBPR is a concern because TOC concentrations are typically high**

Alternate Supply

Not Applicable

Storage

Not Applicable

WATER QUALITY IMPROVEMENTS

SOURCE

- **Seeking to further limit water quality degradation through Barker Slough watershed**
  - Fencing and cattle guards installed to limit pathogen TOC contribution from watershed
  - Reduction in TOC and turbidity would help treatment and limit DBP formation
- **Proceed with projects to re-locate the NBA intake**

CONVEYANCE AND STORAGE

- **Installing two new closed-top tanks for on-site storage to help with tank maintenance and algae control**

TREATMENT

- **Would like to have separate alum and acid addition, rather than premixed acidified alum, to better control pH suppression and alum addition for optimal organic carbon removal**
- **Planning on conducting pilot studies on the membrane treatment plant to improve TOC removal**

CENTRAL/SOUTH DELTA - CONTRA COSTA WATER DISTRICT, BOLLMAN WTP CONCEPTUAL MODEL

BOUNDARY CONDITIONS / CONSTRAINTS

SOURCE

- **Old River Intake**
  - Individual max. diversion - 250 cfs
  - No diversions allowed to fill Los Vaqueros Reservoir for 75 day period from March 15 through May 31 for fish protection
- **Rock Slough Intake**
  - Maximum combined total of 350 cfs can be pumped into the canal
  - January through August use of Old River over Rock Slough preferred for fish protection
  - CCWD preferred intake with respect to pumping costs
- **Mallard Slough Intake**
  - Supplies Contra Costa Canal east of Bollman WTP Max diversion 39.2 cfs
  - No direct Delta diversions (all 3 intakes) April 1 through April 30 for fish protection

CONVEYANCE AND STORAGE

- **Contra Costa Canal**
  - Unlined portion the first 4 miles at Rock Slough
  - Supplied by all three intakes and Los Vaqueros Reservoir
- **Los Vaqueros Reservoir**
  - Supplied by Old River Intake
  - Maximum storage 100,000 acre-feet; 30,000 acre-feet available supply
- **Contra Loma Reservoir**
  - Max storage 2,500 acre-feet
- **Mallard Reservoir**
  - Supplied by Contra Costa Canal
  - Total capacity 3,000 acre-feet; usable capacity 2,100 acre-feet

TREATMENT

- **Receives water from Mallard Reservoir or directly from Contra Costa Canal**
- **Conventional treatment**
  - Flash mix, flocculation, sedimentation, ozone and GAC filtration
- **Coagulant**
  - Alum and cationic filter aid
- **Disinfectant**
  - Ozone off-gassing limits dose to 3 to 4 mg/L
- **Residual disinfectant**
  - Free chlorine

WATER SUPPLY AND TREATMENT SYSTEM

CCWD Delta Intakes

- **TOC is typically 2.5 to 4.5 mg/L,**
  - Short duration peaks of 5 to 7 mg/L in winter
- **Alkalinity ~ 65 mg/L**
  - Last spring alkalinities were low, at ~30 mg/L for a few days
  - Low alkalinity potentially linked to increased SJR flows
- **Chloride levels typically too high to pump from Mallard Slough more than ~30 days per year**
- **Bromide is typically 100 to 150 µg/L; ranges from 40 to 800 µg/L**

Alternate Supply

Not Applicable

Conveyance - Contra Costa Canal

- **Select intakes and operate to maintain chloride at 65 mg/L or less**
- **Algae growth in unlined portion at Rock Slough Intake**

Storage - Los Vaqueros Reservoir

- **Fill when chloride at Old River Intake is less than 50 mg/L**
  - Currently chloride in reservoir is less than 40 mg/L
- **Well mixed**
- **No algae blooms**

Storage - Mallard Reservoir

- **Operated as a forebay to Bollman WTP**
- **Seasonal algae blooms**
  - T&O issues typically related to Mallard Reservoir

Pretreatment

- **Intake water quality**
  - Turbidity is stable at ~ 3 NTU
  - *Cryptosporidium* has not been detected
  - Total/Fecal Coliform varies but does not require additional treatment
- **Alum dose typically 40 mg/L**
- **Approximately 40 percent TOC removal achieved through sedimentation basins**
- **Uncharacteristically low alkalinities last spring hindered coagulation**

Filtration

- **GAC replaced every 4 years**
- **GAC filters act as T&O polishing after ozonation**

Disinfection

- **Ozone provides T&O control**
  - Previously, a simultaneous algae bloom and ozone system outage led to T&O problems
- **Redundant/double CT credit from intermediate ozone and chlorine addition after filtration**
  - THMs 25 to 30 µg/L
  - HAAs <10 µg/L

WATER QUALITY IMPROVEMENTS

SOURCE

- **Working with fish agencies to include alternative days or an alternative schedule to the 75 day no-fill period at Old River**
- **Constructing a new intake near Old River off of Victoria Canal to improve water quality and protect fish**
- **Blending sources (Rock Slough, Old River, and Los Vaqueros) to deliver water with chloride levels at 65 mg/L or less**

CONVEYANCE AND STORAGE

- **Investigating multiple alternatives to control algae and plant growth in reservoirs and conveyance**
  - Use chelated copper at Mallard Reservoir
  - Used sonar treatment at Contra Loma last year
  - Limit chemical application for algae control by trying partial treatments first
  - Use chelated copper and harvest in the unlined portion of the canal
- **Monitoring geosmin and MIB in conveyance and storage from April through October to anticipate T&O problems**
- **Encasing the unlined portion of Rock Slough to mitigate water quality degradation due to filtration**
- **Performing feasibility studies for Los Vaqueros Reservoir Expansion Project**

TREATMENT

- **Planned improvements to ozonation system will allow higher doses by providing better quenching and minimize off-gassing**

CENTRAL/SOUTH DELTA - CITY OF ANTIOCH WTP CONCEPTUAL MODEL

BOUNDARY CONDITIONS / CONSTRAINTS

SOURCE

- **Have San Joaquin River (SJR) water rights**
  - Intake west of the Antioch Bridge within the legal boundary of the Delta
  - Less expensive than other source water
- **Purchase raw water from Contra Costa Water District (CCWD) when SJR rights are not available**

CONVEYANCE AND STORAGE

- **CCWD water via Contra Costa Canal**
  - Open canal, first four miles unlined
  - CCWD notifies City of Antioch when switching from direct Delta Intakes to Los Vaqueros Reservoir
- **SJR water pumped directly to City of Antioch Municipal Reservoir or WTP**
- **Antioch Municipal Reservoir**
  - Storage capacity 735 acre-feet
  - Residence time is 7 to 20 days
- **Los Vaqueros Reservoir**
  - Maximum storage 100,000 acre-feet
  - Typical storage 73,000 acre-feet

TREATMENT

- **Conventional treatment**
  - Flash mixers, flocculation, tube settlers for sedimentation, and multi-media filters with GAC and sand
- **Coagulant**
  - Alum
- **Disinfectant**
  - Pre-chlroination
- **Distribution system residual disinfectant**
  - Combined chlorine

WATER SUPPLY AND TREATMENT SYSTEM

Central Delta - Contra Costa Canal

- **Rock Slough Intake**
  - TOC ~ 3 mg/L
  - Bromide ~ 200 µg/L
- **Old River Intake**
  - TOC ~ 3 mg/L
  - Bromide ~ 150 µg/L

Alternate Supply - San Joaquin River

- **Stop pumping when chloride is greater than 250 mg/L**
- **TOC typically 3 mg/L or less**
- **Typically able to pump from December/January to May**
- **During wet years salinity on the SJR is typically lower and the City an use source longer**
  - During very dry years salinity has precluded pumping

Conveyance - Contra Costa Canal

- **CCWD goal is to deliver 65 mg/L or less chloride**
- **Little change in water quality through the canal**

Conveyance - San Joaquin River

Not Applicable

Storage - Antioch Municipal Reservoir

- **Combined SJR and Contra Costa Canal water**
- **Seasonal algae blooms**
- **Little improvement to water quality or buffering of variability**

Storage - Los Vaqueros Reservoir

- **Spike in turbidity when CCWD switches to Los Vaqueros Reservoir**

Pretreatment

- **Alum dose typically 45 mg/L**
- **Turbidity causes pre-treatment difficulties at >100 NTU and have had to waste water at >120 NTU**
- **Source temperature differences between the reservoir and Contra Costa Canal can cause thermal inversion in the upflow clarifiers**

Filtration - Conventional

- **GAC filters effectively control taste and odor**
- **Filter aids typically not used because they do not improve water quality**
- **TOC removal is currently not a treatment concern**
  - WTP effectively treats episodic highs between 10 to 12 mg/L

Disinfection

- **Ozone provides T&O control**
  - Previously, a simultaneous algae bloom and ozone system outage led to T&O problems
- **Redundant/double CT credit from intermediate ozone and chlorine addition after filtration**
  - THMs ~25 to 30 µg/L
  - HAAs ~10 µg/L

WATER QUALITY IMPROVEMENTS

SOURCE

- **Would like to move San Joaquin River Intake to a location with lower chloride to increase pumping flexibility**
- **Future source reliability is a concern due to population growth**

CONVEYANCE AND STORAGE

- **Limiting algae growth in Antioch Municipal Reservoir with Solar Bees (installed 2006) and copper sulfate**
- **Would like a larger reservoir to capture higher water qualities, attenuate water quality variability, and use a more economical source water, but constrained by land availability and economics**

TREATMENT

- **Installed tube settlers in both clarifiers to address thermal inversions that occur at the WTP**
  - Tube settlers are a critical component in treatment for achieving water quality objectives

SOUTH BAY AQUEDUCT - ZONE 7 WATER AGENCY, PATTERSON PASS WTP CONCEPTUAL MODEL

BOUNDARY CONDITIONS / CONSTRAINTS

SOURCE

- **H.O. Banks Pumping Plant in Clifton Court Forebay**
  - Operated by DWR
- **Lake Del Valle**
  - Multiple use facility
  - Kept at full capacity in summer for recreation
  - Release into SBA operated by DWR
  - Release mixed with Delta water in SBA
  - Less than 20 percent of SBA contractors total source water
  - Typically drawn down during fall months

CONVEYANCE AND STORAGE

- **South Bay Aqueduct (SBA)**
  - SBA intake at Bethany Reservoir
  - Operated by DWR
- **Patterson Reservoir**
  - Storage capacity 30 mg
  - Open, concrete lined tank
  - Filled with SBA water
- **Lake Del Valle**
  - Stores primarily watershed water
  - Filled with Delta water when not filled from watershed

TREATMENT

Parallel Treatment Plants

1) Conventional treatment - 12 mgd
- Dual media filters: anthracite and sand
- Achieve disinfection credit through filters

2) Ultrafiltration Membrane Plant - 8 mgd
- Aquasource® ultrafiltration membranes
- Use chlorine and citric acid to clean membranes
- Operated during the summer to meet peak demands
- Membrane material exposure to chlorine needs to be limited and must be shut down at > 0.02 mg/L Cl

- **Both Treatment Plants**
  - Upflow clarifiers separate for each plant
- **Coagulant**
  - $FeCl_3$
- **Residual disinfectant**
  - Combined chlorine

WATER SUPPLY AND TREATMENT SYSTEM

Delta - H.O. Banks Pumping Plant

- **TOC ~ 3 mg/L, with higher spikes**
- **Bromide ~ 150 µg/L**
  - Highest in November and December
- **High winds cause turbidity spikes in Clifton Court Forebay**
- **Seasonal algae growth occurs in both the Delta and Clifton Court Forebay**
- **Water quality issues are primarily related to the Delta**
- **Variable alkalinity, averages 80mg/L, ranges from 30 to 170 mg/L**

Alternate Supply: Lake Del Valle

- **Higher alkalinity and better water quality than Delta**
- **Used to blend Delta water to address low alkalinity or other problematic water qualities such as taste and odor**

Conveyance - South Bay Aqueduct (SBA)

- **Algae growth**
  - In the past, algae growth occurred from April through November
  - Now algae is variable and year round, driven by water temperature
- **pH fluctuates from 7.5 to 9.5**
  - Algae growth is the main cause of pH fluctuations
- **Alkalinity decreases during the rainy season**

Storage - Patterson Pass Reservoir

- **Helps moderate source water temperature and pH fluctuations**
  - Other Zone 7 WTP has more difficulty with SBA pH fluctuations because it has no intermediate storage
- **Provides settling for some constituents in reservoir**
- **Receives overflow from top 1 to 2 feet of SBA, which is the best water quality in the SBA**

Storage - Lake Del Valle

- **Generally better water quality than Delta water and less algae growth**

Pretreatment

- **$FeCl_3$ used for TOC removal**
  - 26 mg/L results in 40 to 50 percent TOC removal
  - $FeCl_3$ provides better filter performance than alum for the pH range and low alkalinity in the source water
- **Free chlorine used occasionally to treat algae growth in upflow clarifiers**

Filtration - Media and Membrane Filters

- **Algae layer formed on top of upflow clarifiers causes issues with downstream filter performance**
  - Conventional algae can shorten filter runs to 4 to 8 hours, while higher water qualities allow for 120 hour filter runs
  - Membrane 200 µm strainers upstream from the membranes need to be pressure washed up to once a week

Disinfection: Chlorine

- **Chlorine added before the filters in the conventional plant**
- **DBP formation not an issue**
  - THMs ~40 µg/L
  - HAAs 20 to 25 µg/L

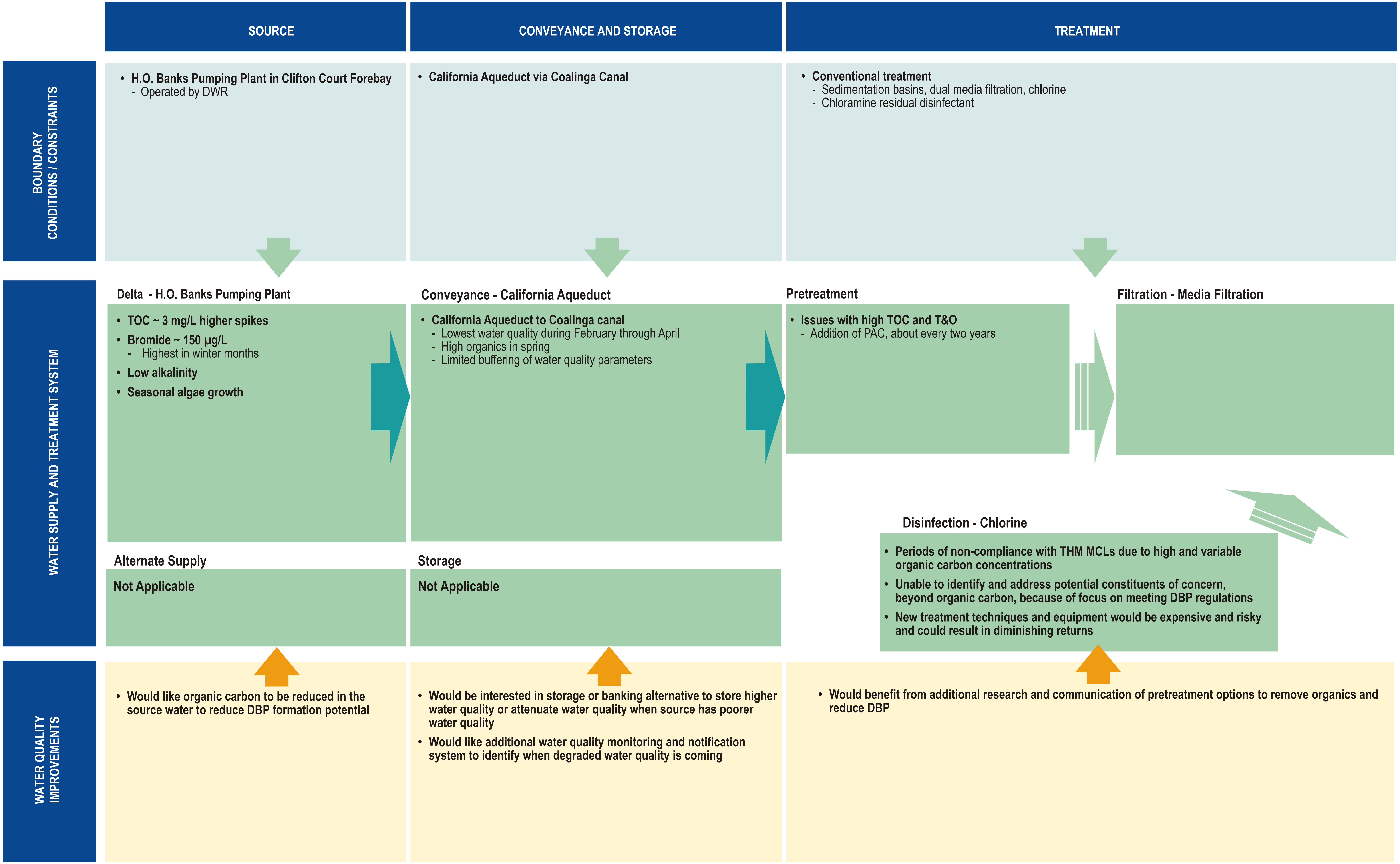
WATER QUALITY IMPROVEMNTS

- **Would like algae growth and other water quality issues in Clifton Court Forebay to be addressed**
- **Submitting requests to DWR to release more Lake Del Valle water when the Delta water quality becomes poor, particularly when the Delta alkalinity is very low**

- **Would like to see additional applications of copper sulfate treatments to the SBA to limit algae problems**
- **Would like open sections of SBA to be covered to limit algae growth and associated T&O**
- **Planned construction under DWR's SBA Improvement and Enlargement Project will assist Zone 7 in meeting water supply demand and improve water quality in the SBA**

- **Will use ozone at the new Altamont WTP because of successes at the ACWD WTP #2, but will need to address bromate formation due to high bromide concentrations**
- **Would like to discontinue the use of ferric chloride and switch to ferric sulfate or alum**
  - $FeCl_3$ generates twice the amount of sludge as alum
  - Periodic, low quality $FeCl_3$ deliveries have caused plugging of chemical piping
  - Only one $FeCl_3$ local supplier

CALIFORNIA AQUEDUCT - CITY OF COALINGA WTP CONCEPTUAL MODEL



SOURCE

CONVEYANCE AND STORAGE

TREATMENT

BOUNDARY CONDITIONS / CONSTRAINTS

- **H.O. Banks Pumping Plant in Clifton Court Forebay**
  - Operated by DWR

- **California Aqueduct via Coalinga Canal**

- **Conventional treatment**
  - Sedimentation basins, dual media filtration, chlorine
  - Chloramine residual disinfectant

WATER SUPPLY AND TREATMENT SYSTEM

Delta - H.O. Banks Pumping Plant

- **TOC ~ 3 mg/L higher spikes**
- **Bromide ~ 150 µg/L**
  - Highest in winter months
- **Low alkalinity**
- **Seasonal algae growth**

Conveyance - California Aqueduct

- **California Aqueduct to Coalinga canal**
  - Lowest water quality during February through April
  - High organics in spring
  - Limited buffering of water quality parameters

Pretreatment

- **Issues with high TOC and T&O**
  - Addition of PAC, about every two years

Filtration - Media Filtration

Alternate Supply

Not Applicable

Storage

Not Applicable

Disinfection - Chlorine

- **Periods of non-compliance with THM MCLs due to high and variable organic carbon concentrations**
- **Unable to identify and address potential constituents of concern, beyond organic carbon, because of focus on meeting DBP regulations**
- **New treatment techniques and equipment would be expensive and risky and could result in diminishing returns**

WATER QUALITY IMPROVEMENTS

- **Would like organic carbon to be reduced in the source water to reduce DBP formation potential**

- **Would be interested in storage or banking alternative to store higher water quality or attenuate water quality when source has poorer water quality**
- **Would like additional water quality monitoring and notification system to identify when degraded water quality is coming**

- **Would benefit from additional research and communication of pretreatment options to remove organics and reduce DBP**

CALIFORNIA AQUEDUCT WEST BRANCH - CASTAIC LAKE WATER AUTHORITY, EARL SCHMIDT FILTRATION PLANT CONCEPTUAL MODEL

BOUNDARY CONDITIONS / CONSTRAINTS

SOURCE

- **H.O. Banks Pumping Plant in Clifton Court Forebay**
  - Operated by DWR
- **Groundwater blended by retail customers**
  - 50 percent of drinking water supply
  - Usage is based on daily, weekly, and seasonal needs

CONVEYANCE AND STORAGE

- **California Aqueduct via the West Branch**
  - From the West Branch water flows through Quail and Pyramid Lakes to Castaic Lake
- **Pyramid Lake**
  - Storage capacity 171,200 acre-feet
- **Castaic Lake**
  - Storage capacity 324,000 acre-feet
  - Large flow fluxes lead to a relatively short residence times

TREATMENT

- **Conventional treatment-**
  - Pre-ozone, flash mixers, solids contact clarifiers, and anthracite mono-media filters
- **Coagulant**
  - $FeCl_3$ and cationic polymer
  - Second addition of cationic polymer prior to filtration
- **Disinfectant**
  - Pre-Ozone
- **Residual disinfectant**
  - Combined chlorine, started in 2005

WATER SUPPLY AND TREATMENT SYSTEM

Delta H.O. Banks Pumping Plant

- **TOC ~ 3 mg/L, with higher spikes**
- **Bromide ~ 150 µg/L**
  - Highest in November and December
- **Algae growth currently not a concern**

Groundwater

- **Contains chloride and is considered very hard**

Conveyance - California Aqueduct

- **No large impacts from Delta source water quality or issue with conveyance because Castaic Lake acts as a buffer for water quality**
  - Minimizes variability

Storage - Castaic Lake

- **TOC ~ 3 mg/L; highest in wet months (January through March)**
- **Bromide up to 300 µg/L**
- **Turbidity is typically < 1 NTU because Pyramid and Castaic Lake act as large settling basins**
- **When the lake is at a low pool, chloride concentrations increase, turbidity does not settle out, and other water quality parameters are not buffered**
  - Plant intakes pull in straight Delta water
- **Total/Fecal Coliform spikes in winter**

Pretreatment

- **$FeCl_3$ dose typically < 1 mg/L**
- **Cationic polymer typically < 1 mg/L**
- **Ozone used for enhanced coagulation and to help with TOC removal**
- **Upflow contact clarifiers are used for turbidity removal**

Filtration - Media Filters

Disinfection - Ozone

- **Ozone**
  - Bromate formation is an issue
- **Prior to installation of ozone in 2005, the plant had a problem with brominated THMs when TOC and bromide concentrations were high**
- **With ozone and combined chlorine THMs and HAAs are lower**
  - THMs are 10 to 20 µg/L
  - HAAs are below 15 µg/L

WATER QUALITY IMPROVEMENTS

- **Using copper sulfate to control algae blooms**
- **Would like the source of winter peaks of Total/Fecal Coliform identified and mitigated**
  - MWD is conducting a study to trace the source
- **Would like Pyramid and Castaic lake to be kept at a full pool to settle turbidity (and solids) and limit chloride concentration**

- **Installed new upflow contact clarifiers in 2005 for turbidity removal**
  - Previously had more traditional flocculation/sedimentation
- **Researching a new process for bromide removal that may also be applied for chloride removal**

CALIFORNIA AQUEDUCT, EAST BRANCH - ANTELOPE VALLEY EAST KERN WTP, QUARTZ HILL WTP CONCEPTUAL MODEL

BOUNDARY CONDITIONS / CONSTRAINTS

SOURCE

- **H.O. Banks Pumping Plant in Clifton Court Forebay**
  - Operated by DWR

CONVEYANCE AND STORAGE

- **California Aqueduct via the East Branch**
  - Intake is directly off of the East Branch

TREATMENT

- **Conventional treatment**
  - Raw water meters, moss screen, rapid mixer, flocculators/clarifiers and anthracite filters
- **Coagulant**
  - Alum
- **Disinfectant**
  - Post-chlorination
- **Residual disinfectant**
  - Free chlorine

WATER SUPPLY AND TREATMENT SYSTEM

Delta H.O. Banks Pumping Plant

- **TOC ~ 3 mg/L, with higher spikes**
  - Problems with TOC removal is a major concern in DBP formation
- **Bromide ~ 150 µg/L**
  - Highest in November and December
- **Low alkalinity typically 30 to 50 mg/L**
- **Algae growth**

Conveyance - California Aqueduct

- **Algae growth occurs during summer**
  - Recent incident resulted in the need to scrape algae off of moss screens 24 hours a day
  - DWR limits the use of copper sulfate due to the threat of toxins produced
- **Plant closes off intakes as "cloud" of algae and copper sulfate pass by**

Pretreatment

- **Alum dose typically 40 to 55 mg/L**
- **Cationic Polymer is occasionally used during low turbidity with dose typically 1 to 2 mg/L**
- **PAC is used occasionally for T&O**
- **Clarification process provides most of TOC removal**
- **Low alkalinity water (40 to 50 mg/L) is difficult to coagulate**
  - Results in poor turbidity and TOC removal

Filtration - Media Filtration

- **Will be upgrading to anthracite filters to improve TOC removal through the filters**

Alternate Supply

Not Applicable

Storage

Not Applicable

Disinfection - Chlorine

- **DBPs are highest during the winter (November through January) when both TOC and bromide concentrations are the highest of the year**
  - Brominated THMs and HAAs forms
- **With the switch to ozone, bromate formation will be a concern due to high bromide concentrations**

WATER QUALITY IMPROVEMENTS

SOURCE

- **Would like additional real time monitoring and reporting of the water quality along the California Aqueduct**
  - Now relying on early warnings or forecasting information from Central Coast Water Agency

CONVEYANCE AND STORAGE

- **Would like alternate algae mitigation strategies used because of copper sulfate use limitations**

TREATMENT

- **Modifying WTP to increase TOC removal and address high bromide concentrations, modifications include;**
  - Ozone
  - GAC instead of anthracite
  - Combined chloramines for residual disinfectant

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant:	City of Redding, Foothill Water Treatment Plant, Redding, CA
Date:	Thursday, June 14, 2007

Attendees:

Brown and Caldwell	
Sarahann Dow	Senior Scientist
Emily Moshier	Staff Engineer
CALFED	
Lisa Holm	Water Quality Program Manager
Water Agency/City	
Greg Norby, P.E.	Water Utility Manager
Rob Clarke, P.E.	Water Treatment Supervisor
CA DHS	
Mike Ricks, P.E.	Associate Sanitary Engineer, Lassen District

Boundary Conditions/Constraints and Infrastructure	
Source:	1. Sacramento River intake a. Located about 1 mile downstream of Shasta and Keswick Dams b. Contract right is 21,000 acre-feet, currently divert about 16,000 af c. Minimal contribution to Sacramento River flow between dams and intake d. Spring Creek minimal contribution upstream of Intake 2. Divert water directly from Spring Creek Conduit to the Buckeye Treatment Plant
Raw Water Conveyance:	1. Water pumped directly to treatment plant in enclosed pipe
Raw Water Storage:	None
Treatment Plant:	1. Treatment train: a. Flash mixers, flocculation/sedimentation, media filtration 2. Chemical Addition a. Poly - Aluminum chlorhydrate (PACl) with a combined cationic polymer included prior to flash mixing i. PACl dose typically 1.5 to 3 ppm ii. Polymer dose is 1 ppm b. Pre and Post chlorination with free chlorine

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: City of Redding, Foothill Water Treatment Plant, Redding, CA

Date: Thursday, June 14, 2007

Water Supply and Treatment System	
Source Water Quality and Reliability	1. Lake Shasta attenuates most water quality constituents resulting in fairly constant temperature and stable (limited variability) water quality throughout the year 2. TOC is typically 2 mg/L and does not vary significantly 3. Turbidity: a. Typically .5 to 3 NTU b. Short lived spikes in winter associated with stormwater runoff, typically 10 to 12 NTU but can be higher 4. Shasta is nutrient limited therefore algae growth is not a concern 5. Pathogens: essentially no *Cryptosporidium*
Conveyance Water Quality	NA
Storage Water Quality	NA
Treatment	1. Sedimentation basins help equalize the higher turbidity and turbidity spikes associated with stormwater. 2. Turbidity concentration is the controlling water quality parameter at the treatment plant. 3. Increase coagulant doses in the winter if turbidity spikes. 4. Low river water stages exposed intakes this past spring bringing oak pollen on the water surface into the treatment plant and causing short filter runs 5. Very low DBPs 6. Only T&O complaints associated with distribution system dead zone issues
Opportunities to Improve Water Quality and Reliability	
Source	1. Stop treating water when turbidity spikes above 10 to 12 NTU because spikes are typically short duration 2. Informally work with Anderson Cottonwood Irrigation District to keep the river stage above the intake structure to minimize pollen coming into the water treatment plant. ACID's diversion dam is approximately 1 mile downstream of the water treatment plant intake.
Conveyance and Storage	NA
Treatment	1. Operate plant with direct filtration during summer

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: City of Redding, Foothill Water Treatment Plant, Redding, CA
Date: Thursday, June 14, 2007

Other	
Source	1. Working to ensure water supply (surface and ground) can meet expected population growth a. Current population served is approx. 80,000 b. Expected service population is 140,000 to 150,000 people in 2040 c. Buckeye Treatment Plant is being expanded 2. Historic and active mining operations in the upper tributaries are a potential threat to source water quality but a recent slurry spill upstream of Whiskeytown Lake did not affect the Buckeye Water Treatment Plant source water quality and spills upstream of the Sacramento intake would be diluted in Lake Shasta resulting in minimal impact. 3. Illegal discharges from Shasta Lake houseboats are a potential threat to water quality but are regulated by the State.
Data Gathered	
Water Quality	1. TOC/DOC: raw water, 8 data points 2004 - 2006 2. Turbidity: raw and finished water daily averages 2005 - 2006 3. DBPs: speciated concentrations in the distribution system, 2005 - 2007 4. TDS/bromide: none 5. Pathogens: monthly total and fecal coliform 2004 – 2006, monthly *Cryptosporidium* and *Giardia* 2005 - 2006 6. Nutrients: annual nitrate 7. Algae counts/chlorophyll-a: none 8. Taste and Odor complaints: essentially zero, any taste and odor complaints they receive are associated with dead ends in the distribution system and mineral precipitation from the groundwater supply
Cost to Treat	1. Chemicals costs 2. Labor cost

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: City of Sacramento, Sacramento River Water Treatment Plant, Sacramento, CA

Date: Tuesday, May 15, 2007

Attendees:

Brown and Caldwell	
Sarahann Dow	Senior Scientist
Emily Moshier	Staff Engineer
Brett Farver	Senior Water Treatment Manager
CALFED	
Lisa Holm	Water Quality Program Manager
Sam Harader	Water Quality Program
Water Agency/City	
Roland Pang	Water and Sewer Superintendent
CA DHS	
Terry Macaulay	Sacramento District Engineer

Limitations, Constraints and Infrastructure	
Source:	1. Sacramento River intake a. Located immediately downstream of the confluence with the American River b. Moved intake in 2000 for infrastructure reliability which also resulted in less variable water quality 2. American River Intake for Fairbairn Treatment Plant a. Second water treatment plant provides reliability if there is an episodic event on the Sacramento River b. Due to the formation of the Sacramento Regional Sanitation District sewage spills on the lower American River have been essentially eliminated. c. Hodge Flow agreements – limit the City's diversion and sales to wholesale customers when the American River flow past the Fairbairn Water Treatment Plant diversion is less than the Hodge Flow Criteria.
Raw Water Conveyance:	None
Raw Water Storage:	None

Treatment Plant:	1. Treatment Train; a. Intake, grit basin, flash mixers, coagulation/flocculation, sedimentation basin, filters (anthracite and sand), disinfection, 3 treated water storage reservoirs b. Filter wash water returned to flash mix 2. Chemical Addition a. Chlorine is added to the grit basin and after filtration. Achieve CT through sedimentation basins. i. Ability to add chlorine in the treated water storage but typically do not. b. Alum and anionic or cationic polymers are added through flash mixing for coagulation. c. Have the ability to add polymers prior to filtration but typically do not. d. Lime/caustic addition prior to flash mixing used to address higher coagulant dosage needs due to seasonal high turbidities. e. Slaked lime and fluoride are added after filtration. 3. Operate additional plant on the American River – Fairbairn Water Treatment Plant a. More flexible and cost effective treatment plant to attenuate changes in demand. b. Distribution system appears to favor the operation of Sacramento River Water Treatment Plant c. Water quality considerations for balancing two water treatment plants (discussed below).
Water Quality	
Source Water Quality and Reliability	1. TOC: First flush causes a spike, otherwise stable concentrations on a daily basis, seasonal variation 2. Turbidity: Seasonal variation, higher in winter. 3. Nutrients/Algae: a. Algae blooms typically occur in summer, mainly on the American River 4. Pathogens: The required log removals are 3-log *Giardia* and 4-log virus 5. Natomas Drain management a. irrigators required to hold water for rice pesticide degradation or move it to the next grower without returning it to the river b. area becoming more urban c. rice pesticide interaction with chlorine was a taste and odor issue but has been mostly addressed through Natomas Drain management 6. American River supply a. American River has more algae bloom taste and odor issues. When an algae bloom occurs on the American River production at the Sacramento River Water Treatment Plant is ramped up.
Conveyance Water Quality	NA

Storage Water Quality	NA
Treatment	1. Taste and Odor: a. After algae blooms they get an initial spike in complaints and then people get used to the taste b. Reaction of rice herbicides and chlorine can cause taste problems after chlorination but has been limited due to Natomas Drain management 2. Turbidity – increase alum and caustic addition to effectively address high turbidity
Opportunities to Improve Water Quality and Reliability	
Source	1. A treatment plant further upstream on the Sacramento River is in the very initial planning stages. This option would increase the reliability of the Sacramento River supply because a spill or other water quality concern on the American River currently impacts both plants. 2. A new (replacement) intake at the Sacramento River Water Treatment Plant was put in operation in 2000 which improved the consistency of raw water quality.
Conveyance and Storage	NA
Treatment	1. The treatment plant is designed to treat 3 mg/L or less TOC, they haven't had to treat more than this.
Data Gathered	
Water Quality	1. TOC/DOC: daily average raw and filter effluent 2. Turbidity: daily average raw and finished 3. DBPs: quarterly at the distribution system location nearest the water treatment plant 4. Pathogens: weekly total coliform and E. coli, monthly Cryptosporidium and Giardia 1/04 to 2/05 5. TDS/Bromide: monthly raw and finished 6. Nutrients: yearly nitrate and nitrite, raw and tap 7. Algae counts/chlorophyll a: not available 8. Taste and Odor complaints: monthly count
Cost to Treat	$98.586 per MG includes power and chemicals Monthly flows and %recycled, monthly treatment chemical usage

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Contra Costa Water District Bollman Water Treatment Plant, Concord, CA
Date: Thursday, June 21, 2007

Attendees:	Brown and Caldwell	
	Brett Farver	Senior Water Treatment Manager
	Emily Moshier	Staff Engineer
	CALFED	
	Lisa Holm	Water Quality Program Manager
	Water Agency/City	
	David Huey	Manager of Water Operations
	Kent Nelson	Water Quality Superintendent
	Lucinda Shih	Associate Water Resources Specialist
	CA DHS	
	Betty Graham	San Francisco District Engineer
	Dmitriy Ginzburg	Associate Sanitary Engineer

Boundary Conditions/Constraints and Infrastructure	
Source:	1. Contra Costa Canal a. Old River i. Max. diversion 250 cfs. ii. Flows to Contra Costa Canal and Los Vaqueros Reservoir. iii. 75 day no fill period (March 15 to May 31): cannot pump from Old River to fill Los Vaqueros Reservoir; for fish protection. iv. January to August fisheries agencies prefer that Old River is used over Rock Slough since the Old River intake has a fish screen. Federal power allocations are provided during this time. b. Rock Slough i. Max. total combined diversion into the Contra Costa Canal is 350 cfs c. Mallard Slough i. Max. diversion 39.3 cfs. ii. District water quality goals for chloride typically limit use of the intake to 1 month per year d. No direct Delta diversions (all 3 intakes) April 1 to April 30 e. EBMUD Intertie (Under Construction) i. connects EBMUD's Mokelumne Aqueduct with Los Vaqueros Pipeline ii. Allows CCWD to divert a portion of their Central Valley Project water from the Sacramento River at Freeport

Treatment Plant: Contra Costa Water District Bollman Water Treatment Plant, Concord, CA

Date: Thursday, June 21, 2007

Raw Water Conveyance:	1. Contra Costa Canal a. Supplied by Rock Slough, Old River, and Mallard Slough intakes as well as Los Vaqueros and Contra Loma Reservoirs b. Unlined portion the first 4 miles from the west end of Rock Slough to Pumping Plant #1 forebay c. No copper application allowed in the summer before July 1 2. Multi-purpose pipeline can be operated as an emergency back-up to the canal west of Randall-Bold WTP
Raw Water Storage:	1. Los Vaqueros Reservoir a. Max storage 100,000 acre-ft i. Top of minimum storage is 70,000 acre-feet ii. Top of emergency storage is 44,000 acre-feet 2. Contra Loma Reservoir a. Total storage is 2,500 af b. 900 af useable capacity 3. Mallard Reservoir a. 2,100 af usable capacity
Treatment Plant:	1. Water can be diverted directly from Contra Costa Canal or from Mallard Reservoir 2. Treatment Train Flash mix, flocculation, sedimentation, ozonation, GAC filter, clear well 3. Chemical Addition a. Sulfuric acid upstream of flash mix b. Alum and cationic polymer added at flash mix c. Ozone dose is 3 to 4 mg/L maximum, off gas prevents higher dose d. Chlorine added downstream of GAC filters, before other chemicals, for dual CT e. Caustic, ammonia, and fluoride added between filters and clear well 4. Several treated water interties exist between the CCWD distribution system and the EBMUD distribution system could be activated in an emergency situation

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Contra Costa Water District Bollman Water Treatment Plant, Concord, CA
Date: Thursday, June 21, 2007

Water Supply and Treatment System	
Source Water Quality and Reliability	1. TOC: a. Typically 2.5 to 4.5 mg/L b. Short duration peaks of 5 to 7 mg/L in winter 2. Turbidity is stable and typically 3 NTU at WTP intake 3. Pathogens: a. *Cryptosporidium* monitoring has historically been nondetect b. Total coliform varies slightly, log reduction requirements are consistently 3-log *Giardia* and 4-log virus 4. Low alkalinities last spring caused coagulation problems a. Alkalinities are typically ~ 65 mg/L, but experienced ~ 30 mg/L for a few days b. The low alkalinity was likely caused by higher flows on the San Joaquin River
Conveyance Water Quality	1. NA
Storage Water Quality	1. Reservoirs act as nutrient sinks and provide attenuation of variable turbidities, TOC, and bromide 2. Los Vaqueros Reservoir a. Fill when chloride at Old River is less than 50 mg/L i. Current chloride concentration in reservoir is less than 40 mg/L because of higher Delta water quality the last few years b. Well mixed, typically get a thermocline 2 or 3 weeks in August c. Hypolimnetic oxygenation system installed to provide oxygen to the hypolimnion when thermocline develops. d. No algae blooms 3. Contra Loma a. Aeration system installed to promote destratification and increase dissolved oxygen levels. 4. Mallard Reservoir a. Operated as a forebay to Bollman WTP i. Reservoir filled from the canal b. Taste and odor problems are typically linked to Mallard Reservoir (and Martinez Reservoir further downstream in the system, not affecting Bollman WTP)
Treatment	1. Achieve about 40% TOC removal through sedimentation basins 2. THMs typically 25 to 30 μg/L 3. HAAs typically less than 10 μg/L 4. Dual CT credit from intermediate ozone and chlorine addition between filters and clear well. 5. Conditional 40/30 waiver from Stage 2 DBPR IDSE granted by CDPH.

Opportunities to Improve Water Quality and Reliability	
Source	1. Work with fish agencies to include alternative days or an alternative schedule to the 75 day no-fill period at Old River. 2. Pump from Delta only when chloride is less than 65 mg/L a. Water quality at Mallard Slough typically limits pumping to less than 30 days per year 3. Alternative intake project for Old River Intake will provide a new intake off of Victoria Canal improving water quality and fish protection
Conveyance and Storage	1. Goal is to deliver water from Contra Costa Canal that is 65 mg/L or less chloride after the blending point between Rock Slough and Old River (may include water from Los Vaqueros) 2. Fill Los Vaqueros Reservoir when chloride at Old River is less than 50 mg/L 3. Operate intakes and Los Vaqueros based on chloride concentrations, a. Switching intakes typically occurs every week or two b. Alternating intakes can be as frequent as 2-3 times per day 4. Operate hypolimnetic oxygenation system at Los Vaqueros if a thermocline develops 5. Aeration system at Contra Loma, separated swim lagoon for recreation 6. No body contact recreation allowed at any reservoir, recreation monitoring conducted 7. Algae, periphyton, and aquatic plant control in reservoirs: a. Apply copper (chelated) to Mallard Reservoir b. Used sonar treatment at Contra Loma last year c. Testing alternatives to copper, including use of sodium carbonate peroxyhydrate d. Try partial treatments to keep herbicide application to a minimum e. Apply herbicides to the land after drawing down reservoir and allowing banks to dry 8. Control algae in the unlined portion of the canal at Rock Slough with chelated copper and by harvesting; apply herbicides on embankments above liner 9. Perform semi-annual canal cleaning 10. Monitor Geosmin and MIB in conveyance and storage from April through October to anticipate taste and odor problems 11. Constructed 5 box culverts along canal at locations where safety/reliability could be affected including under the Highway 4 overpass and at the Chevron pipeline crossing 12. Canal replacement project is planned for entire unlined portion at Rock Slough. a. Initial project will encase the final 2,000 feet of canal, immediately upstream of PP1 forebay, in an area known to have infiltration

<table>
<tr><td></td><td>13. Multi-purpose pipeline (in service in 2003) provides treated water from Randall-Bold WTP to north Concord and improves canal capacity and reliability for municipalities receiving canal water. The MPP can act as a backup to the canal.
14. Contra Loma swim lagoon opened in 2002 to allow swimming while protecting drinking water source from pathogens and viruses
15. Pipeline from Mallard Slough Pump Station to Contra Costa Canal constructed in 2002 provides operational flexibility in addition to existing pipeline from pump station to Mallard Reservoir
16. Performing feasibility studies for Los Vaqueros Reservoir Expansion Project which would improve water supply reliability and water quality</td></tr>
<tr><td>Treatment</td><td>1. GAC replaced every 4 years
2. Constructing new chemical system to improve ozone quenching.
3. Control bromate formation with a combination of pH suppression and source bromide control
4. Regional desalination pilot project at Mallard Slough Pumping Plant in planning phase
5. Monitor for Geosmin and MIB in treated water from April through October in addition to the weekly flavor profile analysis
6. Multi-purpose pipeline from Randall-Bold WTP to the Bollman WTP service area provides capability to blend out taste and odor in Bollman WTP finished water, if necessary</td></tr>
<tr><td colspan="2">Other</td></tr>
<tr><td colspan="2">Data Gathered</td></tr>
<tr><td>Source and Conveyance Water Quality</td><td>1. TOC: Rock Slough, Old River, Los Vaqueros Reservoir
2. DOC: Rock Slough, Old River
3. TDS: Rock Slough, Old River
4. Bromide: Rock Slough, Old River, Los Vaqueros Reservoir
5. Nutrients: ammonia, nitrate, and orthophosphate at Rock Slough, Old River, and Los Vaqueros Reservoir
6. Algae Counts: Rock Slough, Old River, Los Vaqueros Reservoir
7. Turbidity: Rock Slough, Old River, Los Vaqueros Reservoir
8. Pathogens: Total/fecal and <i>E. coli</i> at Rock Slough, Old River, and Los Vaqueros Reservoir</td></tr>
<tr><td>Treatment Plant Water Quality</td><td>1. TOC/DOC:
2. Turbidity:
3. DBPs:
4. Pathogens:
5. Nutrients:
6. Taste and Odor complaints:</td></tr>
</table>

Cost to Treat	Chemicals costs Labor cost Cost to purchase

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: City of Antioch Water Treatment Plant, Antioch, CA

Date: Thursday, May 17, 2007

Attendees:

Brown and Caldwell	
Sarahann Dow	Senior Scientist
Emily Moshier	Staff Engineer
CALFED	
Lisa Holm	Water Quality Program Manager
Water Agency/City	
Vince Darone	Water Treatment Superintendent
Lori Sarti	Water Quality Analyst
Phil Harrington	Director of Capital Improvements
CA DHS	
Betty Graham	San Francisco District Engineer
Dmitriy Ginzburg	Associate Sanitary Engineer

Boundary Conditions/Constraints and Infrastructure	
Source:	1. San Joaquin River intake a. Screened, pumped to Antioch Municipal Reservoir b. Contract with DWR guarantees Antioch can draw water from the San Joaquin River with less than 250 mg/L Cl for 218 days per year, otherwise DWR pays portion of Contra Costa Canal water purchase. Contract runs out in 2008. 2. Contra Costa Canal a. Purchase from CCWD b. Pump to Antioch Municipal Reservoir or directly to WTP
Raw Water Conveyance:	1. One 39-inch diameter and one 24-inch diameter pipeline, both connect the Contra Costa Canal to both the Antioch Municipal Reservoir and the WTP. 2. Pipeline from San Joaquin River Pumping Station to Antioch Municipal Reservoir
Raw Water Storage:	1. Antioch Municipal Reservoir a. 735 acre feet capacity 2. A larger reservoir would be preferred to store more of the higher quality San Joaquin River water but land availability and economics preclude it.

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: City of Antioch Water Treatment Plant, Antioch, CA

Date: Thursday, May 17, 2007

Treatment Plant:	1. A and B treatment plants are completely discrete and have identical treatment trains 2. Treatment train: Intake, flash mixers, flocculation chamber, sedimentation basins with tube settlers, GAC filters (4 ft GAC, 1.5 ft sand), 1 MG clear well 3. Chemical Addition a. Chlorine and alum are added prior to the flash mixers i. Chlorine dose is typically 2.5 to 2.8 mg/L ii. Achieve log removal requirements prior to filtration b. Chlorine, fluoride, ammonia, and caustic added after filtration c. Filter aids have not been found to be effective
Water Supply and Treatment System	
Source Water Quality and Reliability	1. TOC: TOC varies seasonally. It is typically 3 mg/L or less but has spiked in the past, usually early in the year. a. They have treated TOC as high as 10 to 12 mg/L without problems b. TOC is not a treatment concern. 2. Turbidity: there is a spike in turbidity when CCWD switches from Old River to Los Vaqueros Reservoir a. Episodic – at 100 NTU pre-treatment becomes difficult b. Above 120 NTU have had to waste water 3. Nutrients/Algae/taste and odor: seasonal concern 4. Pathogens: variability in total coliform results in additional log removal requirements 5. Temperature differences between sources can cause treatment difficulties, particularly thermal inversion in the upflow clarifiers. a. CCWD notifies Antioch by fax what percentage of supply is Los Vaqueros water and when they switch sources, i. sometimes not in sufficient time to make adjustments
Conveyance Water Quality	NA
Storage Water Quality	1. Antioch Municipal Reservoir a. Supplied from the San Joaquin River and Contra Costa Canal b. Residence time in winter typically 20 days, summer 7 days c. Not run to provide equalization d. Little effect on water quality i. Local watershed runoff diverted by culvert around reservoir ii. Algae blooms are seasonal - installed Solar Bees ® to address algae blooms iii. Little settling

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: City of Antioch Water Treatment Plant, Antioch, CA
Date: Thursday, May 17, 2007

Treatment	1. Log reduction requirements vary between 3-log *Giardia* and 4-log virus and 4-log *Giardia* and 5-log virus 2. THMs are higher from August to October with increased raw water chloride. 3. Source temperature differences between the reservoir and canal can cause thermal inversion in the upflow clarifiers, more often a problem at Plant A where the clarifier is covered
Operations	
Source	1. San Joaquin Rive Intake a. Pump when chloride < 250 mg/L i. Typically December or January through May. ii. Wetter winters increase the time span they can pump. iii. In past dry years Antioch has not been able to pump from the San Joaquin for longer periods of time. Tides play into the daily pumping time span. b. Pumps are operated day to day as chloride concentrations fluctuate if economically feasible.
Storage	1. Use copper sulfate to treat algal growth in the reservoir. 2. Solar Bee installed to help prevent algae blooms in June 2006.
Opportunities to Improve Water Quality and Reliability	
Source	1. Moving the San Joaquin River water rights to another intake could allow year-round pumping, Antioch is currently discussing alternative intake and source protection options with the state.
Conveyance and Storage	None identified.
Treatment	1. Installed tube settlers, first in Plant A and currently in Plant B, to improve clarification when thermal inversion hinders treatment 2. Additional tube settlers would help with turbidity spikes.
Other	
Source	Future Source Reliability is a concern. 1. Planned projects, both diversions and inputs, may adversely affect the San Joaquin River source quality and reliability. 2. Population growth, industrial expansion, and other increases in upstream diversion may affect the City's source water quality and reliability in the future. 3. Antioch is concerned about protecting water quality at their only independent intake in the western Delta because the only other water agency with interests in the western Delta, CCWD, has other intake alternatives.

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: City of Antioch Water Treatment Plant, Antioch, CA
Date: Thursday, May 17, 2007

Data Gathered	
Water Quality	1. TOC/DOC: monthly average TOC at water treatment plant intake and treated water. 2. Turbidity: daily average in water treatment plant intake, pretreated, and filtered water. 3. DBPs: speciated concentrations in distribution system 4. Pathogens: median monthly total coliform 5. Nutrients: nutrients, algae counts, and chlorophyll-a are not monitored 6. Taste and Odor complaints: April to September 2006, 35 complaints, all associated with algae.
Cost to Treat	Chemicals are $70 to $110 per MG, maybe a little more in the winter Labor is $225 per MG The cost to purchase raw water from CCWD is $1,500 per MG. Monthly treatment chemical usage provided.

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Zone 7 Water Agency Patterson Pass Water Treatment Plant

Date: Thursday, June 7, 2007

Attendees:

Brown and Caldwell	
Brett Farver	Senior Water Treatment Manager
Jill Cunningham	Principal Engineer
CALFED	
Lisa Holm	Water Quality Program Manager
Zone 7 Water Agency	
Rick Anderson	Patterson Pass Plant Supervisor
Vince Cirelli	Operator
Gurpal Deol	Laboratory Supervisor
Conrad Tona	Production Manager
CA DHS	
Betty Graham	San Francisco District Engineer
Dmitriy Ginzburg	Associate Sanitary Engineer

Boundary Conditions/Constraints and Infrastructure	
Source:	1. H.O. Banks Pumping Plant intake at Clifton Court Forebay
Raw Water Conveyance:	1. Bethany Reservoir to South Bay Aqueduct via South Bay Pumping Plant.
Raw Water Storage:	1. Patterson Pass Reservoir a. 30-MG capacity b. Open, concrete-lined

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Zone 7 Water Agency Patterson Pass Water Treatment Plant

Date: Thursday, June 7, 2007

Treatment Plant:	1. 20-mgd Patterson Pass Water Treatment Plant a. 12-mgd conventional plant i. Intake, flash mixers, upflow solids contact clarifier, filters, clearwell ii. Sodium hypochlorite (occasionally) and ferric chloride added after Patterson Reservoir and before the upflow solids contact clarifier iii. Sodium hypochlorite added after the upflow solids contact clarifier and before the filters iv. Sodium hypochlorite, sodium hydroxide, and ammonia added after the filters and before the clearwell b. 8-mgd ultrafiltration plant (membrane) i. Intake, rapid mixer, upflow solids contact clarifier by WesTech, membrane feed pumps, strainers, ultrafiltration membranes by Aquasource, chlorine contact tank, clearwell ii. Ferric chloride added prior to rapid mixer iii. Sodium hypochlorite added after the membranes prior to chlorine contact tank iv. Caustic and ammonia added prior to clearwell v. Citric acid and chlorine used for membrane cleaning
Water Supply and Treatment System	
Source Water Quality and Reliability	1. Turbidity: a. High winds result in high turbidity spikes in Clifton Court Forebay
Conveyance Water Quality	1. Algae growth in South Bay Aqueduct (SBA) a. In the past, the presence of algae was predictable and algae growth occurred annually from April through November b. Recently, algae growth driven by water temperature, which is unpredictable and changes daily 2. During the winter, stormwater runoff causes high turbidity, which is difficult to treat, particularly using Zone 7's super pulsators at the Del Valle WTP 3. In the spring, alkalinity decreases

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Zone 7 Water Agency Patterson Pass Water Treatment Plant
Date: Thursday, June 7, 2007

Storage Water Quality	1. Patterson Pass Reservoir (30-MG, open, concrete-lined) a. Helps with source water temperature and pH fluctuations b. Receives spillover from the top 1-1/2 to 2 feet of the South Bay Aqueduct, which is the area in the aqueduct that has the best water quality c. Settling does occur in the reservoir d. Issues with algae adhering to concrete lining
Treatment	1. Generally, no prechlorination but occasionally use sodium hypochlorite to treat algae growth. The ultrafiltration membranes cannot be subjected to chlorine and will shutdown if residual is >0.20 mg/L. 2. Currently, bromide not an issue. However, bromide will be an issue with the new Altamont Water Treatment Plant, which will use ozone. 3. THMs (around 40 mg/L) and HAAs (concentrations 20-25 mg/L) are not an issue. 4. As long as turbidity is managed, TOC is not an issue. For TOC removal, once used alum and now primarily use ferric chloride at a dosage of 26 mg/L, resulting in 40-50% removal. Ferric chloride helps with filter performance during certain times of the year. Zone 7 is considering discontinuing the use of ferric chloride and switching to ferric sulfate or alum at higher doses for the following reasons: received bad deliveries of ferric chloride that have plugged plant chemical piping, ferric chloride generates twice the sludge as alum, and only one local supplier provides ferric chloride. Alkalinity influences the effectiveness of ferric chloride. Alum didn't form floc during certain times of the year due to low alkalinity. 5. Algae in the raw water is the main cause of pH changes. Algae causes scum (algae) to form on top of upflow solids contact clarifier, affects filter performance by causing media loss due to entrapped air, and clogs the 200-micron strainers in the ultrafiltration plant. Due to the algae growth, the strainers must be disassembled and pressured washed weekly during certain times of the year. The pH of the water originating from the South Bay Aqueduct has fluctuated from 7.5 to 9.5. 6. No site-specific issues with DBPs and no problems with individual constituents 7. Zone 7 makes operational modifications to react to unexpected changes in water quality. Responding to maintain process set points with an anticipated notice.
Opportunities to Improve Water Quality and Reliability	
Source	1. No comments

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Zone 7 Water Agency Patterson Pass Water Treatment Plant

Date: Thursday, June 7, 2007

Conveyance and Storage	1. Requested that copper sulfate be added more often to the South Bay Aqueduct 2. Cover the South Bay Aqueduct
Treatment	1. Ozone helps at the ACWD ____ WTP and is one of the reasons Zone 7 will have ozone at the new Altamont WTP
Other	
Source	1. No comments
Conveyance and Storage	1. The California Department of Water Resources will improve and enlarge the South Bay Aqueduct by bringing the aqueduct's actual water conveyance capacity to its original design capacity. This project will consist of the following components: a. Dyer Reservoir – with a capacity of 400 acre-feet, will store water prior to treatment b. 78-inch diameter, 3-mile long pipeline – will transport water from the aqueduct to the Dyer Reservoir and then on to the new Altamont Water Treatment Plant c. Expanded South Bay Pumping Plant
Treatment	1. The new Altamont Water Treatment Plant will supplement Zone 7's current Patterson Pass and Del Valle WTPs. The plant will initially be designed to treat up to 24 mgd and ultimately have a production capacity of as much as 42 mgd. The plant will use ozone for taste and odor control.
Data Gathered (2003 – 2006)	
Water Quality	1. TOC/DOC: daily average in source and raw water storage reservoir from Department of Water Resources and other sources; weekly in treatment plant intake, after pre-treatment, and finished water. 2. Turbidity: daily average in source and raw water storage reservoir from Department of Water Resources and other sources; every 4 hours in treatment plant intake, after pre-treatment, and finished water. 3. DBPs: finished water. 4. Pathogens: monthly average in source and raw water storage reservoir from Department of Water Resources and other sources; monthly average in treatment plant intake. 5. Nutrients (nitrogen and phosphate): monthly average in source and raw water storage reservoir from Department of Water Resources and other sources; monthly average in treatment plant intake and finished water 6. Taste and Odor complaints: 6-month period with highest number of complaints
Cost to Treat	Chemicals costs range from $10 to $80 per MG.

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Alameda County Water District Water Treatment Plant #2, Fremont, CA

Date: Wednesday, May 23, 2007

Attendees:

Brown and Caldwell	
Sarahann Dow	Senior Scientist
Laura Lindenmayer	Staff Hydrogeologist
CALFED	
Lisa Holm	Water Quality Program Manager
Water Agency/City	
Doug Chun	Water Quality Manager
Laura Hidas	Water Supply Supervisor
Beth Gentry	Environmental Engineer
Jeannette Weber	Water Quality Laboratory Supervisor
Karl Stinson	Water Treatment Operations Manager
Luisa Sangines	Environmental Engineer
CA DHS	
Betty Graham	San Francisco District Engineer

Limitations and Constraints and Infrastructure	
Source:	1. H.O. Banks intake at Clifton Court Forebay 2. Lake Del Valle a. Used for peak demands and emergency supply, usually during the summer b. Blend with Delta water in the South Bay Aqueduct (SBA) when Delta water quality becomes problematic c. Shared water rights with Zone 7 for creek that runs into Del Valle and fills Del Valle in the winter 3. Future Reliability a. Need for the lake as an alternative supply will increase in the future i. Del Valle has historically been more of an emergency water supply ii. East Bay Regional Park District likes to keep Lake at full pool during the summer iii. If the lake does not fill in the winter, then water from the aqueduct is used to fill Del Valle

Raw Water Conveyance:

1. SBA operated by DWR
2. Increased growth in Zone 7 will lead to an expansion in the aqueduct – project will increase from 300 to 430 cfs

Raw Water Storage:

1. Lake Del Valle
   a. Primarily water from the watershed and alternate source
   b. Multiple use facility
   c. Recreation
   d. Some grazing influence (researching grazing practices in watershed)

Treatment Plant:

1. Treatment Train
   a. Conventional treatment with Pre-ozone: Ozonation, coagulation ($FeCl_3$), flocculation, sedimentation, filtration (three filters with anthracite and sand and three filters with GAC over sand), chloramines used for residual disinfectant (chloramine)
      i. CO_2 added to raw water to lower the pH based on bromide levels and pH to minimize bromate formation
      ii. Pre-treatment with ozonation for algae control and disinfection and minimize trihalomethane and haloacetic acid formation
   b. Post treatment: pH adjustments for distribution and fluoride addition

Water Supply and Treatment System

Source Water Quality and Reliability:

1. Delta Influences
   a. Primary issue is with the Delta water quality
   b. Most pathogen influences have been identified as coming from Delta water
   c. Low alkalinity (makes coagulation in treatment process difficult)
      i. Any time organic carbon concentrations are above 3 mg/L there is an increased concern.
2. Clifton Court
   a. As of 2007, can no longer use copper sulfate to prevent algae growth due to fish protection (first year that this will go into effect)
      i. This may result in increased algae growth and potential future issues
3. There may becsome negative impact to water quality from a small drainage ditch near the SBA intake in Bethany Reservoir. ACWD would like it cleaned out

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Alameda County Water District Water Treatment Plant #2, Fremont, CA

Date: Wednesday, May 23, 2007

Conveyance Water Quality:

1. Algae growth in aqueduct
   a. Highest growth occurs April through the fall
   b. Blend with Del Valle water when growth intensifies
   c. Copper sulfate used to control algae growth
      i. During high growth season, water treatment plants are proactive and keep in contact with DWR about when copper sulfate will be used – address growth before it becomes a major issue
2. Future possibility of the suspension of copper sulfate at other locations and potential algae growth issues
3. Some *Cryptosporidium* detected from a small holding pond in Bethany Reservoir
   a. Bin 1 designation for Long Term 2 Enhanced Surface Water Treatment Rule

Treatment:

1. Pre-ozonate to prevent treatment issues associated with algae and prevents associated taste and odor issues
2. Ozone has been online since construction of plant in 1993
3. Greater pH reduction with CO_2 necessary as bromide increases
4. Disinfection by products (DBP) are at their worst when high bromide and dissolved organic carbon(DOC) concentrations overlap
5. Bromate peak in Nov/Dec because of bromide peaks in raw water
6. Log removal – mostly ozone
   a. Total chlorine dose is 4.1 mg/L
      i. 2.5 – 2.8 mg/L chloramines in the distribution
7. When meeting finished water turbidity requirement total organic carbon (TOC) reduction is sufficient
   a. $FeCl_3$ is used for TOC reduction
   b. Have tested alum but historically it has been somewhat less effective for organics removal compared to $FeCl_3$

Opportunities to Improve Water Quality and Reliability

Source:

1. Primary water quality concern is Delta source water quality

Conveyance and Storage:

1. Limited number of areas within the watershed and conveyance structures that would provide water quality improvements
   a. Currently encouraging implementation of BMP grazing practices
2. Requested that drainage ditch in within Bethany Reservoir be cleaned up and repaired to function properly
   a. Limit *Cryptosporidium* inputs
   b. Workshop to discuss Bethany Reservoir

Treatment Plant: Alameda County Water District Water Treatment Plant #2, Fremont, CA

Date: Wednesday, May 23, 2007

Treatment:	1. Looking at new bromate analysis method which is more sensitive a. May see more peaks in the finished water quality 2. Treatment plant is able to address most water quality issues they experience 3. CO_2 additions began in 2001 (this was the last treatment plant upgrade associated with water quality)
Other	
Treatment:	1. Mission San Jose WTP a. Same intake water quality w/in 50 feet of WTP#2 b. KOCH Ultra-Filtration inside-out membrane treatment plant c. Filtrate water quality fine but have numerous water quality issues with membrane treatment plant that are not seen at WTP#2 i. membrane fouling ii. difficult to meet DBP regulations at membrane plant
Data Gathered	
Water Quality:	1. TOC/DOC: TOC weekly averages for raw, after pre-treatment, and finished; some 06 DOC data 2. Turbidity: Daily averages for all locations 3. Bromide: Weekly averages for raw and finished water 4. TDS: Quarterly for raw and bi-monthly for finished 5. DBPs: Weekly TTHMS, bi-monthly HAA5s, weekly Bromate 6. Pathogens: Daily averages for E. Coli and Coli form at raw and finished water 7. Nutrients: Quarterly averages for Nitrate at raw and finished 8. Taste and Odor complaints: 9. CO_2: 10-22 mg/L with an average of 14 mg/L, based on pH
Cost to Treat:	Treatment costs (CO_2 increase from $87/ton to $173/ton) Labor cost Flows Cost to purchase

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Castaic Lake Water Agency Earl Schmidt Filtration Plant, Castaic, CA

Date: Tuesday, June 19, 2007

Attendees:

Brown and Caldwell	
Laura Lindenmayer	Hydrogeologist II
Jill Cunningham	Principal Engineer
CALFED	
Lisa Holm	Water Quality Program Manager
Castaic Lake Water Agency	
David Eugene Kimbrough, Ph.D.	Water Quality and Laboratory Supervisor
Jim Leserman, P.E.	Senior Engineer
Jason Yim, P.E.	Senior Engineer

Boundary Conditions/Constraints and Infrastructure	
Source:	1. H.O. Banks intake at Clifton Court Forebay
Raw Water Conveyance:	1. California Aqueduct to West Branch
Raw Water Storage:	1. Castaic Lake (via Quail Lake and Pyramid Lake) provides storage for the Earl Schmidt Filtration Plant. 2. Lake water is conveyed by gravity directly from the Castaic Lake Dam and into the Earl Schmidt Filtration Plant intakes. 3. The Metropolitan Water District of Southern California owns and operates the underground, 13-mile Foothill Feeder, which stretches from Castaic Lake to the Joseph Jensen Water Treatment Plant. The Foothill Feeder supplies the Rio Vista Water Treatment Plant.

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Castaic Lake Water Agency Earl Schmidt Filtration Plant, Castaic, CA
Date: Tuesday, June 19, 2007

Treatment Plant:	4. Earl Schmidt Filtration Plant (56 mgd) a. Intake; addition of ozone, cationic polymer, and ferric chloride; flash mixers; six solids contact claifiers (Robert's filter, which has a small footprint and works well for low turbidity water); addition of cationic polymer; six filters (mono medium, deep bed, anthracite coal, with a loading rate of 10 gpm/SF if using ozone), addition of chloramines; clearwell; distribution system (40 miles of pipelines with the smallest pipeline diameter being 20 inches) b. Chemical addition: ozone, cationic polymer, and ferric chloride 5. Rio Vista Water Treatment Plant (currently 30 mgd, will be expanded to 60 mgd due to population growth) a. Same treatment train as the Earl Schmidt Filtration Plant b. Currently, 6 clarifiers and 6 filters c. In the future, 12 clarifiers and 12 filters d. Uses NaOH as a chlorine concentration reducer e. Backwash the clarifier and filter every 24 hours
Water Supply and Treatment System	
Source Water Quality and Reliability	1. Area groundwater is very hard and contains some chloride, but does not result in treatment issues.
Conveyance Water Quality	1. No comments
Storage Water Quality	1. Bromide – the biggest issue; current bromide concentration approximately 190 µg/L; in the past, bromide concentrations have been known to reach the low 300s 2. TOC is somewhat of an issue; can't remove TOC with existing treatment processes; unable to perform enhanced coagulation 3. Turbidity – low (less than 1 NTU). Pyramid Lake and Castaic Lake act as large settling basins. Due to low turbidity jar testing is not effective. 4. Nutrients – not an issue 5. Chloride is an issue due to the Total Maximum Daily Load (TMDL), which is concentration based and not mass based (100 ppm). Chloride concentrations have increased 50% in the last 6 months as a result of draining of Castaic and Pyramid – when refilling occurred, water was drawn from the lakes before the buffering effects could be felt by the WTP. 6. The presence of algal blooms in Castaic Lake is due to natural processes in the lake and is not nutrient driven. The Department of Water Resources uses copper sulfate to treat the algal blooms. 7. As a result of the buffering effect from Pyramid and Castaic lakes, the Castaic Lake Water Agency does not see the large water quality

	impacts (spikes) from Delta source water.
Treatment	1. THMs – Brominated THMs were an issue before chloramines were used (prior to 2005); now Bromate is a rising concern because of the use of ozone 2. HAAs – in the single digits 3. Pathogens – not an issue
Opportunities to Improve Water Quality and Reliability	
Source	1. No comments
Conveyance and Storage	1. MWD is currently conducting a study on Castaic Lake in order to trace the source of Total Fecal Coliform peaks in the winter.
Treatment	1. Castaic Lake Water Agency has allocated $200,000 in next year's budget to research a new physical process involving volatilization for the removal of bromide from drinking water. This research may be applied to chloride removal in drinking water.
Other	
Source	1. Half of the water demand in the Santa Clarita Valley is met by groundwater supplies and the other half is met by State Water Project water. This blending occurs on the side of the retailer.
Conveyance and Storage	1. No comments
Treatment	1. Castaic Lake Water Agency converted to chloramines in 2005. a. A substantial amount of log removal credits are obtained through chloramines. Other credits are obtained by conventional treatment, disinfection, and sometimes ozone. 2. The plant was updated about 2-3 years ago from the traditional flocculation/sedimentation practices to the current contact clarifiers. These upgrades, as well as switching to ozone as a primary disinfectant, came online in 2005. b. Due to the up-flow contact clarifiers the plant was not able to comply with the TOC removal requirements of the IESWTR. In order to meet these requirements, CLWA signed an agreement with the USEPA (not DHS) that they would convert to ozone and chloramines no later than June 30, 2005 as part of that alternative compliance mechanism. Turbidity removal is sole objective of the up-flow contact clarifiers.

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Castaic Lake Water Agency Earl Schmidt Filtration Plant, Castaic, CA
Date: Tuesday, June 19, 2007

Data Gathered	
Water Quality	1. TOC/DOC: Monthly averages for all TOC 2. Turbidity: Raw daily averages 3. DBPs: Monthly (quarterly?), speciated 4. Bromide: Raw and finished monthly averages 5. Pathogens: Daily T. Fecal Col., Fecal Col., and E. Coli. 6. Nutrients: Raw and finished monthly averages for Nitrate and Nitrite 7. Taste and Odor complaints: CLWA is a water wholesaler therefore T&O complaints are delt with through the water retailer.
Cost to Treat	1. Chemical usage rates: Chemical usage is adjusted based on turbidity levels. Turbidity is rarely a problem, however, so this may not be pertinent. 2. Labor cost 3. Cost to purchase
Miscellaneous	

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Antelope Valley East Kern Quartz Hill Water Treatment Plant, Palmdale, CA

Date: Wednesday, June 20, 2007

Attendees:

Brown and Caldwell	
Laura Lindenmayer	Hydrogeologist II
Jill Cunningham	Principal Engineer
CALFED	
Lisa Holm	Water Quality Program Manager
Antelope Valley-East Kern Water Agency	
Jon K. Bozigian	Manager of Operations
Maureen M. Smith	Laboratory Manager
CA DHS	
Sutida Bergquist	Associate Sanitary Engineer
Stefan Cajina	District Engineer

Boundary Conditions/Constraints and Infrastructure	
Source:	1. H.O. Banks intake at Clifton Court Forebay
Raw Water Conveyance:	1. California Aqueduct
Raw Water Storage:	1. Not applicable
Treatment Plant:	1. Quartz Hill Water Treatment Plant (65 mgd) a. Intake, raw water meters, moss screen, rapid mixer, flocculators/clarifiers, anthracite filters, clearwell b. Chemical addition: 40 to 55 ppm aluminum sulfate, 0.5 ppm zinc orthophosphate for corrosion control, occasionally 1 to 2 ppm cationic polymer, occasionally powdered activated carbon for taste and odor control, chlorine is added after the filters
Water Supply and Treatment System	
Source Water Quality and Reliability	1. No comments
Conveyance Water Quality	1. Lower conductivity makes treating water difficult during the coagulation process. High conductivity is indicative of high bromide concentrations. 2. Higher TOC and bromide concentrations in the winter/wet months significantly affect the treatment process. 3. The pH varies but this doesn't have a notable effect on the treatment

	process. 4. Low alkalinity impacts coagulation which in turn impacts both turbidity and TOC removal. 5. Aluminum sulfate is used to treat organic carbon and turbidity. 6. DBPs are most prevalent during the winter time (November, December, and January). 7. Taste and odor issues occur in late summer and early fall. Since Antelope Valley-East Kern Water Agency is a wholesaler, the retailers must deal with the taste and odor complaints. 8. Algae flowed into Quartz Hill Water Treatment Plant about three weeks ago. Crews worked 24 hours a day to scrape algae off of the moss screens. The Department of Water Resources will occasionally use copper sulfate to treat algae growth, but they are reluctant at times due to the threat of fish kills.
Storage Water Quality	1. Not applicable
Treatment	1. Pre-treatment: The clarification process provides the most TOC removal.
Opportunities to Improve Water Quality and Reliability	
Source	1. Antelope Valley-East Kern Water Agency is investigating the use of groundwater recharge or an aquifer storage and recovery system as an additional water supply. 2. Not much groundwater in the area.
Conveyance and Storage	1. Real time monitoring and reporting of the water quality in the California Aqueduct would be helpful. Currently, Antelope Valley-East Kern Water Agency relies on early warnings or forecasting information from Central Coast Water Agency.
Treatment	1. At a cost of $90 million, currently expanding the existing Quartz Hill Water Treatment Plant from 65 mgd to 90 mgd to accommodate rapid population growth. To improve on the treatment of TOC and bromide, the following modifications will be made to the existing plant: adding ozone, changing from anthracite to granular activated carbon, changing from sodium hypochlorite to chloramines.
Other	
Source	1. No comment.
Conveyance and Storage	1. No comments
Treatment	1. Antelope Valley-East Kern Water Agency operates four water treatment plants: Acton, Eastside, Quartz Hill, and Rosamond. 2. An intertie with Palmdale Water District can feed Los Angeles County.

CALFED Detailed Study Treatment Plant Meeting Summary

Treatment Plant: Antelope Valley East Kern Quartz Hill Water Treatment Plant, Palmdale, CA
Date: Wednesday, June 20, 2007

Data Gathered	
Water Quality	1. TOC/DOC: 2. Turbidity: 3. DBPs: 4. Pathogens: 5. Nutrients: 6. Taste and Odor complaints:
Cost to Treat	1. Chemicals costs 2. Labor cost 3. Cost to purchase

APPENDIX E

System Water Quality Conceptual Model

SYSTEM WATER QUALITY CONCEPTUAL MODEL

WATER SUPPLY AND TREATMENT SYSTEM

	SOURCE	CONVEYANCE AND STORAGE	TREATMENT: Filtration	TREATMENT: Disinfection	
TOC	• Interaction with Cl_2 forms regulated DBPs during disinfection • TOC removal requirement in treatment based on concentration • *TOC and DOC concentrations*	• Change in concentration and/or nature of TOC due to alternative sources, conveyance, and storage • *TOC and DOC concentrations*	• Removal of TOC during conventional treatment • Membranes do not remove TOC • *TOC concentration*	• Interaction with Cl_2 forms regulated DBPs during disinfection • Change in TOC • *CT target/requirement* • *TTHM and HAA5 concentrations by species*	DBPs
Bromide / TDS	• Interaction of bromide and ozone forms bromate during disinfection • Usability • USEPA secondary standard for TDS is 500mg/L • *Bromide and TDS concentrations*	• Change in concentrations due to alternative sources, conveyance, and storage - Dilution or increase - Attenuation • *Bromide and TDS concentrations*	• Minimal to no change in concentration through conventional treatment	• Interaction of Bromide and ozone forms bromate during disinfection • Taste and usability impacts • *CT target/requirement* • *Bromide and TDS concentrations* • *Customer complaints*	Bromate
Nutrients/ Algae	• Increased nutrients increase algae growth • Nitrate/Nitrite MCL • Algae produces mal taste and odors • *Nutrient and chlorophyll a concentrations, algae counts*	• Residence time, temperature, light exposure and depth may impact algae growth • Control/management practices • *Nutrient and chlorophyll a concentrations, algae counts*	• Removal of algae and T & O • Algae can clog filters and impact treatment operation	• Oxidation of algae by-products and improved T & O • *Customer complaints* • *Nitrate/Nitrite concentations*	Taste and Odor
Pathogens/ Indicator Organisms	• Source concentrations inform treatment requirements • *Total/Fecal, Giardia, E. coli, HPC, Cryptosporidium concentrations*	• Increased light and temperature can inactivate some pathogens • Inputs along conveyance • Watershed inputs • *Total/Fecal, Giardia, E. coli, HPC, Cryptosporidium concentrations*	• Receive log removal credit for pretreatment and filtration (limits necessary disinfection) • *Log removal achieved/target*	• *Log removal achieved/target* • *CT* • *Total/Fecal, Giardia, E. coli, Cryptosporidium concentrations, HPC*	Pathogens / Indicator Organisms

Items in italics are information to be collected.

REFERENCES

CALFED Bay-Delta Program, 2005. *Issues with Delta Drinking Water Treatment*, Brown and Caldwell, July, 2007

State Water Project Contractors Authority, 2007. *California State Water Project Watershed Sanitary Survey 2006 Update*, Draft Report April 2007.