Bay-Delta Water Quality Evaluation Draft Final Report

California Urban Water Agencies

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Preface by California Urban Water Agencies

One objective of the CALFED Bay-Delta Program is to provide good water quality in water diverted from the Delta to meet drinking water needs. To accomplish this, CALFED must select a long-term solution that provides a quality of source water that urban water providers can treat with reasonable cost to meet current and future federal and state health-based drinking water standards. To enable a quantitative assessment of the impact of alternative Bay-Delta solutions, specific water quality criteria must be chosen for analysis. Although there are numerous water quality constituents of concern in meeting drinking water standards, the major constituents of health concern in Delta water are pathogens (Giardia and Cryptosporidium) and disinfection by-product (DBP) precursors (bromide and total organic carbon). The quality of water diverted from the Delta will bear heavily on the treatment technology which needs to be employed to meet increasingly stringent drinking water standards. Municipal water providers are already investing hundreds of millions of dollars in advanced treatment processes to meet more restrictive treatment standards. Without a higher quality of source water, probable future standards could make these investments obsolete and force technology which can neither be guaranteed to perform, be feasible due to market constraints or environmental regulation constraints, or be realistically affordable to the end users.

Setting water quality criteria requires knowledge about both the future regulatory setting under the Safe Drinking Water Act and the relative performance characteristics of currently available treatment technologies under a variety of actual conditions. Rather than asking its treatment experts to make this assessment. CUWA convened a panel of nationally recognized drinking water quality experts to determine the required criteria for total organic carbon (TOC) and bromide that will allow utilities treating Delta water to comply with current and probable future drinking water regulations utilizing available advanced technology. The expert panel consists of Douglas Owen, P.E. Vice President at Malcolm Pirnie, Inc., Phillippe Daniel, P.E. Associate at Camp Dresser & McKee and R. Scott Summers, PhD, Associate Professor at the University of Cincinnati. The purpose of the expert panel report is to recommend Delta drinking water quality criteria with which CALFED staff can evaluate Bay-Delta alternative's relative performance in meeting program objectives. These criteria have been developed in recognition of the interaction between source water quality, treatment efficacy and probable regulatory outcomes, as developed by the panel. This report, however, does not represent CUWA's or any of its members endorsement of a specific regulatory outcome.

This report concludes that for currently available advanced water treatment technology (i.e., enhanced coagulation and ozone disinfection) to be able to meet potential long-term drinking water quality standards for water diverted from the Delta, the source water quality should have concentrations less than 3.0 mg/L for TOC and less than 50 μ g/L for bromide (<20 mg/L chloride concentration). Although using granular activated carbon or membranes allows upward flexibility in these values, the feasibility of these processes in terms of cost,

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residual disposal, and construction is uncertain (there are only one or two facilities in the United States of the size applicable to CUWA member facilities which use GAC or membranes for drinking water treatment). Source water quality with concentrations higher than 3.0 mg/L TOC and 50 μ g/L bromide could still meet a near-term regulatory scenario, but the long-term scenario is more appropriate for planning eventual CALFED Bay-Delta solution.

CUWA recognizes that based upon historic concentrations of these constituents measured at Clifton Court Forebay in the Delta, it is unlikely that the above criterion for bromide could be met by all urban water agencies using ozonation under existing conditions, even in wet years. Therefore, CALFED must carefully analyze a variety of actions within its alternatives analysis to determine which combination of actions can assure the achievement of the program's drinking water quality objective in concert with other important objectives. These actions should include at least the following:

- The capability of in-Delta hydraulic modifications to limit seawater intrusion and resulting increase in bromide concentration
- Pollutant source control programs for TOC and pathogens (actions should include areas where water is degraded after diversion from the Delta as well as the Bay-Delta watershed itself.)
- Water storage and storage management
- Increased outflow
- An isolated facility

These actions must be assessed in appropriate combinations designed to meet CALFED's multiple program objectives.

CUWA also recognizes that CALFED should assess the environmental and economic impact and the practical feasibility of **not** providing a water quality for Delta diversions which would allow future standards to be met with currently available advanced technology. CUWA does not believe such technology, including membrane technologies and granulated activated carbon filtration, are either affordable or feasible on the scale needed for municipal treatment in California and are not likely to be in the foreseeable future.

Public water agencies have a unique public trust responsibility to provide the highest quality of water reasonably achievable. This approach to public health protection is one that is balanced by combining (1) source selection to enhance water quality, (2) source protection to preserve water quality, and (3) effective and reliable treatment technology. CUWA believes the CALFED Bay-Delta Program solution should be consistent with the following principles.

- Maintenance and improvement of existing high quality urban water supplies and in-Delta supplies as the most effective means to protect public health
- A strong program of water pollutant source control is required to assure public health and environmental quality
- Provision for the highest quality drinking water quality reasonably available.
 This will assure the greatest likelihood that available treatment technologies will meet future drinking water standards.

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EXECUTIVE SUMMARY

The California Urban Water Agencies (CUWA) retained the assistance of three water quality and treatment specialists who have specific expertise in the formation of disinfection by-products (DBPs). These three individuals — the expert panel — evaluated specific source water quality characteristics which would be necessary to permit diverted water from the San Francisco Bay/Sacramento-San Joaquin River Delta (Delta) to be used for meeting potential public health related water quality standards under defined treatment conditions. Specifically, the expert panel was charged with 1) developing potential future regulatory scenarios, 2) defining appropriate process criteria for coagulation, ozonation, granular activated carbon and membrane treatment processes, and 3) estimating source water quality diverted from the Delta which would allow users implementing the defined treatment technologies to comply with the regulatory scenario. The source water quality characteristics were framed in the context of total organic carbon (TOC) and bromide concentrations, both constituents which have the potential to be controlled by different management strategies for the Delta.

Two potential regulatory scenarios were projected based upon regulatory negotiations conducted in 1992-93 and 1997. The near-term scenario focuses on Stage 1 of the Disinfectant/Disinfection By-Product (D/DBP) Rule and the Interim Enhanced Surface Water Treatment Rule. The long-term scenario focuses on Stage 2 of the D/DBP Rule and the Long Term Enhanced Surface Water Treatment Rule. The potential regulatory scenarios include specific limits for two organic classifications of DBPs recently proposed in rulemaking by EPA; total trihalomethanes (TTHMs) and the sum of five haloacetic acids (HAA5). In addition, a potential limit was projected for bromate, an inorganic by-product formed by the ozonation of bromide-containing waters; a standard has been proposed by EPA for this DBP, as well. These DBP limits were coupled with various potential requirements for microbial removal and inactivation.

The treatment criteria specified by the expert panel for the near-term regulatory scenario included: 1) the use of 40 mg/L of alum at a pH of 7.0 and possibly as low as 6.5 in the coagulation process, followed by chlorine disinfection with a chloramine residual in the distribution system, and 2) the use of ozone at specific ozone: TOC ratios followed by a chloramine residual. The chlorine and ozone disinfection criteria were proposed to meet potential 1 or 2 log *Giardia* inactivation requirements. For the long-term regulatory scenario, the use of post-filter GAC adsorbers, GAC in combination with ozone, membrane filtration in combination with ozone, and nanofiltration with free chlorine were considered. The long-term scenario included inactivation for *Giardia* and *Cryptosporidium*, the latter of which could only be achieved by ozone disinfection or the "absolute barrier" of membrane treatment.

The expert panel used data submitted by CUWA members, available literature and ongoing research, as well as their own experience and best professional judgement to arrive at potential source water quality requirements. Available models for DBP formation were evaluated to investigate threshold DBP formation behavior and to support the initial conclusions reached by the expert panel.

Specific combinations for TOC and bromide necessary in the water diverted from the Delta can vary depending upon the treatment technology implemented and microbiological inactivation required. Further, the selected bromate level of 5 µg/L in the long-term regulatory scenario is significant in establishing limiting bromide levels in this evaluation. The rationale for this level in this analysis ultimately may be modified by a variety of factors including allowing for trade-offs for disinfection and the formation of organically-based brominated DBPs (e.g., THMs or HAAs) or evidence of a cancer threshold for bromate (investigations underway). On the other hand, there are other potential regulatory outcomes involving 1) further lowering the MCLs for DBPs, 2) the regulation of individual DBP species (rather than the groups of compounds represented by TTHM and HAA5 due to the potentially more severe health effects associated with brominated compounds), 3) regulating other DBPs beyond TTHMs and HAA5, including the addition of other regulated HAAs (there are nine total) as analytical methods are developed and refined, 4) a comparative risk framework which balances all of the risk attributable to the DBPs formed, rather than providing specific MCLs for each group, and 5) concerns over reproductive and developmental effects that may be associated with DBPs, which may lower the regulatory levels and/or the permissible maximum concentration (i.e., annual averaging may no longer be the basis for determining compliance).

In summary, it was the opinion of the panel that < 3 mg/L of TOC and $< 50 \,\mu$ g/L of bromide would be necessary to allow users the flexibility to incorporate either enhanced coagulation or ozone disinfection to meet the potential long-term regulatory scenario in this evaluation. The TOC value is constrained by the formation of total trihalomethanes when using enhanced coagulation for TOC removal and free chlorine to inactivate *Giardia*. The bromide value is constrained by the formation of bromate when using ozone to inactivate *Cryptosporidium*. Looking only at the potential near-term regulatory scenario provides significantly more source water flexibility when using enhanced coagulation or ozone, with source water TOC concentrations ranging between 4 and up to 7 mg/L (the 90th percentile value for waters diverted from the south Delta) and bromide ranging between 100 and 300 μ g/L, depending upon the extent of *Giardia* inactivation required (the near-term scenario does not include *Cryptosporidium* inactivation).

Similarly, the use of either GAC or membrane treatment in the long-term regulatory scenario broadens the allowable source water quality. For GAC, a source water TOC value of 5 mg/L is acceptable with bromide of 150 μ g/L or 50 μ g/L, depending upon *Giardia* inactivation. GAC alone is not applicable to instances in which *Cryptosporidium* inactivation is required, and must be coupled with ozone disinfection. This allows the source water TOC concentration to increase to at least 7 mg/L, although bromide is constrained to < 50 μ g/L even at an ozone pH of 6.5.

The use of microfiltration or ultrafiltration, coupled with ozone for primary disinfection and chloramines for secondary disinfection, is an "absolute barrier" for protozoan (Giardia and Cryptosporidium) removal. Viruses, however, must still be inactivated. This treatment scheme allows source water TOC concentrations to increase to at least 7 mg/L. The bromide concentration is again limited by bromate formation under ozone addition for virus inactivation, and is < 150 μ g/L for microfiltration and < 300 μ g/L for ultrafiltration (less virus inactivation is required for ultrafiltration). If nanofiltration is used with free chlorination, TOC concentration can be up to 10 mg/L for all bromide concentrations evaluated (< 300 μ g/L).

It is important to note that when ozone disinfection is used for treatment, the allowable TOC is not unlimited. There are concerns regarding the ability of biological filters or GAC to remove biodegradable organic carbon to adequate levels as TOC approaches 7 mg/L (the 90th percentile for water diverted from the south Delta). In general, ozone disinfection is more effective and reliable as TOC decreases.

The feasibility of implementing either GAC or NF/RO membranes in California, given cost considerations, environmental permitting constraints, and limited residual disposal options, is uncertain. The use of MF/UF membranes address some residual disposal issues, but large system design issues affect feasibility on a site-specific basis.

1.0 INTRODUCTION

The California Urban Water Agencies (CUWA) engaged the services of three water quality experts to assist in providing input to the CALFED process regarding potential management alternatives in the San Francisco Bay/Sacramento-San Joaquin River Delta (Delta). The expert panel was charged with determining the required raw water quality diverted from the Delta which would permit the effective implementation of specific drinking water treatment processes to meet potential future drinking water quality standards. The expert panel was comprised of Douglas M. Owen, P.E., Vice President at Malcolm Pirnie, Inc., Phillippe A. Daniel, P.E., Associate at Camp, Dresser & McKee, and R. Scott Summers, PhD, Associate Professor at the University of Cincinnati.

The expert panel used data submitted by CUWA members, available literature and ongoing research, as well as their own experience and best professional judgement to arrive at potential source water quality requirements. Available models for DBP formation were evaluated to investigate threshold DBP formation behavior and to support the preliminary conclusions reached by the expert panel. This report presents the best professional judgement from this expert panel.

This report is subdivided into the following chapters:

- Chapter 2 Potential Regulatory Scenario and Schedule
- Chapter 3 Treatment Processes to Meet Regulatory Requirements
- Chapter 4 Evaluation of Source Water Quality and Treatment Efficiency

In Chapter 2, the general trends in drinking water regulations are discussed and plausible, future regulatory criteria are presented. Treatment processes relevant to users of water diverted from the Delta are presented in Chapter 3, together with general assumptions regarding the design and application of these processes. In Chapter 4, source water quality is projected which allows the treatment processes defined in Chapter 3 to be used to meet the potential regulatory scenario presented in Chapter 2.

2.0 POTENTIAL REGULATORY SCENARIO AND SCHEDULE

2.1 REGULATORY SCENARIO

2.1.1 Introduction

From a perspective of water quality parameters which can be controlled through management strategies in the Delta [e.g., total organic carbon (TOC) and bromide], the most critical present and future human health-related regulations affecting the implementation and performance of drinking water treatment processes for agencies using Delta water are:

- 1. <u>Microbiological control</u> The focus for disinfection and microbial control currently pivots around the removal and inactivation of *Giardia* and *Cryptosporidium*. Currently, 3 log (99.9 percent) removal and inactivation of *Giardia* is required in the Surface Water Treatment Rule (SWTR). The EPA began considering an Enhanced SWTR (ESWTR) starting in late 1992, which would address the ability of systems to maintain microbiological control as disinfection practices were scrutinized. This rule would also address the removal/inactivation of *Cryptosporidium*, through either removal or inactivation. The ESWTR has been proposed in two stages (USEPA, 1994) and is currently being re-evaluated, as discussed below.
- 2. <u>Disinfection By-Product Control</u> The disinfectant residual concentration and the organic and inorganic compounds formed by the disinfection process (termed disinfection by-products or DBPs) will be regulated under the Disinfectants/Disinfection By-Products (D/DBP) Rule. This rule also was proposed in two stages (USEPA, 1994) and is currently being re-evaluated.

Other water quality contaminants, such as pesticides, herbicides, and metals, are of concern but are not likely to constrain treatment requirements as significantly as the microbial and DBP regulations, based upon their occurrence in water currently diverted from the Delta.

Both stages of the ESWTR and D/DBP Rule will impact the CUWA members and will affect the quality of water diverted from the Delta to meet regulatory requirements using an array of treatment technologies. Although a longer-term view of the regulations (i.e., second stage) is more appropriate to coordinate with the ultimate Delta management solutions, these future regulations are still relatively uncertain. The initial regulations — Stage 1 of the D/DBP Rule and the Interim ESWTR — have been agreed to in principle

through a Federal Advisory Committee Act (FACA) process involving stakeholder meetings held in the Spring and Summer of 1997. Consequently, the expert panel evaluated potential future source water quality requirements using the specified technologies for both the near-term and long-term regulations.

The following sections discuss potential regulatory scenarios for both the near-term (i.e., Stage 1 D/DBP Rule and Interim ESWTR) and the long-term (i.e., Stage 2 D/DBP Rule and Long Term 2 ESWTR) regulations. Source water quality requirements are developed in Chapter 4, using the defined technologies in Chapter 3, to meet both the near-term and long-term potential regulatory outcomes.

2.1.2 Potential Near-Term Regulatory Scenario

Stage 1 D/DBP Rule

The requirements for the Stage 1 D/DBP Rule have been agreed to in principle through the FACA process. The requirements most significantly impacting treatment technologies and source water quality requirements include maximum contaminant levels (MCLs) and a treatment technique. Relevant MCLs include an 80 μ g/L standard for total trihalomethanes (TTHMs) and 60 μ g/L value for the sum of five haloacetic acids (HAA5). In addition, a 10 μ g/L MCL has been proposed for bromate (a compound formed in bromide-containing waters, particularly with ozone treatment).

The treatment technique is enhanced coagulation and enhanced precipitative softening. For the CUWA members, the requirements of enhanced coagulation are more relevant than those for softening. With a few exceptions based upon treated water quality, enhanced coagulation must be implemented at existing conventional treatment facilities. It will not be enforced for direct filtration facilities. The treatment requirements for enhanced coagulation, as they apply to this evaluation, are discussed in Chapter 3.

Interim ESWTR

The Interim ESWTR (IESWTR), also agreed to in principle at the FACA negotiations, is designed to provide microbial protection as systems are potentially modifying treatment practices to comply with Stage 1 of the D/DBP Rule. In summary, the IESWTR focuses on maintaining the level of chemical disinfection currently provided at

existing facilities, while requiring a higher standard of particle removal. Briefly, the standard for combined filtered water turbidity will be reduced to <0.3 NTU at least 95% of the time. Individual filter turbidities must be monitored and there is a series of evaluations which must be performed if individual filter water turbidities exceed 1 or 2 NTU for consecutive 15 minute measurements.

The chemical disinfection requirements are based upon a microbial "backstop." In concept, the backstop focuses on maintaining the minimum level of disinfection that existing facilities have historically been providing. If a system modifies disinfection practices to meet the requirements of Stage 1 of the D/DBP Rule, they must either 1) meet or exceed the "backstop" disinfection practice, or 2) discuss their proposed disinfection modifications with the primacy agency (e.g., California Department of Health Services). The backstop is calculated through profiling existing disinfection practices as follows:

- 1. The monthly average of daily *Giardia* inactivation is calculated for three consecutive calendar years.
- 2. The minimum monthly average inactivation is identified for each calendar year.
- 3. The three minimum monthly average inactivations are averaged to calculate a single, "backstop" value.

This backstop is only applicable if a significant change in disinfection (e.g., disinfectant type, dosage) is implemented by the system which results in an inactivation that is less than the backstop value. It is important to note that the backstop triggers a discussion with the primacy agency. It is possible that the utility may be allowed to reduce the level of disinfection below the backstop level, depending upon the backstop value, disinfectant type, and other site-specific issues. The final disinfection requirements, if less than the backstop, are determined by the primacy agency together with the utility.

Historical disinfection data submitted by the Metropolitan Water District of Southern California and the Alameda County Water District were reviewed to determine a "central tendency" backstop for the CUWA members. The evaluation indicated that the backstop value could vary between 90 percent (1 log) and 99 percent (2 log) inactivation of *Giardia*.

Therefore, the expert panel considered both of these backstop values in determining source water quality requirements.

Potential Near-Term Regulatory Scenario

Based upon the above discussion, the potential near-term regulatory scenario is summarized in Table 2.1:

TABLE 2.1
POTENTIAL NEAR-TERM REGULATORY SCENARIO

Regulation	Parameter	Treatment Requirement or MCL
Interim ESWTR	Giardia	Additional 1 or 2 log inactivation by disinfection, after treatment removal credit
Stage 1 D/DBP Rule	TTHMs	80 μg/L
	HAA5	60 μg/L
	Bromate	10 μg/L

2.1.3 Potential Long-Term Regulatory Scenario

Stage 2 D/DBP Rule

Stage 2 DBP levels which were proposed in 1994, while acknowledged to be "placeholder" values until additional data can be collected and reviewed, were assumed to be reasonable targets for this analysis (i.e., TTHM of $40 \mu g/L$, HAA5 of $30 \mu g/L$). Further, a bromate MCL of $5 \mu g/L$ was considered for the long-term. The rational for this level is based upon a host of factors. First, the 10^4 , 10^5 , and 10^6 excess cancer risk levels for bromate are $5 \mu g/L$, $0.5 \mu g/L$ and $0.05 \mu g/L$, respectively. These levels were confirmed in EPA's recent Notice of Data Availability for Disinfectants and Disinfection By-Products in March 1998 (USEPA, 1998). Although a $5 \mu g/L$ limit was considered during the regulatory negotiation in 1992-1993, a value of $10 \mu g/L$ was established based upon practical quantitation levels (PQLs) for this compound at that time. Since 1994, however, many improvements have been made in the analytical technique for bromate thereby providing an excellent potential for reducing the PQL in future rulemaking. Because of EPA's reaffirmation of the carcinogenicity of bromate in recent studies and the improvement in analytical techniques, a bromate target of $5 \mu g/L$ was selected for the long-term scenario.

Long-Term ESWTR

The final outcome for a Long Term 2 ESWTR (LT2ESWTR) is uncertain, but many alternatives in the ESWTR proposed by EPA require treatment based on pathogen density in source waters (USEPA, 1994). Based upon 1) a review of pathogen data collected at various locations in the Delta by the Metropolitan Water District of Southern California, and 2) regulatory alternatives proposed in the ESWTR, plausible requirements identified by the expert panel for Delta water range from 1 log and 2 log inactivation of *Giardia* to 1 log inactivation of *Cryptosporidium*. This level of inactivation would be required after treatment removal credit is achieved. These criteria assume that higher log inactivations will be required as the concentration of pathogens in the source water increases. For every log increase in source water concentration, an additional log increase in removal/inactivation is required to achieve a constant finished water quality. This concept was proposed in the SWTR Guidance Manual and was furthered in several proposals published by EPA for the ESWTR.

Potential Long-Term Regulatory Scenario

Based upon the above discussion, the potential long-term regulatory scenario is summarized in Table 2.2:

TABLE 2.2
POTENTIAL LONG-TERM REGULATORY SCENARIO

Regulation	Parameter	Treatment Requirement or MCL
Long-Term 2 ESWTR	Giardia	Additional 1 or 2 log inactivation by disinfection, after treatment removal credit
	Cryptosporidium	Additional 1 log inactivation by disinfection, after treatment removal credit
Stage 2 D/DBP Rule	TTHMs	40 μg/L
	HAA5	30 μg/L
	Bromate	5 μg/L

While there are many factors that contribute to the uncertainty surrounding the projected regulatory scenario in Table 2.2, it is the selected bromate level of 5 μ g/L that most keenly influences the analysis. The rationale for this level (i.e., advances in detection limit, the weight of the carcinogenic evidence, the precedence for THM and HAA5 limits in Stage 2 at half the Stage 1 levels) in this analysis could ultimately be modified by a variety of factors. Nevertheless, in the absence of more definitive direction, the panel considers a 5 μ g/L value to be both prudent and plausible.

There are other potential regulatory outcomes involving 1) further lowering the MCLs for DBPs, 2) the regulation of individual DBP species (rather than the groups of compounds represented by TTHM and HAA5 due to the potentially more severe health effects associated with brominated compounds), 3) regulating other DBPs beyond TTHMs and HAA5, including the addition of other HAAs (there are nine total) as analytical methods are developed and refined, 4) a comparative risk framework which balances all of the risk attributable to the DBPs formed, rather than providing specific MCLs for each group, and 5) concerns over reproductive and developmental effects that may be associated with DBPs, which may lower the regulatory levels and/or the permissible maximum concentration (i.e., annual averaging may no longer be the basis for determining compliance). The potential implications of such regulatory outcomes is briefly discussed in Section 4.4.

2.2 REGULATORY SCHEDULE

The recently-enacted 1996 Amendments to the Safe Drinking Water Act (SDWA) have caused EPA to adopt a more ambitious schedule than EPA presented in June 1996 (see Table 2.3). The June 1996 dates were based upon a scenario in which EPA would not be "pushed" to develop an Interim ESWTR, and promulgate Stage 1 of the D/DBP Rule and the Interim ESWTR, until pathogen data were available from the Information Collection Rule (ICR).

TABLE 2.3
COMPARISON OF OLD AND NEW REGULATORY SCHEDULE

	Promulgation Date		
Regulation	Initial (June 1996)	Revised (August 1996)	
Interim ESWTR	June 2000	November 1998	
Long Term 2 ESWTR	NA (1)	November 2000	
Stage 1 D/DBP Rule	June 2000	November 1998	
Stage 2 D/DBP Rule	June 2003	May 2002	

Notes:

EPA understands, however, that the LT2ESWTR and Stage 2 of the D/DBP Rule, at a minimum, are linked to data availability through the ICR. Monitoring for the 18-month ICR began in July 1997. Consequently, EPA was pressed between the statutory requirements and the recognition that a longer time frame would be required to promulgate Stage 1 of the D/DBP Rule and the IESWTR if the ICR data were to be considered. Therefore, EPA proceeded with interim regulations for microbial and DBP control based upon the existing knowledge base rather than waiting for the ICR data. The FACA process for the agreement in principle concluded in June 1997 to allow EPA to meet the schedule in Table 2.3 for the near-term regulations. Nevertheless, both the LT2ESWTR and Stage 2 of the D/DBP Rule will ultimately need to be finalized and become effective by the dates given in the reauthorized SDWA (November 2000 and May 2002, respectively) and take the ICR data into account. Even though the ICR monitoring has begun, the schedule will remain tight as a result of the time needed to analyze the data and to perform treatability studies to support compliance forecasts for the Stage 2 D/DBP Rule.

⁽¹⁾ NA = Not available

3.0 TREATMENT PROCESSES REQUIRED TO MEET FUTURE REGULATIONS

In this chapter, general process criteria are defined to characterize specific treatment processes relevant to users of water diverted from the Delta. Source water quality is determined in Chapter 4 which permits these treatment processes to meet the potential regulatory scenarios discussed in Chapter 2.

3.1 SELECTION OF TREATMENT PROCESSES TO BE EVALUATED

As a part of this effort, CUWA requested that the expert panel initially focus on those treatment processes which were considered to be the most cost-effective for simultaneously meeting the requirements of the D/DBP Rule and the ESWTR when treating water diverted from the Delta. These processes were defined as enhanced coagulation, a treatment technique proposed for Stage 1 of the D/DBP Rule, and ozone disinfection. These two processes are also relevant for Stage 2 of the D/DBP Rule and were considered appropriate because they can be implemented into facilities currently owned and operated by the CUWA agencies (as well as a majority of conventional filtration facilities across the country). For example, the majority of filtration systems across the country use conventional treatment including sedimentation, which allows for increased coagulation dosages to meet proposed enhanced coagulation requirements. In addition, some CUWA facilities already use ozone disinfection. The most cost-effective option(s) for meeting potential future regulations is specific for each water purveyor, depending upon water source and quality.

Based upon comments received from the Natural Resources Defense Council (NRDC), CUWA also directed the expert panel to evaluate the impact of implementing post-filter granular activated carbon (GAC) adsorbers and membranes on the potential allowable source water quality characteristics. Neither of these processes are currently used by any of the CUWA members and their feasibility for large scale water treatment facilities in California is uncertain. Post-filter GAC adsorbers and membranes can be at least an order of magnitude more expensive than ozone and the feasibility of these technologies is much more uncertain based upon cost, environmental permitting constraints, and availability of

residual handling alternatives. This view is shared by much of the water industry. For reference, only one or two treatment plants in the country at the size comparable to many of the CUWA members use post-filter GAC or membranes for drinking water treatment.

There are CUWA members who now treat much higher quality water than that currently diverted from the Delta. These entities are able to use in-line filtration or simply disinfection without filtration to produce high quality drinking water. It should be emphasized that the determination of feasible treatment processes is dependent upon the existing source and that this evaluation is based only upon those entities currently using water diverted from the Delta.

3.2 GENERAL ASSUMPTIONS FOR SELECTED TREATMENT PROCESSES

3.2.1 Enhanced Coagulation

Enhanced coagulation offers the advantages of removing naturally-occurring organic material, thereby removing DBP precursors which, upon disinfection, form DBPs. As such, MCLs for TTHMs and HAA5 can be addressed by enhanced coagulation, when followed by chlorine disinfection. Upon review of the potential for DBP formation, it was determined that enhanced coagulation would only be required under conditions in which free chlorine is used for primary disinfection (pathogen inactivation), followed by chloramines for secondary disinfection to maintain a distribution system residual. Further, this treatment option is only applicable to instances in which either 1 or 2 log *Giardia* inactivation is required to demonstrate microbial control, as discussed in Chapter 2. It was assumed that *Cryptosporidium* inactivation could not be achieved by free chlorine disinfection under treatment conditions feasible for drinking water systems.

The conditions for enhanced coagulation were defined according to the specific percent removal requirements for Total Organic Carbon (TOC) -- as proposed in Stage 1 of the D/DBP Rule (USEPA, 1994) and amended through the FACA process -- by raw water TOC and alkalinity. Given the specific TOC removal percentages in the proposed D/DBP Rule, this translated to a projected 40 mg/L dosage of alum at a coagulation pH of 7.0, and possibly as low as 6.5. Consequently, acid addition may be required since the 40 mg/L

dosage will likely only lower the pH to a value between 7.0 and 7.2. These coagulant dosages are not atypical of those currently being used by some CUWA members (e.g., Alameda County, Contra Costa, and Santa Clara Valley Water Districts), although these systems do not reduce pH with acid to improve precursor removal. It was assumed that a chlorine: TOC ratio of 1:1 and 60 minutes of free chlorine contact (t₅₀) would be required to achieve 1 log inactivation of *Giardia*. For 2 log *Giardia* inactivation, 120 minutes of free chlorine contact would be required. The above criteria for chlorine dose and contact time assume a chlorine residual of approximately 1 to 1.5 mg/L after the associated contact time, with a t₁₀:t₅₀ ratio of between 0.5 and 0.6 in a moderately well-baffled contactor. This allows for the appropriate CT values to be met at the limiting case of a temperature between 10 and 15° C and a chlorination pH of 7.0 to 7.5. The 1 and 2 log *Giardia* inactivation targets are applicable to both the backstop for the IESWTR and some of the microbial requirements for the LT2ESWTR in the potential regulatory scenarios in Chapter 2.

In the above definition, it is assumed that chlorination would be postponed until after coagulation, flocculation and sedimentation is complete. It is recognized that during the latest round of regulatory deliberations, the USEPA accepted that utilities may need to provide raw water chlorination — and receive credit for microbial inactivation — simultaneously with removing organic material to reduce DBP formation. Recent enhanced coagulation research (Summers, 1997) indicates that the DBPs formed when chlorination is delayed until after sedimentation may be only 75 to 80 percent of those formed when prechlorination is practiced. Consequently, the definition of enhanced coagulation used in this evaluation represents the best that systems could achieve in terms of DBP production. This translates to a larger allowable range for source water quality. In addition, the above definition assumes that the systems can and will construct additional dedicated contact chambers to meet inactivation requirements, if required. There are costs associated with providing additional clearwell contact time beyond that currently available.

In the evaluation in Chapter 4, regions of "uncertainty" are illustrated to delineate those source water conditions under which the selection of specific treatment technologies will be highly system-specific. For enhanced coagulation, these regions will include the uncertainty associated with potential differences in DBP formation based upon whether or not prechlorination is practiced under enhanced coagulation conditions.

3.2.2 Ozone Disinfection

The use of ozone disinfection offers the opportunity to meet the MCLs for TTHM and HAA5 in the potential regulatory scenario by again using chloramines as the secondary disinfectant. Therefore, additional removal of naturally-occurring organic matter may not be necessary. That is, enhanced coagulation may not have to be coupled with ozone disinfection, as long as the source water TOC is ≤ 4.0 mg/L and alkalinity is > 60 mg/L as CaCO₃. Implementing ozone and chloramines under the Stage 1 timeframe to meet both Stage 1 and Stage 2 MCLs is one strategy for water utilities to avoid implementing enhanced coagulation when treating source waters with TOC concentrations ≤ 4.0 mg/L and alkalinity > 60 mg/L as CaCO₃. Many entities using water diverted from the Delta, however, treat source water TOC concentrations > 4 mg/L.

Based upon the ozone dosage and inactivation data from the CUWA members, the expert panel's experience, and recent research, possible ozone: TOC ratios which may be required to achieve pathogen inactivation were evaluated. These ratios take into consideration a host of factors, including 1) CT requirements for 1 log *Cryptosporidium* inactivation may be up to 10 times that required for 1 log *Giardia* inactivation, 2) ozone residuals increase as dosages increase for a fixed contact time once the initial ozone demand has been satisfied, and 3) pH affects the persistence of ozone residuals. The ratios were adjusted for pH effects (i.e., greater ozone residual persistence as pH decreases resulting in lower ozone requirements). For example, to meet 1 log *Giardia* inactivation at ambient pH, Alameda County Water District routinely requires an ozone to TOC ratio of 0.8 (ambient pH for entities using water diverted from the Delta can range from 7.5 to 9.5, a "typical" value of 7.8 is used in this analysis). At pH 7, MWD's demonstration plant results indicated roughly a 0.7 ozone: TOC ratio for achieving 2 log *Giardia* inactivation. It is important to note that CT compliance needs to be achieved continuously, and therefore an approximate

20 percent safety factor was applied to the CUWA member data. This also partially accounts for EPA's approach in setting CT values based upon 90 percentile values versus median (50 percentile values) which are represented by the CUWA member data. The selection of ozone: TOC ratios also considered operational issues, for which it was assumed that there would be a certain "overshoot" of specific dosage targets to ensure continual CT compliance. Based upon these assumptions, bromate formation was evaluated at a range of ozone: TOC ratios and pH values, as summarized in Table 3.1.

TABLE 3.1

OZONE: TOC RATIO AND PH CONDITIONS FOR BROMATE EVALUATION

pН	Ozone: TOC Ratios
7.8	0.8, 1.2, 1.5
7.2	0.7, 1.0, 1.3
6.8	0.6, 0.9, 1.1
6.5	0.5, 0.75, 1.0

The ozone: TOC ratios at each pH were considered to inactivate 1 log *Giardia*, 2 log *Giardia*, and 1 log *Cryptosporidium*. The 1 and 2 log *Giardia* inactivation is relevant to both the potential near and long-term regulatory scenarios presented in Chapter 2. The 1 log *Cryptosporidium* inactivation is only relevant to the LT2ESWTR in the potential regulatory scenario in Chapter 2.

It is recognized that the above ozone:TOC ratios are dependent upon other ozone design criteria proposed, such as a 12 minute contact time in a single, multi-chamber contactor. Other facility configurations, such as two-stage ozonation (e.g., ozone added at raw and settled water) and longer ozone contact times may yield different source water quality constraints for a fixed water quality target (e.g., bromate MCL). The criteria proposed here are based upon typical ozone system designs throughout the country.

The expert panel was also requested to evaluate bromate formation at pH 6.0. Relatively fewer data are available at this pH, and this value is outside the boundary conditions of available models (Ozekin, 1994) that were used to assist in validating the expert panel's initial opinions. Further, very few systems with moderate to high alkalinity

(> 60 to 80 mg/L as CaCO₃) would consider providing treatment at a pH of 6.0. It has a significant impact on chemical (acid) feed requirements to reduce pH which, in turn, have secondary impacts. For example, total dissolved solids (TDS) levels can increase significantly as a result of acid addition to achieve a pH of 6.0 in moderate to high alkalinity waters. A pH of 6.0 is also very aggressive to basin and pipe surfaces, and special precautions should be implemented in the design and construction of facilities to accommodate this pH.

It is the relative lack of data, however, that led the expert panel to not predict bromate production at a pH of 6.0. Any bromate concentration predicted at this pH would be speculative in nature, and would have a much greater uncertainty than other values presented in this report. Consequently, predictions of bromate formation at pH 6.0 are not presented.

3.2.3 Granular Activated Carbon Adsorption

Post-Filter GAC

Like enhanced coagulation, granular activated carbon controls the formation of DBPs through the removal of DBP precursors. Initially, GAC can remove over 80 percent of the organic DBP precursors. It is an unsteady-state process, however, in which the effluent concentration increases with time and the GAC has a finite adsorption capacity. Thus, when the effluent treatment objective is exceeded the GAC must be removed from the adsorbers and reactivated or replaced. The critical design parameter is the empty bed contact time (EBCT), which is the ratio of the volume of GAC to the volumetric flow rate. The critical operational parameter is the reactivation time or run time to the controlling effluent treatment objective. For the control of DBP precursors, typically measured as TOC, design EBCTs of 15 to 30 minutes are used and the GAC is operated until the effluent concentration (C) reaches 30 to 70 percent of that in the influent (C₀). The EBCTs are chosen so that the reactivation periods are at least 60 days. More frequent removal/reactivation of the GAC is expensive and limits feasibility from an operational perspective.

GAC is normally applied after the coagulation/sedimentation process and was assumed to follow rapid media filtration for this evaluation (post-filter adsorption mode). A GAC influent TOC range of 3 to 7 mg/L was evaluated and Table 3.2 lists the resulting effluent TOC concentration values for a range of breakthrough ratios (C/C_0).

TABLE 3.2

PREDICTED GAC EFFLUENT QUALITY FOR
A RANGE OF INFLUENT TOC CONCENTRATIONS

Influent TOC (mg/L)	Effluent TOC (mg/L)		
	$C/C_0 = 0.3$	$C/C_0 = 0.5$	$C/C_0 = 0.7$
3	0.9	1.5	2.0
4	1.2	2.0	2.8
5	1.5	2.5	3.5
6	2.8	3.0	4.2
7	2.1	3.5	4.9

The same disinfection assumptions that applied to enhanced coagulation are also applicable to post-GAC microbial inactivation (i.e., a 1:1 chlorine to TOC dose ratio, 60 and 120 minutes of free chlorine contact to yield 1 and 2 log *Giardia* inactivation, respectively; free chlorine followed by chloramines for distribution system residual; no *Cryptosporidium* inactivation with this chlorine/chloramine combination).

Ozone and GAC Treatment

It is important to note that GAC, by itself, will not remove pathogens. Therefore, some systems, particularly in Europe, use GAC following ozone disinfection. In this configuration, ozone provides a strong disinfectant and the GAC is used to control biodegradable ozonation by-products through biological activity and to remove precursors of chlorination/chloramination by-products through adsorption. Many of the biodegradable ozonation by-products can be completely removed, and depending on the EBCT and water quality conditions, the biodegradable organic carbon (BDOC) can be decreased to the levels in the water prior to ozonation. GAC has not been shown to be efficient, however, for removing bromate using feasible design criteria in full-scale applications. This is discussed in greater detail in Section 4.2.2.

Following ozone, GAC can be used in a steady-state mode where the GAC is replaced at a very low frequency (once every 3 to 10 years) and a 20 to 30 percent removal of DBP precursors can be expected. In an unsteady state mode, as described above, the GAC is replaced more often (more than once per year) in which higher removal (30 to 70 percent) of DBP precursors can be expected. In this evaluation of ozone and GAC, ozone is expected to provide inactivation of *Cryptosporidium*, and chloramines will be applied after the GAC to provide a distribution system residual. A free chlorine contact time of 5 minutes was assumed sufficient to provide post-GAC inactivation of heterotrophic plate count bacteria, prior to the application of ammonia.

In this evaluation, it was assumed that the ozone and GAC act somewhat independently for the inactivation and removal of water quality contaminants. For example, ozone can be used to inactivate *Cryptosporidium*; GAC does not appreciably remove microbial contaminants. Ozone forms bromate; GAC does not adsorb bromate in feasible full-scale applications. Ozone does not remove precursors for organically-based DBP compounds (THMs and HAAs); GAC adsorbs these compounds. It is recognized, however, that ozone creates biodegradable organic components which can be adsorbed by GAC, thereby reducing the DBP formation potential through biodegradation. The amount of this removal compared to direct adsorption of organic material is relatively small and within the error of the estimates projected by the expert panel for GAC adsorption, alone.

3.2.4 Membrane Treatment

For simplicity, membrane treatment is divided into two categories in this evaluation:

- 1. Membrane filtration (e.g., microfiltration, ultrafiltration), which removes particles, protozoan cysts (*Giardia* and *Cryptosporidium*), and some viruses. Membrane filtration does not remove dissolved organic material, hardness, or ionic compounds (e.g., bromide) to any significant degree.
- 2. Membrane softening (e.g., nanofiltration, reverse osmosis), which removes particles, protozoan cysts, dissolved organic carbon, hardness, viruses and some ions (e.g., bromide). These "tighter" membranes must be preceded by particle removal to reduce fouling. Recently, the use of nanofiltration and reverse osmosis for dissolved organic carbon removal is challenging the traditional use for softening. RO membranes provide more complete rejection of salt (e.g., chloride bromide) than NF membranes.

Membrane filtration and membrane softening differ in many aspects. In general, capital costs for membrane softening are at least twice those for membrane filtration and much higher operating pressures are required for membrane softening (80 to 200 psi) as compared to membrane filters (15 to 30 psi). Therefore, the higher quality water produced by membrane softening comes at a price.

Membrane Filtration

Membrane filtration is being evaluated in a wide array of drinking water applications. The largest facility with an operating history in the United States is a 5 mgd facility in San Jose, CA. Larger facilities are under design, construction, and are being put on-line. Design of a 28 mgd facility is underway with planned operation in 2000 in Del Rio, Texas. Nevertheless, the use of membrane filtration for large plants (> 40 to 50 mgd) has not been demonstrated and the feasibility is uncertain. Most MF/UF installations showing demonstrated performance have modular units in the 1 to 1.5 mgd capacity range. Therefore, large plants require a large number of treatment modules, which significantly increases facility complexity.

The major advantage of membrane filtration is that, in the absence of coagulation, it does not produce a chemically-treated waste product. Consequently waste disposal is simpler. Further, the cost of membrane filtration is competitive with complete conventional treatment. The feasibility of membrane filtration, however, is dependent upon the source water. It performs best on low turbidity waters and waters low in TOC. Because membrane filters do not remove dissolved compounds, additional pretreatment (i.e., coagulation, flocculation and possibly sedimentation or flotation) must precede this technology if removal of organic carbon is necessary. This may reduce the cost efficiency of membrane filtration compared to conventional treatment.

Because membrane filters do not remove TOC or bromide, and because some virus inactivation still is required after treatment, the use of ozone disinfection followed by a chloramine residual in the distribution system will allow for the maximum flexibility in source water quality diverted from the Delta. In this evaluation, it was assumed that microfilter (MF) or ultrafilter (UF) membranes would follow existing, conventional sedimentation. Assuming 1 log and 2 log virus removal credits for sedimentation coupled

with MF and UF, respectively, additional 3 log (MF) and 2 log (UF) virus inactivations will be required by ozone to meet regulatory requirements. The CT requirements for 1 and 2 log virus inactivation by ozone are similar to that required for 0.5 log and 1.5 log *Giardia* inactivation, respectively. Therefore, bromate formation still is a concern using a membrane filtration/ozone/chloramine treatment strategy. Consequently, it was assumed that an ozonation pH of 6.5 would be required to maximize the flexibility in source water bromide concentrations diverted from the Delta.

Instead of using ozone, it is possible to use free chlorine following MF or UF to provide virus inactivation. The use of chlorine, however, introduces source water limitations based upon TTHM and HAA5 concentrations. Consequently, ozone was evaluated for disinfection rather than free chlorination following membranes. In addition, it may be possible to demonstrate a 4 log virus removal using UF, thereby eliminating any need for supplemental primary disinfection. This would have to be demonstrated to the satisfaction of the primacy agency.

Membrane Softening for DOC and Bromide Removal

There are a few membrane softening plants used for potable water treatment throughout the country, mostly in Florida. The largest membrane softening application for drinking water in the United States is 12 mgd. Slightly larger facilities have been constructed for groundwater recharge in California.

NF/RO membrane provides distinct advantages compared to MF/UF in that microbial contaminants (*Giardia*, *Cryptosporidium* and some viruses), dissolved organic carbon and bromide are all removed. There are two major issues which affect the feasibility of NF/RO membrane treatment in California. One is the disposal of membrane concentrate and the other is the volume of concentrate "wasted" from the system, which is much larger than that "wasted" by MF/UF systems. In a water-short regions such as California, the reject of 15 percent of the source water volume may be considered unacceptable. Further, this reject is highly concentrated with dissolved ions, and therefore disposal options, other than the ocean (if this can be environmentally permitted) are limited. Consequently, these considerations must be carefully weighed when determining whether it is feasible to implement NF/RO treatment.

For softening membranes, it is assumed that existing conventional treatment available at the CUWA treatment facilities, followed by cartridge filters, will provide sufficient pretreatment. Research and full-scale operations suggest that NF treatment can achieve at least 90 and 50 percent removal of TOC and bromide, respectively. It is recognized that RO could provide even higher levels of bromide removal (up to 90 percent), but NF was used as the limiting case in this evaluation. Further, it was assumed that membranes would be treating the entire flow. It is recognized that many facilities by-pass a portion of the membrane influent to achieve a target value for specific parameters (e.g., total dissolved solids) to lower costs and reduce corrosivity. This refinement, however, is beyond the scope of this effort as the extent of blending desired is site-specific.

Application of NF/RO is considered in combination with post-membrane chlorination for both primary and secondary disinfection in this evaluation because of the generally good quality (low TOC and TDS) of the treated water. Uniform formation conditions (UFC) were used to simulate the distribution system conditions (Summers et al., 1996); 24 hour contact time, pH 8.0, temperature of 20° C and a free chlorine residual of 1 mg/L after 24 hours.

3.3 CONCEPTUAL UNIT COSTS FOR TECHNOLOGIES

The technologies presented in this chapter have unique capital and operation and maintenance (O & M) costs. In this section, conceptual unit costs for specific technologies are provided. The estimates show a range of incremental costs, on a \$/acre-ft (AF) basis (e.g., the increased unit cost for water treatment), for enhanced coagulation, ozone disinfection, granular activated carbon (GAC), membrane filtration (MF/UF), and membrane softening (NF/RO).

A range is provided to demonstrate that there is a spectrum of costs associated with a given technology, which is highly dependent upon factors such as design criteria, system size, and other site-specific factors. It must be emphasized that the costs presented here are incremental costs, and do not include costs for other aspects of treatment. For example, the membrane treatment costs do not include pretreatment, which will be considerable for NF/RO treatment. It is possible that conventional treatment including filtration can provide

adequate pretreatment for NF/RO, but the consistency of the pretreated water is critical for the success of the NF/RO technology.

The range of costs presented are based upon the expert panel's experience with systems around the country and are consistent with costs prepared for the USEPA during their development of the D/DBP Rule. These technology costs were peer-reviewed during the regulatory negotiation in 1992-1993 and were deemed acceptable by water industry representatives. Further, the costs were updated for the 1997 deliberations, and membrane costs were modified to reflect the substantial improvements in technology since 1992.

The expert panel did not generate independent cost estimates for CUWA members, as such costs are extremely site-specific and such an evaluation is not with the scope of this effort. The costs presented in this Section were compared to costs developed by the Metropolitan Water District of Southern California for all technologies, with the exception of membrane filtration. When Metropolitan's estimates are converted to unit costs (\$/AF), the values fall within the range of costs presented here.

Table 3.3 provides unit costs for the technologies on a \$/AF basis. These conceptual costs include amortized capital costs (e.g., 20 year design period, 8 percent interest) added to annual O & M costs. Again, these costs assume treatment of the entire facility flow, without bypassing and blending.

Table 3.3

Conceptual Incremental Unit Cost Treatment

Treatment	Incremental Cost \$/Ac-Ft
Enhanced Coagulation	16-34
Ozone	26-42
Granular Activated Carbon	100-210
MF/UF Membranes	140-250
NF/RO Membranes	340-650

It is important to note that costs for controlling pH are not provided in the above table. These costs are highly site-specific but can add \$5 to \$10/Ac-Ft to incremental costs. In addition, it is important to reemphasize that all incremental costs are highly dependent upon many site-specific factors. A sample of potential factors affecting costs is presented in Table 3.4.

Table 3.4
Some Factors Affecting Incremental Treatment Costs

Technology	Example Factors Affecting Incremental Costs
Enhanced Coagulation	1. System size
	2. Existing coagulant dosage
	3. Required Coagulant dosage/pH
	4. Existing and feasible sludge disposal method
Ozonation	1. System size
	2. Oxygen feed source
	3. Ozone dosage and pH conditions
	4. Energy costs
Granular Activated Carbon	1. System size
	2. GAC reactivation frequency
	3. Method of reactivation/replacement
	4. Energy costs
MF/UF Treatment	1. System size
	2. Operating philosophy
	3. System configuration
	4. Backwash disposal
NF/RO Treatment	1. System size
	2. Operating philosophy
	3. Energy costs
	4. Concentrate disposal option

4.0 EVALUATION OF SOURCE WATER QUALITY AND TREATMENT EFFICIENCY

4.1 WATER QUALITY IMPACTS AND VARIABILITY

In this section, water quality constraints are described which will allow implementation of specific treatment processes to meet potential regulatory goals. In general, the water quality constraints will be described in terms of two measurable surrogate parameters which affect DBP formation; TOC and bromide. In evaluating these water quality variables and interpreting the results, it is important to recognize that:

- 1. TOC is a heterogeneous mixture, and is comprised of humic and fulvic acids and other naturally-occurring organic material which varies from source to source and from location to location within a source. Consequently, TOC from different regions of the Delta will not have an identical impact on DBP formation. In this effort, it was necessary to assume that TOC could be a unifying variable for organic DBP precursor material, even given the inherent variability in the material which comprises this parameter.
- 2. The extent to which bromide participates in DBP reactions is dependent upon its oxidation state as well as its relative concentration with other competing oxidants (e.g., chlorine). The following analysis is not stoichiometrically-based, but rather is empirical in nature based upon measured formation rates and other data available to the expert panel.
- 3. The formation of DBPs is dependent upon many other water quality parameters beyond TOC and bromide, alone. Some of these include temperature and pH. The expert panel focused on TOC and bromide because it was assumed that management alternatives for the Delta had the opportunity to affect these variables, and therefore their control will influence subsequent DBP formation through treatment processes.

In the following presentation, bromide concentrations are provided in $\mu g/L$. It is recognized that bromide is often related to chloride concentration, as both are present in salt water which can intrude into the Delta system. If chloride concentrations relevant to stated bromide concentrations are of interest, the following conversion (Krasner et.al. 1994) can be used:

Cl⁻ (mg/L) =
$$\frac{Br'(\mu g/L) + 4.96}{3.27}$$

4.2.1 Halogenated Organic By-Products

To assist in assessing the formation of DBPs from treated water from the Delta, a TTHM formation model developed for the Metropolitan Water District of Southern California was used (Malcolm Pirnie Inc., 1993). The model was developed from 648 data observations under bench-scale conditions using various blends of water diverted from the Delta. A chlorine-to-TOC dose ratio of 1:1 and free chlorine contact times of 60 and 120 minutes (to yield 1 and 2 log *Giardia* inactivation, respectively) were used in the analysis. A pH of 7.0, a temperature of 20° C and bromide concentration values of 50, 100, 150, 200 and 300 μ g/L were also used. These conditions were within the experimental boundaries of the model. A more detailed description of the model is provided in Appendix A. The predicted TTHM values are summarized in Table 4.1.

The TTHM values were compared to the data supplied by the CUWA members, those in the open literature, and with the experience of the expert panel. A summary of the data provided by the CUWA members is included in Appendix B. The available data and the expert panel's experience agreed well with values in Table 4.1.

HAAs are also formed under these reaction conditions. The Stage 1 and Stage 2 proposed TTHM MCLs of 80 and 40 μ g/L, and HAA5 MCLs of 60 and 30 μ g/L, respectively, yield a mass concentration TTHM-to-HAA5 ratio of 1:0.75. The DBP data supplied to the expert panel by the CUWA members indicate that the TTHM values exceed the HAA5 concentrations by greater than this ratio of 1:0.75 in 84% of the 160 cases where paired TTHM and HAA5 data were available. Other data from both research and full-scale applications in waters containing at least 50 μ g/L of bromide confirm these findings (Summers, et. al., 1996, Cheng, et. al., 1995, Shukairy, et.al., 1994). Thus, it was concluded that TTHMs are the DBP of regulatory concern for this evaluation of organic DBP precursor removal. It is important to note, however, that HAA5 represents only five of the nine HAA compounds and three of the four remaining are mixed bromo-chloro compounds which have been shown to have significant levels of formation in bromide containing waters (Cowman and Singer, 1996). If HAA6 or even HAA9 were to become regulated, then the controlling parameters and values could be affected. Further, for source water bromide levels

TABLE 4.1
PROJECTED THM FORMATION FROM TREATED WATER

	7	TTHM Formation (µg/L)		
Treated TOC (mg/L)	Bromide (μg/L)	1 hr. contact	2 hr. contact	
2.0	50	23	28	
	100	26	31	
	150	28	33	
	200	31	36	
	300	36	43	
2.25	50	26	31	
	100	29	34	
	150	31	38	
	200	34	41	
	300	40	48	
3.0	50	34	41	
	100	38	45	
	150	41	49	
	200	45	54	
	300	53	63	
3.25	50	37	44	
	100	40	48	
	150	44	53	
	200	48	57	
	300	57	68	
3.9	50	43	52	
	100	47	57	
	150	52	62	
	200	56	67	
	300	66	79	
4.55	50	49	59	
	100	54	65	
	150	59	71	
	200	64	77	
	300	76	90	
5.2	50	55	66	
	100	61	72	
	150	66	79	
	200	72	86	
	300	85	101	
5.4	50	57	68	
	100	62	75	
	150	68	82	
	200	75	89	
	300	87	104	
6.0	50	62	74	
	100	68	81	
	150	75	89	
	200	81	97	
···	300	95	114	

considerably lower than 50 μ g/L, it is recognized that HAA5 may control over TTHM (Cowman and Singer, 1996). These low bromide values were not considered relevant for this study.

A 20 percent safety factor on THM and HAA5 production was used in determining the source water conditions which would result in the target DBP concentrations following treatment. Thus a target TTHM concentration value of 64 μ g/L (80% of 80 μ g/L) was used for Stage 1 evaluations and 32 μ g/L (80% of 40 μ g/L) was used for Stage 2 evaluations.

4.2.2 Bromate Formation and Removal

Bromate Formation

The formation of bromate by ozone has come into focus only recently. The ultimate MCL for this compound is of critical importance to facilities which have bromide in their source water and are currently using, or anticipating the use of, ozone for drinking water treatment. Even small concentrations of bromide ($< 50~\mu g/L$) can result in measurable concentrations of bromate after ozonation. Therefore, the expert panel carefully evaluated available data from the CUWA members, other available literature, and ongoing research on bromate formation to evaluate potential source water constraints. Based upon these data, the expert panel arrived at initial conclusions regarding potential source water bromide concentrations which would be required to limit bromate formation within the potential regulatory scenarios in Chapter 2.

Unfortunately, bromate formation is strongly dependent upon the nature of the experimental system design (e.g., bench versus pilot or full-scale). In addition, bromate formation depends upon ozone dosage and residual, which is often specific for full-scale facilities, making the direct comparison of these data difficult. Therefore, a bromate model (Ozekin, 1994) was utilized to systematically evaluate the impact of ozone dose, bromide, TOC and pH on the formation of bromate and thereby supplement the available literature (Shukairy et.al., 1994), data supplied by the Alameda County Water District, Contra Costa Water District, Santa Clara Valley Water District, and Metropolitan Water District of Southern California, and the expert panel's experience. The model was developed from data from several source waters including water diverted from the Delta, including results from source waters containing bromide concentrations between 70 μ g/L and 440 μ g/L. A contact

time of 12 minutes was chosen and the concentrations of TOC, bromide, ozone dose and pH were varied over representative ranges as discussed in Chapter 3. At each pH, three ozone: TOC ratios were estimated to provide the following levels of inactivation; 1 log *Giardia*, 2 log *Giardia* and 1 log *Cryptosporidium*. The dose of ozone estimated for these inactivations decreases with decreasing pH as a higher ozone residual is maintained at the lower pHs. The results of the modeling supported the initial conclusions reached by the Panel based upon the available literature and review of the CUWA data. A more detailed description of the model is provided in Appendix A.

Figure 4.1 illustrates bromate formation as a function of source water bromide and ozonation pH. Relationships are shown for 1 and 2 log *Giardia* inactivation for both 5 and 10 μ g/L bromate standards, and 1 log *Cryptosporidium* inactivation for a 5 μ g/L bromate requirement.

Bromate Removal

Bromate removal after ozonation has been studied for the following technologies:

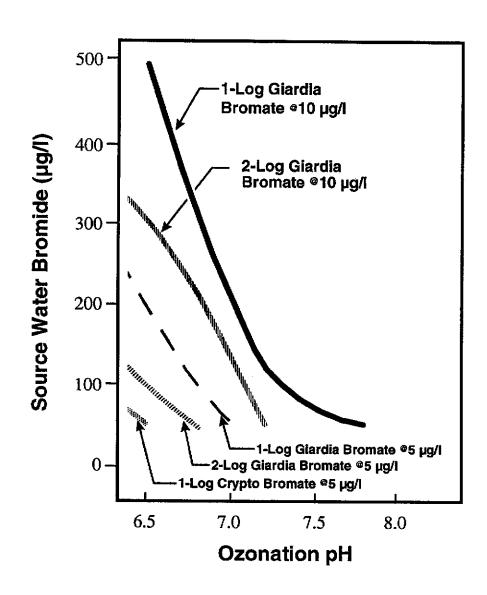
- Ferrous salt coagulation
- Reduction on a GAC surface
- UV Irradiation

It is important to recognize that research on bromate removal mechanisms is relatively new and has only been conducted for about the last five years. Consequently, the technologies presented below have been evaluated on a laboratory scale and published literature on full-scale applications is not available. It is premature to consider that these bromate removal technologies could be implemented reliably and cost-effectively on a full-scale basis.

Ferrous Salt Coagulation

Based on results of an AWWARF project conducted at the University of Colorado and currently in press, ferrous salts have been evaluated as a bromate removal technique with pre-ozonation. Up to 50 to 70 percent removal was reported though filterability problems (turbidity and particle breakthrough) were experienced. Ferric addition in conjunction with ferrous salts somewhat circumvented these filterability problems, though the issue has not yet been sufficiently evaluated. Bromate levels after ozonation ranging

Figure 4.1
Projected Bromide & Ozonation pH Requirements
to Meet Potential Regulatory Scenarios
for Microbial Inactivation and Bromate



<u>Notes</u>

- 1. Partially based on modeling equations of ozonation (Ozekin, 1994).
- 2. Approximate value only.

from 20 to 50 μ g/L were reduced to below 10 μ g/L. Consequently, it is not certain whether a 5 μ g/L limit could be met (this depends, in part, on levels exiting the ozone contactor).

Reduction on a GAC Surface

Bromate removal in a GAC contactor is expected to be a two step process in which the bromate is first adsorbed onto the GAC and subsequently is reduced to bromide. Almost complete bromate removal can be expected on a fresh GAC bed. The adsorption and chemical reduction, however, rapidly reaches a steady state with a reduction in removal percentage of bromate from the influent water. The time to reach a steady state varies as a function of empty bed contact time (EBCT). In general, the rapid breakthrough shown to date would result in very short reactivation frequencies that would be difficult to implement on full-scale.

Expected bromate removals are based upon rapid small-scale column test (RSSCT) experiments without biological activity. The effect of biological activity on bromate removal is not known. Additional research is being currently conducted to study these effects.

UV Irradiation

UV irradiation from medium pressure mercury lamps has been found to be effective in the removal of bromate. Limited bench top continuous flow experiments have been performed thus far (Siddiqui and Amy, 1994). A contact time of less than 10 minutes combined with at a UV dose of 600 mW-sec/cm² was found to reduce 50 to 100 μ g/L of bromate to less than 2 μ g/L. Although this technology has been effective on a bench scale, the cost-effectiveness and reliability of UV in large scale application has not been demonstrated or completely evaluated. This technology has not been applied for any purposes at drinking water facilities the size of those operated by the CUWA members.

4.3 SOURCE WATER QUALITY FOR REGULATORY SCENARIOS

In the following discussion, source water quality in terms of TOC and bromide is estimated based upon the implementation of specific treatment technology (defined in Chapter 3) and the potential regulatory outcome (described in Chapter 2). Source water concentrations of TOC were evaluated between 2 and 7 mg/L. The 7 mg/L value represents the 90th percentile for TOC concentrations diverted from the Delta. Bromide concentrations

were evaluated up to 300 μ g/L, as this was also considered a practical maximum in this evaluation. The data presented here are summarized in Section 4.5 both in tabular and graphical form.

4.3.1 Stage 1 D/DBP Rule and IESWTR

Enhanced Coagulation

For enhanced coagulation, source water TOC concentrations in the range of 3 to 7 mg/L and bromide concentrations of 50, 100, 150, 200 and 300 μ g/L were evaluated. As discussed in Chapter 3, an alum dose of 40 mg/L at a coagulation pH of 7.0, and possibly as low as 6.5, was projected to be required to meet the TOC removal requirements. These TOC removal requirements, which are a function of influent alkalinity and TOC concentrations, and the resulting effluent TOC concentrations are shown in Table 4.2.

TABLE 4.2

DETERMINATION OF TREATED WATER TOC
FOR ENHANCED COAGULATION

Influent TOC (mg/L)	Required Removal (%)	Treated TOC (mg/L)
3	25	2.25
4	25	3.0
5	35	3.25
6	35	3.9
7	35	4.55

To assess the TTHMs formed from the chlorination of effluents with this TOC range, the results in Table 4.1 can be utilized to draw the following projections:

1. For a 1 log Giardia inactivation using free chlorine for 60 minutes following enhanced coagulation, it was projected that the following water quality conditions would permit compliance with the stage 1 TTHM target of 64 μ g/L in the regulatory scenario:

Raw Water TOC Concentration, mg/L	Bromide Concentration, µg/L
<7	<150-200
<6	<200
<5	<300

2. For a 2 log *Giardia* inactivation using free chlorine for 120 minutes following enhanced coagulation, it was projected that the following water quality conditions would permit compliance with the stage 1 TTHM target of 64 μ g/L in the regulatory scenario:

Raw Water TOC Concentration, mg/L	Bromide Concentration, µg/L
<7	<50-100
<6	<150
<5	<200
<4	<300

For both of the above scenarios, certain combinations of raw water TOC and bromide concentrations that lie between the bounded concentration ranges are also projected to meet the target DBP values. For example, raw TOC concentrations between 6 and 5 mg/L and bromide concentrations between 200 and 300 μ g/L, are projected to meet the DBP target values under a 1 log *Giardia* inactivation.

Ozone Disinfection

Bromate formation is the limiting DBP (as opposed to TTHM and HAA5) for the ozone treatment and disinfection strategy specified in this evaluation. It is the opinion of the expert panel that the controlling source water quality parameter for the formation of bromate, in the context of this evaluation, is bromide. It is recognized that higher concentrations of TOC will result in higher ozone dosages to achieve a given CT, and, as a result, may increase the concentration of bromate formed depending upon ozone residual, bromide concentration and potentially other parameters such as contactor design. Higher ozone dosages as a result of higher TOC also result in increased capital and operational costs for ozone treatment. Further, TOC can also be limiting to the extent that the biodegradable material, formed by the reaction between ozone and naturally-occurring organic matter (NOM), is not completely controlled through biofiltration, thereby creating an undesirable regrowth potential in the distribution system. The extent to which regrowth will be a problem is a function of the distribution system design, as well as disinfectant residuals maintained and other water quality parameters which are agency-specific. Nevertheless, sufficient data were not available to isolate the impact of TOC on bromate formation, in the absence of variation in bromide, pH and other water quality factors.

Based upon the data supplied by the CUWA members and other bromate formation studies and the model results, the expert panel concluded:

- 1. A bromate standard of 10 μ g/L is restrictive at ambient pH values. At pH 7.8 (ambient for some pre-ozonated waters) it is projected that a bromide level of 50 μ g/L or less would be needed to meet a bromate standard of 10 μ g/L for 1 log Giardia inactivation. This bromate standard could not be met for ozone dosages providing 2 log Giardia inactivation at ambient pH.
- 2. Lowering the pH of ozonation is an effective means of reducing bromate formation. If the ozonation pH were lowered to 6.5, then a 10 μ g/L level of bromate may be achievable with:
 - 1 log Giardia inactivation in the bromide range of less than 500 μ g/L.
 - 2 log Giardia inactivation in the bromide range of less than 300 μ g/L.
- 3. The potential for reliably meeting bromate standards using the bromate removal technologies currently being evaluated is unknown at this time. Although some technologies show promise, many have been demonstrated only on bench scale and the understanding of full-scale feasibility is limited. Consequently, the expert panel does not propose the use of bromate removal techniques as a well-understood and currently feasible and reliable method for increasing the allowable source water concentrations for bromide.
- 4. Limiting TOC concentrations were not estimated because of the limited availability and robustness of the data illustrating the impact of TOC on bromate formation, in the presence of bromide. It should be recognized, however, that higher TOC concentrations translate to higher ozone dosages to meet a given disinfection criterion and thereby can result in higher bromate formation. This is empirically validated in reviewing bromate formed during settled water ozonation as opposed to raw water ozonation. In general, when TOC concentrations are lower at a given facility, ozone dosages to achieve a given disinfection requirement are lower, and measured bromate concentrations are lower. Lower pH in settled water also helps reduce bromate concentrations.

The expert panel recognizes that there are variations in bromate production data and therefore looked for indications relating to threshold behavior. That is, evaluating source water bromide concentrations which result in a clear increase in bromate concentrations for a given set of ozonation conditions. Given some variation in the formation of bromate reported at lower source water bromide concentrations ($< 50 \mu g/L$), the expert panel took a position of plausible conservatism.

GAC and Membrane Treatment

It was the opinion of the expert panel that, given the relative flexibility that enhanced coagulation and ozone disinfection provided to meet the near-term regulatory scenario, CUWA members would not implement GAC or membrane treatment for this potential regulatory outcome. Consequently, source water quality limitations were not developed for these technologies in the near-term regulatory scenario.

4.3.2 Stage 2 D/DBP Rule and LT2SEWTR

Enhanced Coagulation

Using the same approach taken for the stage 1 D/DBP Rule and IESWTR, the following projections can be made for source water quality when using enhanced coagulation to achieve the potential long-term regulatory outcome:

- 1. For a 1 log Giardia inactivation using free chlorine for 60 minutes following enhanced coagulation, it was projected a raw water TOC concentration < 3.0 mg/L and a bromide concentration $< 150 \mu\text{g/L}$ would permit compliance with the Stage 2 TTHM target of 32 $\mu\text{g/L}$ in the regulatory scenario.
- 2. For a 2 log *Giardia* inactivation using free chlorine for 120 minutes following enhanced coagulation, it was projected that a raw water TOC concentration < 3.0 mg/L and a bromide concentration <50 μ g/L would permit compliance with the TTHM target concentration of 32 μ g/L in the regulatory scenario.

Ozone Disinfection

The estimates illustrated in Figure 4.1 were again used to evaluate potential source water limitations using ozone disinfection in the long-term regulatory scenario. The expert panel arrived at the following conclusions:

- 1. A bromate standard of 5 μ g/L is very restrictive at pH values above 7. At pH 7.8 (ambient for some pre-ozonated waters) it is projected that this standard will not be met for any of the potential microbial inactivation requirements.
- 2. If the ozonation pH were lowered to 6.5, then a 5 μ g/L level of bromate may be achievable with:
 - 1 log Giardia inactivation in the bromide range of less than 200 μ g/L.
 - 2 log Giardia inactivation in the bromide range of 100 to 150 μ g/L.

- 1 log Cryptosporidium inactivation with a bromide concentration of less than $50 \mu g/L$.
- 3. The potential for reliably meeting bromate standard using the bromate removal technologies currently being evaluated is unknown at this time. Although some technologies show promise, many have been demonstrated only on bench scale and the understanding of full-scale feasibility is limited. Consequently, the expert panel did not propose the use of bromate removal techniques as a well-understood and currently feasible and reliable method for increasing the allowable source water concentrations for bromide.
- 4. Limiting TOC concentrations were not estimated because of the limited availability and robustness of the data illustrating the impact of TOC on bromate formation, in the presence of bromide. It should be recognized, however, that higher TOC concentrations translate to higher ozone dosages to meet a given disinfection criterion and thereby can result in higher bromate formation. This is empirically validated in reviewing bromate formed during settled water ozonation as opposed to raw water ozonation. In general, when TOC concentrations are lower at a given facility, ozone dosages to achieve a given disinfection requirement are lower, and measured bromate concentrations are lower. Lower pH in settled water also helps reduce bromate concentrations.

GAC Treatment

In assessing the use of GAC to meet the Stage 2 TTHM target of 32 μ g/L, several constraints were used. The values in Table 4.1 suggest that the treated water TOC concentration must be below about 2.5 mg/L to approach this TTHM target within the range of bromide concentrations evaluated. To achieve this level of TOC in the finished water then the GAC influent TOC must be below 5.0 mg/L at a breakthrough (C/C₀) of 0.5, (see Table 3.2). As shown in Table 4.3, an EBCT of 20 minutes or greater is needed to achieve this effluent concentration while maintaining run times greater than 60 days (Summers et al., 1994, Hooper et al., 1996).

TABLE 4.3
ESTIMATED TIME TO 50 PERCENT BREAKTHROUGH
AT DIFFERENT GAC EMPTY BED CONTACT TIMES

Influent	Effluent	Time to 5	0% Breakthroug	th (days)
TOC	TOC	EBCT (min) 15	EBCT (min) 20	EBCT (min) 30
3	1.5	62	83	124
4	2.0	47	68	93
5	2.5	38	50	75
6	3.0	32	42	63
7	3.5	27	36	54

The assumption of 10 to 15 percent TOC removal by the coagulation process prior to GAC yields a maximum raw water TOC of 5 mg/L for the GAC use scenario.

Using the results in Table 4.1 the following projections can be made based on the above analysis:

- 1. For a 1 log Giardia inactivation using free chlorine for 60 minutes following conventional coagulation and GAC, it was projected that a raw water TOC concentration of < 5 mg/L and a bromide concentration of < 150 μ g/L would permit compliance with the Stage 2 TTHM target of 32 μ g/L in the regulatory scenario.
- 2. For a 2 log *Giardia* inactivation using free chlorine for 120 minutes following coagulation and GAC, it was projected that a raw water TOC concentration of < 5 mg/L and a bromide concentration of <50 μ g/L would permit compliance with the stage 2 TTHM target of 32 μ g/L in the regulatory scenario.

Higher GAC influent TOC concentrations can be used with breakthroughs (C/C_0) lower than 0.5 to achieve effluent TOCs lower than 2.5 mg/L. For example an influent TOC of 6 mg/L and a C/C_0 of 0.4 yields a GAC effluent of 2.4 mg/L. The run times are below 60 days, however, even at an EBCT of 30 minutes. The run time at a C/C_0 of 0.4 is about 20 percent shorter than that at 0.5 (Summers and Hooper, 1997 unpublished data).

As discussed in Section 3.2.3, ozone can be used in combination with GAC to enhance disinfection and provide a good medium to remove biodegradable organic carbon (BDOC) formed by the application of ozone. Because of the particular constituents of concern in this evaluation, it was assumed that ozone and GAC operate somewhat

independently for microbial inactivation and removal of water quality contaminants. This particular treatment scenario allows GAC to be used when *Cryptosporidium* inactivation is required.

For GAC in combination with ozone, source water TOC can increase up to at least 7 mg/L (the 90th percentile for water diverted from the south Delta). Bromide concentrations using

ozone at a pH of 6.5 are limited to <200, 100 to <150, and <50 μ g/L for 1 log *Giardia*, 2 log *Giardia*, and 1 log *Cryptosporidium* inactivations, respectively.

The source water for this combined treatment is limited by the ozonation process for bromide. For TOC values approaching 7 mg/L there is a concern that the TTHMs formed in the five minutes of contact with free chlorine will exceed the Stage 2 target. However, there are few TTHM formation data available at contact times as short as this. In addition there is concern that the GAC will be able to adequately control BDOC. High levels of ozonation by-products in the distribution system can lead to microbial regrowth, although currently these compounds are not regulated.

Membrane Treatment

As discussed in Chapter 3, two types of membrane treatment can be considered; membrane filtration and membrane softening. Because both of these processes represent "absolute barriers" to *Giardia* and *Cryptosporidium*, the source water quality does not vary based upon the extent of protozoan removal required. Based upon this understanding, the following projections were made:

1. For microfiltration, ozone, and chloramine treatment, it was assumed that ozone would be required to provide 3 log virus inactivation. This corresponds to CT values which are similar to 1.5 log *Giardia* inactivation. To provide the greatest degree of flexibility for source water bromide concentrations, it was assumed that ozonation would be conducted at pH 6.5. Referring to Figure 4.1, this results in a limiting source water bromide concentration of < 150 µg/L. A specific limit for source water TOC was not estimated for this treatment scheme. For TOC values approaching 7 mg/L (the 90th percentile for water diverted from the south Delta) there is a concern that biological filtration will be able to adequately control BDOC. High levels of ozonation by-products in the distribution system can lead to microbial regrowth, although currently these compounds are not regulated.

- 2. For ultrafiltration, ozone, and chloramine treatment, it was assumed that ozone would be required to provide 2 log virus inactivation. This corresponds to CT values which are similar to 0.5 log *Giardia* inactivation. To provide the greatest degree of flexibility for source water bromide concentrations, it was assumed that ozonation would be conducted at pH 6.5. This results in a limiting source water bromide concentration of < 300 μg/L. A specific limit for source water TOC was not estimated for this treatment scheme. For TOC values approaching 7 mg/L (the 90th percentile for water diverted from the south Delta) there is a concern that biological filtration will be able to adequately control BDOC. High levels of ozonation byproducts in the distribution system can lead to microbial regrowth, although currently these compounds are not regulated.
- 3. For the application of nanofiltration followed by free chlorine addition for distribution system residual maintenance, TOC is limited by the extent to which TTHMs are formed in the distribution system. Under these conditions, the treated water TOC should be below 1 mg/L and the bromide level below 0.15 mg/L, as predicted by uniform formation conditions (Summers et. al., 1996). Assuming a 90 percent TOC removal and a 50 percent bromide removal by nanofiltration, a source water TOC of up to 10 mg/L is estimated at all source water bromide levels examined ($< 300 \, \mu g/L$).

4.4 IMPACT OF OTHER POTENTIAL REGULATORY OUTCOMES

4.4.1 Introduction

This section describes the impact of other potential regulatory outcomes on treatment requirements and/or allowable source water quality. It was not possible for the expert panel to evaluate all of the potential scenarios and the most plausible were discussed in Chapter 2. This section discusses broad trends based upon regulatory outcomes that were conceived during the regulatory negotiations, as affected by recent developments.

4.4.2 Lower MCLs and/or Maximum MCLs for Halogenated Organic Compounds

Plausibility: The current placeholder values could possibly go lower based on new health effects research. First, THM and HAA levels might be lowered. EPA has been conducting research on reproductive effects that may be associated with various THM and HAA species. Given the intense concern expressed during reg-neg over the New Jersey epidemiology studies and the potential associations with neural tube defects, lower MCLs

than the 40 μ g/L and 30 μ g/L would be plausible. In addition, a recently released study based in California developed an association between TTHM, individual THM compounds, and spontaneous abortion. Because this is considered an acute affect, this increases emphasis for considering a maximum value for DBPs, rather than a running annual average. Second, the current bromate MCL is based on what was considered to be the Practical Quantitation Level (PQL). Much effort is being focused on improving the method which could lead to a lower MCL, especially given the toxicology which suggests the high carcinogenic potency of bromate. Third, HAA regulatory levels are currently based on five species. There are, however, four other species that can form in the presence of bromide. Such compounds could dramatically increase the total HAA. Due to the apparently greater potency, it is possible that the MCL for total HAAs may decrease, though they may increase.

Impacts: Lower MCLs, or maximum rather than running annual average values, for THM or HAA will require either TOC or bromide to be reduced. A lower bromate PQL would require lower ozonation pH, depending on the actual level. But a very low level (e.g., less than 1 μ g/L) could make use of ozone prohibitive.

4.4.3 MCLs For Individual DBP Species

Plausibility: A wide variation in relative potency of individual species within a given class has been observed. For example, bromodichloromethane is much more potent than chloroform, and has been associated with spontaneous abortion in a California based study. Its metabolism is more rapid leading to higher tissue concentrations, it has a greater capacity for binding proteins and lipids and the mutagenic response is much greater. These types of observations, particularly associated with bromine substitution in the place of chlorine-intensifying toxicity, lends credence to regulating individual species rather than broad chemical classes. Further, EPA recently proposed increasing the MCLG for chloroform from zero to $300 \,\mu g/L$, thereby recognizing threshold behavior for carcinogens. These differences provide emphasis to regulating individual DBPs.

Implications: Low MCLs for species such as bromodichloromethane could preclude the use of chlorine for primary disinfection in waters containing measurable amounts of bromide. Membrane filtration, which requires some inactivation of virus, would require an alternative disinfectant to chlorine (e.g., ozone). Enhanced coagulation would be of marginal benefit. GAC would still be relevant though it would need to be evaluated in light of the proposed levels.

4.4.4 DBPs Other Than THMs and HAAs Are Regulated

Plausibility: While there are a variety of DBPs, resources for health effects research are currently directed on the brominated analogues of the haloacids and trihalomethanes, not new compounds. Regulations for DBPs such as chloral hydrate, chloropicrin, haloketones or halocetonitriles are not anticipated.

Implications: It is not possible to evaluate the impacts of what appear to be less plausible regulatory outcomes, based upon the likelihood of health effects data supporting such regulation. In general, the more DBPs that are regulated, the greater the constraints on treatment technology and source water quality.

4.4.5 Regulating for a Minimum Total Risk; the "Risk Bubble"

Plausibility: Each technology results in a different mixture of DBPs in terms of relative concentrations. An individual MCL approach does not recognize this and does not allow for DBP - DBP tradeoffs. For example, chlorine will produce greater concentration of chlorinated, brominated and mixed bromo-chloro organics than ozone. Ozone, however, will produce more bromate and oxygenated compounds (e.g., aldehydes, ketones, carboxylic acids). In order to determine the lowest risk associated with the treatment options, it has been argued that a more comprehensive approach is needed, one that considers the wide array of by-products produced, not simply focused on THMs or HAAs. To this end, various approaches have been proposed and have recently been re-discussed in the stakeholder meetings. It has also emerged as part of the comparative risk framework currently being considered by EPA.

Implications: A mixtures approach may allow for greater flexibility in technology choice.

4.4.6 Implication of a Reproductive Endpoint

Plausibility: As there are some indications that reproductive health effects are associated with certain DBPs and that the exposures of interest (e.g., spontaneous abortion) are short-term rather than long-term (i.e., cancer). The current practice of running annual averages of quarterly samples for calculating compliance may not be appropriate. More frequent monitoring and enforcing of maximum levels could be required. Individual MCLs may also be prompted.

Implication: Going from running averages to maximum acute levels may decrease the range and variability of source water quality permissible. This would provide greater restrictions on the ability of all unit processes to meet water quality requirements and would lower the allowable TOC and bromide concentrations, and the allowable variability, depending upon the maximum values established.

4.4.7 Summary of Alternative Regulatory Scenarios

As with the wide array of issues being addressed as part of the overall Delta process, there is no single 'best' solution in formulation of future drinking water regulations — there are a variety of trade-offs which need to be considered. It will be important that CUWA continue to keep these issues before the negotiated rulemaking committee.

4.5 SUMMARY

4.5.1 Summary of Source Water Quality Constraints

Table 4.4 summarizes projected source water quality requirements for TOC and bromide, depending upon the technology applied. In reviewing the values presented in this table, it is evident that there are various water quality constraints for TOC and bromide depending upon the technology used, the DBP concentrations allowed, and the level of microbiological inactivation required. As stated previously, which technology is implemented is agency-specific, and is dependent upon a host of constraints related to cost, permitting issues and residual disposal.

TABLE 4.4
SUMMARY OF SOURCE WATER QUALITY CONSTRAINTS (1)

······			MICROI	BIAL INACT	TVATION RE	QUIRED	
TREATMEN	r scenario/	1 Log	Giardia	2 Log	Giardia	1 Log Crypt	osporidium
	N STRATEGY	Inacti	vation	Inact	ivation	Inactiva	tion (2)
DISINIECTIO	A BIRGILLOI	TOC	Bromide	TOC	Bromide	TOC	Bromide
		(mg/L)	(μg/ L)	(mg/L)	(μg/ L)	(mg/L)	$(\mu g/L)$
	P		ar-Term Reg	ulatory Sce	nario		
Enhanced coagul	ation with free	<7	<150-200	<7	<50-100	- Whit	
chlorine/chloram	ines	<6	<200	<6	<150		
Спотщеленоган	шса	J.E	<300	<5	<200		
		<5	<300	<4	<300		
Ozonation with	at pH 7.8	N/E ⁽³⁾	<50	N/E ⁽³⁾	N/A ⁽⁴⁾		
Chloramines	at pH 6.5	N/E ⁽³⁾	<500	N/E ⁽³⁾	<300		
	P	otential Lo	ng-Term Reg	ulatory Sce	nario		
Enhanced coagul	ation with free	<3.0	<150	<3.0	<50	N/A ⁽⁵⁾	N/A ⁽⁵⁾
chlorine/chloram	ines						
Ozonation with	at pH 7.8	N/E ⁽³⁾	N/A ⁽⁴⁾	N/E ⁽³⁾	N/A ⁽⁴⁾	N/E ⁽³⁾	N/A ⁽⁴⁾
chloramines	at pH 6.5	N/E ⁽³⁾	<200	N/E ⁽³⁾	<100 to 150	N/E ⁽³⁾	<50
Granular Activat	ed Carbon (GAC)	<্	<150	<5	<50	N/A ⁽⁵⁾	N/A ⁽⁵⁾
GAC With Ozon		N/E (3)	<200	N/E ⁽³⁾	<100-150	N/E ⁽³⁾	<50
Membrane	MF with Ozone	N/E ⁽³⁾	<150	N/E ⁽³⁾	<150	N/E ⁽³⁾	<150
Treatment	UF with Ozone	N/E ⁽³⁾	<300	N/E ⁽³⁾	<300	N/E ⁽³⁾	<300
	Nanofiltration	<10 mg/L	<300	<10 mg/L	<300		<300
						<10 mg/L	

Notes:

- Source water quality constraints are based upon achieving: 80 μg/L of TTHM, 60 μg/L of HAA5, and 10 μg/L of bromate for Stage 1 and 40 μg/L of TTHM, 30 μg/L of HAA5, and 5 μg/L of bromate for Stage 2, using the treatment and disinfection conditions presented in Chapter 3.
- 2. 1 log Cryptosporidium inactivation is not a part of the potential near-term regulatory scenario.
- 3. N/E = Not estimated. Limiting TOC concentrations were not estimated because of the availability and robustness of the data illustrating the impact of TOC on bromate formation, in the presence of bromide. It should be recognized, however, that higher TOC concentrations translate to higher ozone dosages to meet a given disinfection criterion and thereby can result in higher bromate formation. It is important to note that when ozone disinfection is used for treatment, the allowable TOC is not unlimited. There are concerns regarding the ability of biological filters or GAC to remove BDOC to adequate levels as TOC approaches 7 mg/L (the 90th percentile for water diverted from the Delta). In general, ozone disinfection is more effective and reliable as TOC decreases.
- 4. N/A = Not achievable. Bromide concentrations would have to be considerably less than 50 μ g/L to achieve a bromate concentration of 5 or 10 μ g/L. Data to determine the necessary bromide concentration relevant to this study were not available.
- 5. N/A = Not achievable. At this time, it is considered that free chlorine can not inactivate Cryptosporidium at dosages practical in water treatment.

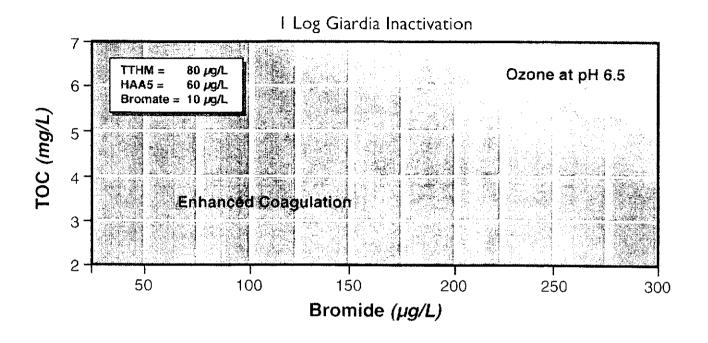
4.5.2 Summary of Compliance Choices

Instead of presenting the data in a table which summarizes the allowable TOC and bromide concentrations as a function of different treatment processes for a given regulatory scenario, it is often helpful to graphically illustrate the technology that can be implemented, as a function of source water TOC and bromide, for a given regulatory scenario. That is, illustrate the area in which a given technology will allow compliance with a regulatory outcome, using a two-dimensional graphic illustrating bromide on the X-axis and TOC on the Y-axis. Therefore, the applicability of technologies in a given regulatory scenario as TOC or bromide increase can be visualized. A comparison of relationships for different regulatory scenarios illustrates how this "compliance forecast" changes when regulations change. It is important to note that the boundaries between technologies are not hard lines, but rather "transitional" regions. The absolute water quality boundaries which trigger the need for a different technology are extremely utility specific, and also are variable within a utility, itself, as criteria which effect technology selection other than water quality change.

Figure 4.2 illustrates the compliance forecast for the Stage 1 D/DBP Rule and IESWTR, for 1 and 2 log inactivations of Giardia. This figure illustrates that enhanced coagulation and ozone treatment can be used to meet the requirements up to TOC and bromide concentrations of 7 mg/L and 300 μ g/L, respectively. In this figure, the colored area represents the region in which it is feasible to use the associated technology for combinations of TOC and bromide. For example, the yellow area describes the region in which ozone at pH 6.5 would be used for specific combinations of TOC and bromide, as opposed to enhanced coagulation. The gradual transition, and region of uncertainty, for combinations of TOC and bromide which require different technologies are also illustrated. The regulatory allowance to provide prechlorination with enhanced coagulation, which increases DBP production, has the impact of reducing the feasible region for enhanced coagulation. Which technology is selected in this transition zone is highly utility specific.

Figure 4.3 illustrates the compliance forecast for the potential Stage 2 D/DBP Rule and LT2ESWTR, for inactivations of 1 log *Giardia*, 2 log *Giardia*, and 1 log *Cryptosporidium*. In this figure, regions of technology application for enhanced coagulation, GAC, ozone and membranes (recall that the maximum bromide concentration for

Figure 4.2
Compliance Forecast for Stage | D/DBP Rule



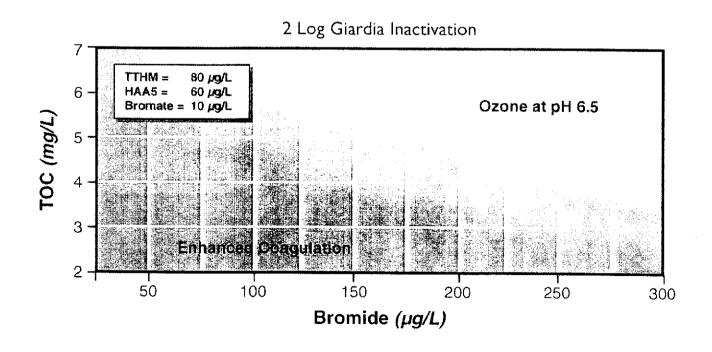
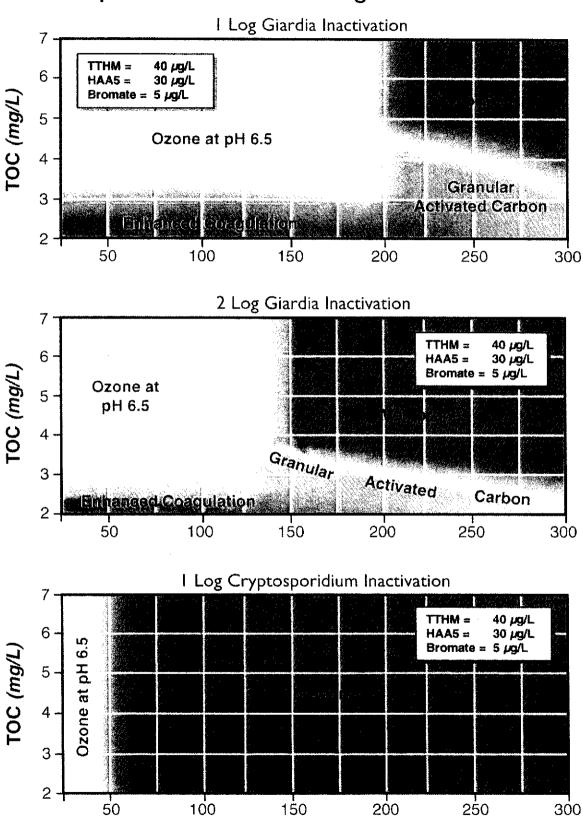


Figure 4.3
Compliance Forecast for Stage 2 D/DBP Rule



Bromide (µg/L)

microfiltration coupled with ozone is 150 μ g/L) are illustrated. Individual systems may determine that other water quality benefits merit the use of more expensive technologies for certain water quality regions that are shown with less expensive technologies (e.g., ozone as opposed to enhanced coagulation; membranes as opposed to GAC). The figure was prepared to show "least cost" technology application, based upon the range of conceptual costs presented in Section 3.3. It is important to note that the region of feasibility for membranes in Figure 4.3 does not differentiate among MF/UF or NF/RO membranes. In general, only MF is somewhat limited for bromide when using ozone for virus inactivation. Table 4.4 summarizes these source water bromide limitations for MF.

It is evident that as the level of microbial inactivation increases, the technologies which may be used to meet the applicable regulation decreases. Of particular interest is that for a Stage 2 D/DBP Rule and LT2ESWTR which requires 1 log inactivation of Cryptosporidium, membrane technology plays a significant role in compliance choices.

As stated in Chapter 3, it is recognized that the above source water quality constraints are based upon the design criteria proposed, such as ozone:TOC dose ratios, ozone contact time, and single, multi-chamber contactor configuration. Other facility configurations, such as two-stage ozonation (e.g., ozone added at raw and settled water) and longer ozone contact times may yield different, and possibly more liberal, source water quality constraints. The source water quality constraints presented here are based upon typical ozone system designs throughout the country.

4.5.3 Concluding Remarks

The expert panel is aware of the significance of bromate in establishing limiting bromide levels in this evaluation. There are many factors that contribute to the uncertainty surrounding the projected numbers, including relatively few studies which have evaluated bromate formation in low bromide waters ($< 50 \ \mu g/L$), variations in treatment conditions which may reduce bromate formation (e.g., using both pre- and post-ozonation to reduce ozone dosages at any single location), and potentially lower CT values for ozone. It is the selected level of 5 μ g/L in the long-term regulatory scenario, however, that most keenly influences the analysis. The rationale for this level (i.e., advances in detection limit, the weight of the carcinogenic evidence, the precedence for THM and HAA5 limits in Stage 2

at half the Stage 1 levels) in this analysis may be modified by a variety of factors including:

- A bromate versus brominated organic compound trade-off (i.e., addressing the difference between DBPs formed with ozone versus those formed with chlorine).
- Evidence of a cancer threshold for bromate (investigations underway).

On the other hand, there are other potential regulatory outcomes involving 1) further lowering the MCLs for DBPs, 2) the regulation of individual DBP species (rather than the groups of compounds represented by TTHM and HAA5 due to the potentially more severe health effects associated with brominated compounds), 3) regulating other DBPs beyond TTHMs and HAA5, including the addition of other HAAs (there are nine total) as analytical methods are developed and refined, 4) a comparative risk framework which balances all of the risk attributable to the DBPs formed, rather than providing specific MCLs for each group, and 5) concerns over reproductive and developmental effects that may be associated with DBPs, which may lower the regulatory levels and/or the permissible maximum concentration (i.e., annual averaging may no longer be the basis for determining compliance).

Given this understanding, if flexibility were provided to all agencies to implement either enhanced coagulation or ozone to meet the potential long-term regulatory scenario, then it is projected that a TOC of < 3.0 mg/L and a bromide of < 50 μ g/L in water diverted from the Delta would be necessary. The TOC value is constrained by the formation of total trihalomethanes when using enhanced coagulation for TOC removal and free chlorine to inactivate *Giardia*. The bromide value is constrained by the formation of bromate when using ozone to inactivate *Cryptosporidium*. Looking only at the potential near-term regulatory scenario provides significantly more flexibility, with source water TOC concentrations ranging between 4 and 7 mg/L (the 90th percentile value in water diverted from the Delta) and bromide ranging between 50-100 and 300 μ g/L, depending upon the extent of *Giardia* inactivation required (the near-term scenario does not include *Cryptosporidium* inactivation).

Similarly, the use of either GAC or membrane treatment in the long-term regulatory scenario broadens the allowable source water quality. For GAC, a source water TOC value

of 5 mg/L is acceptable with bromide ranging between 50 and 150 μ g/L, depending upon Giardia inactivation.

If Cryptosporidium inactivation is required, however, ozone must be coupled with GAC. This allows the source water TOC concentration to increase to at least 7 mg/L (the 90th percentile value for waters diverted from the Delta), although bromide is constrained to $< 50 \mu g/L$ even at an ozone pH of 6.5.

The use of microfiltration or ultrafiltration, coupled with ozone for primary disinfection and chloramines for secondary disinfection, is an "absolute barrier" for protozoan (Giardia and Cryptosporidium) removal. Viruses, however, must still be inactivated. This treatment scheme allows source water TOC concentrations to increase to at least 7 mg/L. The bromide concentration is again limited by bromate formation under ozone addition for virus inactivation, and is < 150 μ g/L microfiltration and < 300 μ g/L for ultrafiltration (less virus inactivation is required for ultrafiltration). If nanofiltration is used with free chlorination, source water quality can range up to 10 mg/L for TOC for all bromide concentrations evaluated (< 300 μ g/L).

It is important to note that when ozone disinfection is used for treatment, the allowable TOC is not unlimited. There are concerns regarding the ability of biological filters or GAC to remove BDOC to adequate levels as TOC approaches 7 mg/L (the 90th percentile for water diverted from the Delta). In general, ozone disinfection is more effective and reliable as TOC decreases.

Finally, the feasibility of implementing either GAC or membranes in California, given cost considerations, environmental permitting constraints, and limited residual disposal options, is uncertain.

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APPENDIX A PREDICTIVE MODELS FOR DISINFECTION BY-PRODUCTS

A.1 THM PREDICTIVE EQUATIONS

Malcolm Pirnie, Inc. (1993) undertook a study on the formation of DBPs in chlorinated waters over a wide range of TOC and bromide concentrations for the Metropolitan Water District of Southern California. A 5 by 5 matrix of discrete samples containing incremental increases in TOC and bromide concentrations were prepared and evaluated. For this study, water was synthesized using low-TOC, low bromide Sacramento River water and high-TOC agricultural drainage water. High-bromide concentrations were achieved by adding sodium bromide.

The database used in this study, consisting of more than 900 observations, was constructed based upon the results of the source water quality monitoring program and the chlorination experiments from the 5 by 5 matrix. One portion of the database represented THM formation in jar-treated waters and another portion represented THM formation in 0.45 μm membrane filtered raw water.

Three sets of THM predictive equations were developed during this study using a non-linear power function format including total organic carbon (TOC), ultraviolet absorbance at 254 nm (UV-254), chlorine dose, bromide concentration, reaction time, temperature and pH as independent variables. The final TTHM predictive equation was based upon a portion of the database representing THM formation in 0.45 μ m membrane filtered raw water (approximately 650 observations). Predictive capabilities of this equation were compared with THM formation in the jar-treated water (approximately 250 observations). The final TTHM equation developed was:

 $[r^2 = 0.96, F = 2010, p < 0.001]$

This equation was developed at TOC concentrations ranging between 1.1 and 7.6 mg/L, bromide between 10 and 800 μ g/L, contact times between 1 and 48 hours, and chlorine doses between 1.0 and 16.4 mg/L. The values for UV-254 to be input into the TTHM equation were predicted using a relationship between TOC and UV-254 developed in the study as follows:

$$UV-254 = -0.0224 + (0.0374)(TOC)$$
$$(r^2 = 0.92)$$

Using free chlorine as a disinfectant, a chlorine-to-TOC ratio of 1:1 and contact times of 1 and 2 hours were projected to yield 1 and 2 log *Giardia* inactivation, respectively. A temperature of 20 ° C and pH of 7 was also input to this equation to yield the values in Table 4.1 in the body of this report.

A.2 BROMATE PREDICTIVE EQUATION

The bromate model of Ozekin and Amy (Ozekin, 1994) was utilized to systematically evaluate the impact of ozone dose, bromide, DOC and pH on the formation of bromate. The model was developed from data from several source waters including waters diverted from the Delta. Source water bromide concentrations ranged between 70 and 440 μ g/L with bromate concentrations ranging between 2 and 314 μ g/L.

The model used has the following form:

$$BrO_3 = 1.63x10^{-6} DOC^{-1.26} pH^{5.82} (O_3 dose)^{1.57} Br^{0.73} time^{0.28}$$

A contact time of 12 minutes was chosen and the concentrations of DOC, bromide, ozone dose and pH were varied over a representative range as input to the above equation. Temperature was held constant at 20 ° C.

It is important to note that the model was only used to support conclusions reached by the expert panel prior to using the model. The bromate model was evaluated to investigate threshold behavior regarding formation at specific levels and to support the initial conclusions reached by the expert panel. The results of the modeling should not be overemphasized. The results of the modeling supported the initial conclusions reached by the Panel based upon the available literature and review of the CUWA data.

APPENDIX B

CUWA MEMBER TREATMENT DATA

Data was provided by the CUWA members, including those resulting from the operation of their treatment facilities as well as bench and pilot studies. There are variations in these data which are unique to each treatment system. For example, some systems supplied data representing ozonation of only raw water, while others supplied data with both pre- and post-ozonation. The expert panel recognizes that there are unique aspects of process operation which can affect the ultimate formation of DBPs. For this study, however, the expert panel defined "unifying criteria" in Chapter 3 for enhanced coagulation and ozone which allow a comparison of these processes and a systematic method by which to evaluate the impact of water quality constraints on DBP formation. This appendix contains the data supplied by the CUWA members.

Lilty (D:					ACW	D		(ACVID,	CCWD, E	BMUD, N	IWD, SC	/WD)					
Study ID:								(Optimiza	ition Stud	y 9/95, et	E.)	<u> </u>					
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							<u></u>	16.2		66.4	 	-	 				
5/30/95 6/6/95		4.3	2.7			40.0		29.0		65.9			28.9			-	
5/13/95		3.6	1,8			42.0		14.1		67.3			40.2				
6/20/95		3.5	1.9			60.0		15.6		66.3			44.0		48.0	_ - -	
6/27/95		3.8	2.0			80.0	ļ	13.4	 -	76.7		 	49.6 45.2			\vdash	
7/4/95 7/11/95	<u> </u>	4.1	2.3			68.0	}	17,4 23.0	 	73.3	 	 	43.0				
7/18/95		3.8	1.9		-	50.0		19.5		73.5			45.9				
7/25/95			2.4			72.0		21.2		72.6			48.0				
6/1/95		4.1	2.2			65.0		13.3		78.3 75.2	 	ļ	49.8		 	 	-
8/8/95		3,5	1.9			60.0 60.0	1	11.5 11.4	[77.0	 	├	58.9	 	 	<u> </u>	├
8/15/95 8/22/95		3.1	2.0		 	55.0	 	10.6	 	75.6			58.9		L	L	
8/29/95						50.0		11.5		71.2							
9/5/95		3.4	2.0			81,0	<20	12.5	ļ	70.5		╄	61.1	 	37.0		44.0
9/12/95		4.1	3.3			42.0 50.0	12.0	2.3	-	68.9	-	1	86.9 85.9		58.0	-	65.0
9/19/95	-	4.0	2.8	ļ	-	53.D	10.0	8.3	 	67.9	 	+	1 22.5	<u> </u>	10.0		
10/3/95		4,1	2.8		_	49.0	17.0	5.0		64.1			55.4		43.0		49.0
10/10/95		4.3	3.0	L		44.0	<40	4.4	-	62.6		-	72.0	<u> </u>		 	<u> </u>
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10/24/95	 	3.8	2.5			45.0	12.0	6.5	 	61.7		 	58.6	-	35.0		40.0
11/7/95		3.8	2.6	0.19	0.07	47.0	13.0	5.3		59,9			72.1				
11/14/95		4,3	3.1	0.18		39.0	12.0					ļ			46.0		52.0
11/21/95	<u> </u>	3.4	3.3	0.19	0,1D 0,1D	42.0 96.0	16.0	 	-	 -	+	 	55.5	 	23.0	-	28.0
11/28/95 12/5/95	 	4.4	3.4	0.14	0.09	50.0	141,0	1.6	 -	58.5	 	1	73.1		2-7,-4	<u> </u>	† <u> </u>
12/12/95	<u> </u>	4.6	4.0	0.12	0.08	39.0	<20	2.2		58.0					56.0		62.0
12/19/95		4.7	3.7	0.14	0.10	38.0	<20	3.9 7.6	ļ	55.8 52.5	 	 	73.3	_	31.0	 	38.0
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2/13/96		5,5	3.6	0.17									76.1	<u> </u>		<u> </u>	
2/20/96		5.8	3.6	0.13	0.31						ļ	 	88.0	1-	_	 	
2/27/96 3/5/96		5.8 0.0	3.0	0.20	0.11		14.0	1	-		+	 	72.8 80.7	1-	54.0	-	57.0
3/5/95		5,6	3.1	0.22	0.09	 -	Q0	 	+	1	1.		<u> </u>				
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4/2/98 4/9/96		<u> </u>	 	0.20	0.08	 	 	1	1	+	1	+	94.7		31.0	 	1
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5/28/96		3.8	2.1	0.22			20.4					\perp	52.3		34.0	+	41.0
6/4/96		3.6	2.3	0.22	0.08	-	24.6 17.2	<u> </u>	+		1	+	70.4 80.1		38.0	 -	43.0
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2/14/95 2/21/95	 	5.7	5.4	3.4		-		150	 	160	140						71.0			61.0 40.0	 		29.70 24.30		0.05 D.05
2/28/95		5.6	5.4	2.7				158		160	144						56.0			42.0			10.50		0.03
3/7/95		5.6 6.1	5.4	3.7				122		120	138						410 500			61.0 34.0			17.10		0.05
3/21/95		5.6	5.1	1.1				102		96	120						80.0		<u> </u>	45.0		Ь	21.20		0.06
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4/18/95		5.6	5.3	1.2				106		112	128						1100			41.0			16.80		0.04
4/25/96		5.8	5.7	3.4				80		94	140						120.0			82.0			12.17		0.06
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10/24/95		3,9	3.7	23			-	94		104	102	<u> </u>					47.0		12.0	18.0 21.0	<u> </u>	<u> </u>	3.77 4.36		0.07
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12/19/95		4.6	3.7	2.3			0.07	137	-	141 90	160 BG			<u> </u>		<u> </u>	34.0 97.0		40	13.0 25.0	 		4.22 5.85	\vdash	0.08
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1/16/95		5.8	4.0 5.6	2.6 3.5		 	0.13		1	89	740 82	-	-		-	 	\$7.D	 	-	40.0	├	 	10.10	\vdash	9.08
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2/13/96 3/12/96		5.5	3.8 5.0	3.4			0.03		†	86	134	 	-		ļ		21.0		<20	10.0	t		31.20		0.08
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3/26/96 4/2/96		5.2 3.3	3.2	2.6		 	0.01		+	#B 59	74	 		 	1		41,0 94,0	1	₹ 0	13.0 37.0			14.00		0.05
49/96		3.4	3.7	22			0.09	58	┖.	62	96				<u> </u>					54,0	Ţ		5,90		0.08
4/16/96		4.0	37	2.4	ļ	=	0.10	62		68	102		—				110.0		11.0	30.0 54.0	 	 	5.70 7.00	 	0.07
4/23/96 4/30/96		3.7	4.1	1.0	 	+	0.09			76 54	100	1			L	ᆣ	120.0	<u> </u>	<10.0	60.0	1		17.50		9.06
5/7/98	i I	1.7	3.7	1.9	ļ		0.00	50		52	90		ľ				140.0		27.0	60.D			7.30	-	0.05
5/14/95 5/21/95		3.7	3.6	1,9	1	-	0.09	52	1	51 59	102	 	1				130.0	 	<20	46.0	 	 	5.90		0.07
5/28/96		3.8	3.0	1.7		╁-	0.09		_	54	105		L			<u> </u>	79.0		<1	28.0	1		21.70		6.08
6/4/96		3.5	3.4	1.6	ļ	Ε	0.08		Ε-	54	75 54					ļ	75.2 58.0		4	18.0 81.0		 	15.60 19.60		0.07 0.07
										56											1				
\$/11/96 6/16/96		3.4	3.7	1.5	-	 	0.08		1	73	82		1	 	1	Ì	58.6		13.6	32.0	L		39.00 19.70		0.07

Litility ID:				<u> </u>		-														 	 -		
1. Study ID:																							
				ļ																			
2. Source w					_		\vdash						-										
3, Source W																							
5. Owecrite	-		_		-	-	-	_		-				-									
(indicate w																							
							ļ	Ì						_	_	_							
6. Indicate						-	-			-	-	-		·	-	_		┝┈╌		-			
WATER QU	 				-		-	-				_	-		-			<u> </u>	TREATME	NT CONDI	TIONS		──
Data		рΚ		Ţe	mperatu	19		Bromut					District	ction By	-	15					ation Conc		
	Rine	Ozon.	FIIL	Raw	(deg. C) Ozos.	Fin.	Raw	Ozon.	FIR		TTHM (Up/L)		-	(µg/L)			HAAA (VIVL)		Ozone	Czone	Contact	Ozone	Ozone temp.
	o.s.					1,1,1				Raw	Ozon.	FIN.	Rese	Ozon.	FIR	Rew	Ozen.	Fill.	(eng/L)	[mg/L]	(min)	Ü	(deg. C)
1/3/95	7.7		7.0	4.6	 					 -		7,0	ļ			-		14	22	0.49		0.1	0.8
1/10/95	7.5		6.7	10.4								7.7							2.3	0.54		8.2	10.0
1/17/95			7.0	11.5	-	-				├		42	<u> </u>		-5-	_	_	5	1.7	0.44		8.0 8.5	11.5
1/31/95	7.0		6.9	11,5								4.4						5	2.0	0,37		9.6	11.6
2/7/95 2/14/95			6.6 6.9	10.2	ļ	-				 		4.B	-	 	5	 	 	-5-	3,5 4.8	0.83		8.4	12.3
2/21/95	7.9		7.1	10.0								4.						7	3.2	2.68		8.2	10.0
2/28/95 3/7/95	8.4		7.4	11.2	_			<u> </u>		 	····	51		 	<u> </u>	\vdash	-	-7-	3.6	0.66	 -	1.6	11.2 12.0
3/14/95	8,1		7.1	11.5		-		\sqsubseteq				3.6			3			8	3.7	0.74		7.7	11.5
3/21/95			7.1	11.2		-		 	6.0	-	 	3.6	 -	 	4	 		3	3.7	0.69		7.3	12.0
4/4/95	8.5		7.0	16.0			!		12.0			12.8						•	3.6	0.38		7.4	18.0
4/11/95 4/16/96			7.1	15.3	-		1	\vdash	8.0	 	<u> </u>	4.9		 	-5			3	3.5 4.7	0.73	 	7.5	15.3
4/25/96	8.4		7.1	15.5					8.0			0.0						2	3.8	0.62		7.4	15.5
5/2/95 5/9/95			7.2 6.9	15.7	-		 					5.4 13.3	 		├—			-	4.0	0.55 ti.60		7.2	16.7
5/16/95	7.6		6.6	16.5								8.4							3.9	0.77		7.5	16.5
5/23/95 5/30/95			6.6	18.0	-	 	├ ─				<u> </u>	5.t 5.0		├	 		├	-	4.2	0.83		7.6	18.0
6/6/95	6.0		6.2	19.D	<u> </u>				_			6.1							3.3	0.59		7,4	18.0
6/20/95		\vdash	6.5 6.6	19.1			-		6.0	_		5.0 4.7		!	3			 	3.0	0.60		7.7	19.2
6/27/95	7.8		6.6	24.B					8.0			6.1							3.3	0.81		7.3	24.9
7/4/95	7.2		6.3	22.7			┼		4.0			6.3	-	├	2		├		4.0	0.47		8.0	22.9 22.7
7/16/95	7,4		6.3	23.2					10.0	二		4.1							4.1	0.52		7,5	23.2
7/25/95 8/1/95	7.5		6.2	21.0 25.0	-	-	├	-	9.0			6.2		 	3	├			2.0	0.42		6.9	21.6 25.9
UA/95	7.7		6.5	24.5				<u> </u>	6.0			3.0		<u> </u>	.3				3.6	0.43		7.6	24.5
8/15/95 8/22/95	7.7	-	6.1 6.3	25.4	 	-	! 	-	7.0 10.0	\vdash	├	3.0	-		11		┝	1	22	0.52		7.4	25.4 24.4
6/29/95	7.6		6.8	22.0					10.0													7.6	22.0
9/5/95 9/12/95	7.3		6.0	19.4	 	 	┼─	45 8.0	11.0	┢		32.8		├─	10			14	4.1	1.20		7.7	21.5 19.4
9/19/95			7.0	21.1				21.0	14.0			13.8			4			8	8.5	0.65		8.1 7.7	21.1
9/36/95		-	6.0	17.8	 		_	4	23.0 5.0			6.1	-		4	_		. 5	2.7	1.00	-	7.0	17.8
10/10/RS	6,9		6.9	16.8				<5 £0	45			5.0	\sqsubseteq			ļ			2.6 2.8	0.78 0.58		7.7	10.6
10/17/95	7.4	Ė	6.0	17.1 16.7		<u>L</u>		45	₹5			L							2.0	9.77		7.6	16.7
10/31/95	7.5		6.9	15.4				45	<5 <5			3.7 6.2			3			•	2.5 3.0	0.67		7,5	18.6
11/14/95	77		6.8	15.0				45	٧						4			5	3.0	0,78		7.7	15.0
11/21/95			6.E 6.7	15.0 14.6	1	\vdash	ļ	14.0	4			3.0			4			5	2.9 3.5	0,81		7.8	15.0 14.6
12/12/95	7.7		7.0	14.5				<5							5			í	2.4	0.65		7.9	14.5
12/19/95			6.0	13.5 11.8	-	-	+	ক	ধ			6.2			2	 	_	3	23	0.50		7.9	13.5
1/2/96			6.9	12.6				<5	6.0			4.6							2.1	0.46		7.7	12.6
1/16/96	7.5 7.5	+	8.6 6.8	10.8		1	┼	4	40	\vdash	⊢	12.2	 	\vdash		+			3.6	9.45 0.50	 	7.1	11.2
1/23/96	7.6		6.4	10.2					5.0				Ĺ						3.7	0.79		8.1	10.2
2/6/96	7.T 7.B		6.3 7.0	10.8		匸	士		\vdash			32.9 5.8							3.5 3.1	0.84 0.54		8.2 8.5	11.6
2/13/96	7.8		7.Q	11.8				45	<u> </u>			6.2			-				2.5	0.50 0.86		8,1	11.6
3/12/96		ł. –	8.9 7.0	12.7		<u>L</u>		< 5	45			6.7			5			6	3.0	0.58		7.5	12.7
3/26/96 4/2/96	7,0	ļ	6.6	13.2			ļ	<5	- 6	-	-	5.4 0.6			3	-	H	4	3.4	0.61	1	7.6	15.3
4/9/96	8.2		6.0	16.3					15.0			2.9							4.0	0.79		7.5	16.3
4/16/96	7.8		7.0	16.3	ļ			8.0	9.0			2.0			2	\vdash		3	3.8	0.66	ļ	7.7	16.3 17.0
4/23/96	8.2		6.9	17.0	<u> </u>		<u> </u>	15.0	12.0			1.3			1			4	3.6	0.75			19.1
5/7/96 5/14/96	0.5		0.0	19.3 19.5		-		18.5	14.0		H	2.6 5.8	F	-	2	₩		3	3.0	0.54 0.90			19.3 19.8
5/21/98	8.3		7.6	17.7					22.0							<u> </u>			3.0	0.69			17.7
5/28/96 6/4/96	7.5		6.7	17.8 24.0	F	-	F	12.57	44.5	-	1	3.t 2.3	\vdash		2	 	-	3	2.7	0.51 0.54	-	 	17.8 24.0
6/11/98	7.6		6.5	22.6				e4.5	<4.5			2.4			1			2	2.5	0.31	†		22.6
6/18/90			7.0	21.4 20.7		-	ļ <u>.</u>		e4 5			2.6	ļ <u>.</u>	F		 		ļ	2.8	0.35 0.45	-		21.4
6/25/96	. 77	:	0	20.7		1		44.3	<4.5	:	٠.	10				•	• .	1	61	- 427 -	 		

Enh.Coag.Data

MANAGE TO S					100			VACUATE 2		10.00	AB 36					
Jtility ID:			 		ACV	VU.		(ACWD, C	JUWU, EL	MUD, M	VVD, SCV	WD)		ļ		
P44-15:		<u> </u>		1		FO -011-1	L	/A-#			<u> </u>					
. Study ID:		ļ	Enr	i. Coagu	auon (m	om EC stud	y data)	(Optimiza	tion Study	9/95, etc	<u>.)</u>					
	Ļ		ļ	<u>`</u>			<u> </u>	<u> </u>	L	<u> </u>	L					
. Source w	ater:				Riv	er	,	(River, lai	ke, ground	lwater, et	c.)					
				<u> </u>												
. Source w	ater ID:			So	uth Bay	Aqueduct		(State Pro	ject wate	r, blend o	f, etc.)					
		<u> </u>														
. Describe		udy:		Sench-			In this dat									
indicate wit	th an 'X')	<u>.</u>		Pilot-sc			after coag	ulation, fi	occulatio	n, sedim	entation,	and				
			×	Full-sc	Lie		filtration.									
							1									
. Indicate v	vith an 'X'	If data re	eported a	s "Filt."	are tro	m samples	collected a	fter sedin	nentation	only:			х			
			1				or aft	er sedime	ntation <u>s</u>	nd Altrat	on:		x			
VATER C	LIALITY	DATA	CON	/ENTIC	NAL		<u> </u>			Ī						
			1		T	 	 	 		 					 	
Date	Time		TOC		All	calinity	-	Hardn	ess.	1	Turbi	dity		pH	Temo	erature
7=00	1131118	 	(mg/L)			as CaCO3)	 	(mg/L as			(NT			n		g. C)
	 	Raw	Filt	FIIL	Raw	Filt.	To	<u> </u>		ium	Raw	Filt.	Raw	Filt	Raw	Filt.
			 	 			Raw	Filt.	Raw	Filt		, , ,,,,,			1,000,00	
			(settled)	(filt)				1			† ·	(settled	<u> </u>			
		3.2	1.9	' ' ' '	104	 	132	, 		1	11.5	2.2	7.7	<u> </u>	21.2	
	 	3.1	2,1	 	105		118	 	 		6.0167	1.1	8.1		20.3	
		3.7	2.8	2.4	112		120			 	4.65	1.7	7.6		17.3	
		4.0	2.7	2,8	127		150				2.1667	0.8	7.9		19.1	
		3.6	2.6	2.5	128		144				2.1167	23	7.9		19,9	
	-	5.8	4.0	3.4	152		142		<u> </u>	 	24,333	6.9	7,9		10	
		5.6	4.2	3,7	158		144		 -		11.933	4.4	B.4		11.1	
	1	5.8	4.1	3.7	127	,	134	 			8.2833	2.4	8.1		11.3	
		6,1	3.8	3.2	110	 	144	 			17.117	3.9	8.2	i	12.5	
		5.8	3.6	2.9	102		120				21,233	2.6	8.3		12.4	
		6.1	3.3		117		134	 		† -	76.667	13.4	8		11.9	
		5.9	4.3	3.6	96		116			1	13.633	2.7	8.6		15	
		5.6	4.0	3,1	87		124				8,9657	2.6	8,7		14.6	
	1	5.8	4.2	3,5	98		118				11.55	3.4	8.5		15.5	
		5.3	3.7	3.4	105		126			ľ	10.783	3.3	8.3		15.7	
		5.1	3.7	2.8	78		108		I		8.6833	2.5	7.9		16.1	
		3.2	2.00		104		132				11.5	2.97	7.7		21.2	
		3.1	2,40		105		118				6.0167	1.53	8.1		20.3	
		3.7	3.10	2.40	112		120				4.65	1.88	7.6		17.3	i
		4.0	2.80	2.80	127		150				2.1667	1.09	7.9		19.1	
		3.6	2.60	2,60	128		144				2,1167	1.00	7.9		19.9	<u> </u>
		5.8	3.70	3.40	152		142	l			24,333	3.02	7.9	ļ	10	<u> </u>
		5.6	4.20	3,50	158		144				11.933	2.98	8.4		11.1	
		5.8	4,10	3.50	127		134			ļ	8.2633	2.18	8.1	<u> </u>	11.3	
		6.1	3.50	3.00	110		144	L		<u> </u>	17.117	2.63	8.2	ļ	12.5	<u> </u>
		5.8	3.30	2.80	102		120	<u> </u>			21.233	3.65	8.3	<u> </u>	12.4	
		6.1	3.30		117		134	ļ		<u> </u>	76.687	4.98	8	<u> </u>	11.9	
	<u> </u>	5.9	4.00	3.50	96		116		ļ		13.633	2.39	8.6	ļ	15	
		5.6	3.60	2,90	87	<u> </u>	124	ļ			8.9667	2.18	8.7	ļ	14.6	
	ļ	5.8	3.70	3.10	98	ļ	118	_	ļ	↓	11.55	2.92	8.5	 -	15.5	
		5.3	3,50	3.20	105	ļ	126	ļ	ļ	 	10.783	2.30	8.3	 	15.7	
		5.1	3.40	2.70	78	1	108	1	1	1	8.6833	2.02	7.9	1	16.1	

Enh.Coag.Data

uia Units D mg/L mg/L	
mg/L	
mg/L	<u> </u>
	<u> </u>
mg/L	
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1.6	1 222
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П			_	_					Γ		_	Γ	Γ			Γ	Γ	븚			8.8	6.9	6	G)	6.9	8.9	Ç)	8.7	8,9	9	88	8.9	П		Γ
\sqcup	-			H	L	L	_	L	L	L	L		_	L	-	품	c	┝		L	7.8	8.1	80	8.2	8.4	8	8.5			80			Н		L
							L	L	L				L		L	L		Raw	L				L								L	L			
Ц		_		L	_	L		_	L	L		L	L		L	Turbidity	Œ	FIR		_	3 0.05				5 0.05		0.05		0.05						
							_	_	L				L		L	Tut	Ē	₽	L			5 24	2.4	3.1		5.7	L.	1	5.5	ł	5	L		Ц	L
		age:		×					L	L			Ŀ		L	TOS	(mg/L)	Ę		L	120	=	110		12	130		18	19	Ĺ	1	120			
		r Indic											L				u)	Rex			06			8		L	130		L	8		L			! ! L
		a wate	ortlons													ide	7	퍒			21.3	21.3	16.3	18	20.4	22.4	29.8	32	94.3	37.5	45.7	38.5			
		unos pe	dold bu	Source						-						Chloride	(mg CHL	Raw		_	21.3	20,3	16.1	17.7	20	22,3	29.6	33.5	8.3	8	1	35.6			
	_	4. If blended source water indicate	sources and proportions;								_	H	-	-		ş	(T)	퍮		H	0.32	-		0.25			0.28	-	-	0.18		-			
1		4.	ě						-			-	-	-	-	Ammonta	mg NH3-N/L	Raw			<0.1			40.1			۸0.1	-	 	å	-	-			
					-	Н		-		Н			×	<u> </u>	-	ą	_	2	\vdash	H	40.1	9	40.1	<0.1	-0.1	<0.1	40.1	40.5	₽.	Ą	6	6			,—-
(QM	1								pue						9	Brownide	Î	Raw	H		<0.1			40.1		_	<0.1			8	-	-	-	1	
Ω. Θ.	1					e(c)		ollecte	tation,	-	_	_	- -	-	۲	þ	^-	Г	FIRE							-	\vdash	H			\vdash		П	1	
WM GO	-	95, etc.)		ter, etc.)		lend of		to data o	sedimer			only:	filtratio	\vdash		,	(203	Calcium	Raw	_		-	_				\vdash	-	_		-	-		1	_
(ACWD, COWD, EBINUD, MWD, SCWVD)	_	(Optimization Study 9/95,		groundwater, etc.)		(State Project water, blend of,		in this data sheet, "Fift," refers to data collected	after coagulation, flocculation, sedimentation, and			entation	or after sedimentation and filtration:			Hardness	(mg/l, as Cacco)	H	黑二		47.9	46.6	47.9	54.8	55.4	81.3	71.5	75.7	76.3	ន	98.6	73.8		1	_
νο oo	-	mization		(River, taloe, (_	e Project		#4. **	on, floce	Н		r sedim	dimenta	-	_		Dw)	Total	Н		47.8	1.75	48.4	53.1	56.1	62	11.8	78	77.5	2	68.2	71.5	$\left \cdot \right $	$\frac{1}{1}$	_
S S		Ö,		(Rive		(S)		dath she	agulatic	ű.		ted after	after se	L		L		ŀ	Raw		44.4	42		54.2										$\frac{1}{2}$	_
		98/		Jough		GC		In this	after co	filtration.		samples collected after sedimentation only:	8			Alkalinity	ng/L as CaCO3)	E.																	
an With		1/95-6/30/96		jh/Rock Slough		oject Water						dmes n				Alk	(mg/L a	Raw			43.9	42.3	47.2	52.4	52.3	54.7	63.2	67.7	<u>8</u>	838	62.5	54.6			
CCWD: Bollmar	1	data 7/		ırd Slou	Н	/alley Pr	-	9	2	•		are from		₹V	-	2	Ē	差			-	l						r	r	l	l				
Š		Historical data 7/1/9		Delta - Mallard Slough		Central Valley Proje		Bench-scale	Pifot-scale	Full-scale		* "FIN."	-	NTION	l	UV-254	(1/cm)	Raw											l	┞	l				
		_		Dell					Ī	×		ported a		CONVI			1	FIR			-									Ī	ľ				
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				ı.		r ID:	-	5. Describe level of study:	CX su			6. Indicate with an 'X' if data reported as "FIR." are from		WATER QUALITY DATA: CONVENTIONAL		Time		-													-	-	$\ $		_
ij	-	1. Study ID:		2. Source water:	_	3. Source water ID:		seribe le	(indicate with an 'X')			Icate wit	_	ER OU	-	Date					98-In:	Aug-95	Sep-95	04-95	56-35	Dec-95	an-96	Feb-96	Mar-96	Apr-96	May-96	86-55			_
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gulants studied:	Coagulant	Alum				T CONDI	Coagu	2007			31.2	33.7	31.8	31.6	31.1	35.6	47.4	42.2	49.9	42.8	36.7	35.7		
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bromate

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Contra Costa WD	· · · · · · · · · · · · · · · · · · ·			ļ	 		<u> </u>
Randall-Bold WTP	 		<u> </u>				
TRITURIT-BOIL WIF	ļ	 			<u> </u>		
Sample	Promoto	Object	D	 			
Date	Bromate	Chioride	Bromide	<u> </u>			
Date	(measured)				<u></u>		
<u> </u>	(µg/L)	(mg/L)	(mg/L)				
0802/00	10.5	70		<u> </u>			
2/23/93	4	72	0.22				
4/6/93	1	89	0.27			<u></u>	
5/21/93	I	55	0.17	<u></u>			
6/15/93	<u> </u>	30	<0.1			<u> </u>	
8/18/93	L	25	<0.1			<u> </u>	
10/5/93	10.3	60	0.18	ļ			
11/17/93	30.4	142	0.43				
1/4/94	1.5	70	0.21				
2/9/94	4.6	70	0.21				
3/1/94	2.6	55	0.17				
4/5/94	7.3	77	0.23				
5/10/94	<3	57	0.17				
7/12/94	<5	112	0.34				
8/9/94	< 5	133	0.4				
10/4/94	51	158	0.48				-
10/10/94	33	118	0.36				
11/1/94	15	150	0.45				
12/6/94	13	162	0.49				
1/10/95	5.7	94	0.28				
2/14/95	17	60	0.18				
3/14/95	7.6	35	0.11				
4/4/95	18	105	0.32				
6/13/95	<5	40	0.12				
7/11/95	21	32	0.1				
8/8/95	7.8	32	0.1				
9/19/95	<5	16	<0.1				
10/3/95		14	<0.1				······································
11/7/95	<5	16	<0.1				
12/12/95	<5	23	<0.1				
2/6/96	<5	40	0.12				
3/5/96	<5	117	0.35				
Moto	<u> </u>	4					
			currently	optimized	for	coagulation,	
	not	bromate	production.	·			
Conservative	ozone	doses:	pre-ozone	2.5-3 ppm	(raw water	<u>-</u>	
				1ppm	(filtered)		<u>. </u>
Plant CT operating	from 2-5	1		- In ta			
							

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(ACWD, CCWD, EBMUD	(Optimication Study 9/95,		River, take, groundwater	_	(State Project water, blen		Γ							Raw		;	3 8	3 2	3	25	3	62	į	101	63	69	÷		sedate o	and dire			
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CCWO: Randall-Bold WTP	Oste 7/1	Ц	Delta (Rock Slough)	╽	A P		6. Describe level of shudy:	(X, U	L	IONAL				*		1	1	1	\downarrow	L	1	L	L	L	L	L	L	L	da pas	4 Randa	- Pre-02	Fil = Post-oz	,
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iii G	. Study ID:		2. Source water:	\parallel	3. Source water ID:	۲		\dagger	H	TER C		Oate	\vdash		H	+	5000	CE STATE	10,000	1,6,0,6	12/4/03	1/8/96	2/5/08	3/4/16	961.7	96/9/9	6/3/96	T	-	1	t	r	

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Utility ID:		1			MV	ID.		(ACMD,	CCWD. EI	MUÖ. M	NO. SC	W/MD)					
1. Study ID:	ļ		Ja	r Tests-	-renge c	i nspwyn	CRW	(Optimiza	tion Study	9795, ex	<u>.)</u>		Indicate coa				
2. Source wat	ec			L	Surf	Ča	!	(River, Isl	se, pround	water, el			1	Congulant		ni formula h=14 H ₂ O	Units mg/i,
	<u> </u>			i .			T	,					2	Potymer		lionic	mg/L
3. Source wat	er ID:				SPW,	CRW		(State Pr	oject water	r, blend o	/, etc.)		3				
E. Describe in	ual ad advadu	<u> </u>	×	Bench	erela		in this det		Eile * mdo	- 10 dat	e collect	لـبـلِ	Document inches	tornativ 3 fe	omelonie 3	mg/L polymer	
(indicate with			- - -	Pilot-e			after coag							a manaj o ço	Complete 27	ingra ponyiner	
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6. Indicate wil	D BU X. N. C	ка геропе	2 88 P4R	4579 17	क्सा क्स	thes colle		er sedime		nel filtrat	ien:	\vdash	ж	60 min setti	ng ome		
WATER QU	ALITY DA	TA: CON	VENTX	MAL				1									
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Study ID		ter	TÇ	XC .	_	V-264	Alkai		Turb		pì				lation Cond	tions	
	% CRW	% SPW	(mg	/L) 下性。	Staw	/cm)	fmg/L as	CaCO3)	(N) Rusw	Filt.	(Cayy	Filt.	Coagulant	Dose	Acid adjusted?	Base adjusted?	Coag.
• • • •			Raw	r=.	ALEW	FBU	1244		REN	FAL	TCS FF	THE	(see above)		(Y/N)	(Y/N)	0
	i														blank=N	blank=N	
MWDIAROI	150		2.42	2.43	0.025	0.039	123		0.74 0.74	0.74	E.03			<u> </u>			1.06
MWDJAR01	100		2.42	2.32	0.025	0.036	123	-	0.74	0.63	1.03	-	-	10 20			7.71
MWDJAROI	109		3.42	2.17	0.025	0.005	123		0.74	0.61	L03		-1	30			7,30
MWDJAR01	100		2.42	2.02	0.025	0.013 0.038	123 123	 	0.74	0,90	L03		1	40 50			724 639
MWDJAROI MWDJAROI	100	 	2.42	1.95 1.86	0.025	0.034	123	· -	0.74	0.91	F.03	-	- 1	60			621
MWDIARDI	108		1.42	1.83	0.025	0.036	123		0.74	027	8.01		1	70			6.72
MWDIAR06 MWDIAR06	100		2.25	2.20	0.019	0,019	132		0.65	0.62	1.29 1.29	\vdash	1	10			7.88
MWDJAR06	100	 	2.25	1.97	0.D19 0.D19	0.011	132		0.65	9.56 0.51	127		1	20			7.44
MWD/AR06	100		2.25	1.95	0.019	0.009	132		0.65	0,43	8,29		1	30			7.49
MWDMR06	100		2.25	1.83	0.019	0.007	132		0.65	0.62	129	\vdash	1.	40			731
MWDJAR06 MWDJAR06	100	 	2.25	1,67	0.019	0.004	(32	 	0.65	6,74	1.29 1.29			50 60	 	-	7.24
MWDIARI6	190		2.25	1.67	0.019	0.003	132	<u> </u>	0.65	0,90	6.29		1	To			6.93
MWDIAR06	100		2.25	1,61	0.019	o.óre	132		0.65	1.00	1.29		1	100			6.84
MWDIAROG MWDIAROG	100		2.25	1.56	9,019	0.001	132	 	0.65	1.30 1.40	8.29		+	90			6.75 6.67
MWDJAR06	100		1.15	1.47	0.019	0,001	132	} 	0.65	1.30	1.29		i	Ild			6.57
MWDIAROT	\$00		2.39	2.41	0.036	0.038	132		0.42	0.34	E.34		1				E.15
MWDJARUT MWDJARUT	100		2.39	2.28	0.036	0.033	132		0.42	0.34 0.36	1.34	\vdash	1	10 18			7.81 7.71
MWDJAR07	100		2.39	1.99	0.036	0.032	132		9.42	0.32	LJ4	-		30			7.56
MWDIARET	100		2.19	1.94	0.036	0.025	132		0.42	0.34	8.34		1	40			7.46
HWDIAM7	100		2.39	1.78	0.036	0.023	132	!	0.42	0.42	134			\$0 \$0			7.31 7.25
MWDIARII7	100	 	2.39	1.76	9.036	0.023	132		9.42	0.57	1.34			70			723
MWDIAR67	100		2.39	1.68	0.036	0.927	132	i	0.42	0.59	E.34		1	JAD .			7.to
MWDIAR07 MWDIAR07	10U 100	-	2.19	1.63	0,036	0,021	132	ļ	0.42	0.60 0.67	134	<u> </u>	1 -	90 100			7.96 6.98
MWDJAROS	100		2.45	1.56	0.010	0.033	122	-	0,40	11,40	LII	-	1	0			7.91
MWDJAROS	100		2.45	244	0,030	0,031	122		0.45	0.32	LIL		1.	10			7.25
MWDIARR	100		2.45	2.26	0.030	0.031	122		0.40	0.25	8.18 8.18		1	20			7.73
MWDIAROS	100		2.45	2.06	6,036	0.025	122		0.40	11.6E	E.IE		-	40			7.52
MWDIARNS	100		2.45	2.03	0,030	0,026	122		9,40	123	\$.18		1	5 0			741
MWDIANUS	100	<u> </u>	2.45	2.01	0.030	0.024	122		0.40	0.34	LIL	<u> </u>		60			7.33
MWDJARJE	100		2.45	1,87	0.030	0.020	122	1	0.40	0.35 0.50	£.18		1 1	70			7.17
MWDIARAS	100		2.45	1.79	0.030	0.020	122		0.40	U.68	8.18		1	90			7.06
MWDIAROS	100		2.45	1.78	0.030	0,019	122		0.40	0.55	Lil	<u> </u>	1	10a			6.91 7.97
MWDIARD9	90		2.55	2.55	0,055	0.046	119 119	 	0.7t	0.62	7.97	┢	1	10		-	7.66
MWZNARO9	90		2.55	2.46	0.035	0.036	119		0.71	0.34	7.97		1	20			7.48
MWDIAROP	90		2,55	2.23	0.055	0,041	119	1	0.71	0.41	7.97		1	30			734
MWDJARD9 MWDJARD9	90	 	2.55	2.19	0.015	0,034	119		0.78 0.78	0.33	7.97	, 	1	40 50		-	7.21 6,89
MWDJAR09	90		2_55	1,92	0.055	6033	119		0,71	0.42	7.97		i	60			6.85
MWDIARDS	90		2.55	2.01	0,055		119		0,7t 0.7t		7.97 7.97	 -	1	70 80			6.79
MWDIARD9	90	 	2.55	1.17	0.055 0.015	 	119	\vdash	0.71 0.71	_	7.91			90		-	6.51
MWDNAR09	90		2.55	1.95	0,055		119		0.71		7.57		1) Del			6.50
MWDIARDS	90		2.55 2.55	1,84	0.055		119		0.7E		7,97	H	1	110	ļ		6.41 6.18
MWDJAR99 MWDJAR10	90	 	2.58	2.52	0.055	0.046	125		0.70	0.55	8.22		1	0			8.16
MWZNARJO	īXI		2.58	1.42	0.015	0,036	125		0.64	DÁO	1.22		1	10			7,74
MWDIARIO	90) 90)		2.58 2.58	2.23 2.04	0.055	0.041	125	ļ <u> </u>	0.64	0.66 9.48	122		1	20 30		-	7.49
MWDIARIU	90	-	2.58	2.04	0.055	0,034	125	 	0.64	0.46 0.78	1.22			40			7.15
MWDSAR10	90	<u> </u>	2.58	1.83	0.055	0,032	125		0.64	0.86	122		1	50			6,98
MWDJARIN MWDJARIO	90		2.51	2.01	0.055	0.027	125	1	0.64	0.75 0.63	8.21 8.22	\vdash	1	70	ļ		7.1\$ 7.04
MWDJARJII	90		2.58	1.93	0.055	0.030	125	1	0.64	9.65	122	i -	1	/U		 	6.84
MWDIARIII	90		2,51	1.92	0.035	0.027	125		0.64	82.0	1.22		1	90			6.82
MWDIARIO	90		2.50	1,76	0.055	0.036	125		0.64	1.30	1.22		1	100			6.75
MWDIARIO			2.51	1.82	0.035	0.028	125	1	0.64	0.45	8.22 L33	 	1	116 (1			6.77 8.40
MWDIARII		 	2.67	1,60	0.053	4.037	128	 	0.49	0.56	8.33		1	10			7.89
MWDIARII	90		2.67	2.44	0.053	0.039	121		0.49	040	8.33		1	20			764
MWDIARII	90 90		2,67	2.21	0.053	0.024	21 21	<u> </u>	0.49	9.72	8.33		1	30 40		<u> </u>	741
MWDIARII	90	 	2.67	1,00	0.013	0,024	128	\vdash	0.47	9.70	8.33	┢	 ;	50		<u> </u>	7.00
MWDIARII	90		2.67	1.77	0.053	0.022	. 129		0.49	0.78	£33		1	60			6.93
MWDJARLI	1 90		2.67	1.72	9.011	0,023	129.	<u>. </u>	1) 49	0.78	1 2.11	!	1	70	1	ŀ	6.83

Study (O	W	iter	TY	oc -	1	V-254	Alka	- نندنه	₹2	Jan-			,				
	% CRW		+	P/LI		1/cm		CaCO3)		ridity TU)	pi (i	1	Coagulant	Coape	Acid		
		Ļ	Raw	Filt.	Raw	Filt.	Raw	Filt	Raw	Filt	Raw	Fill	10	Lose	adjusted?	Base adjusted?	Coag.
		 	 	}—		ļ. <u> </u>		<u> </u>					(500 above)		(Y/N)	(Y/N)	0
MWDIARH	90	i -	2.67	1.66	0.053	0.026	123	 	0.49	1 0.15	133	<u> </u>			blank=N	Mank=N	
MWDIARIE	90		2.67	1.67	0.053	0,022	124		0.49	1.10	8.33	 	- 	90	 -		6.52
MWDIARU2	90	ļ	2.95	3.00	0.042	0.043	120		0.67	0,30	1.23	_		0	-	 	8.20
MWDJARI2	90	 	2.95	2.76	0.042	0.032	128		0.67	0.21	\$23		1	10			7.80
MWDLARI2	90		2.95	2.50	0.042	0.031	120	 	0.67	0.21	8.23 8.23	-	1 1	20			7.64
MWDIARI2	90		2.95	2.35	0.042	0,029	120		0.67	023	LUS	-	 		 		7.44
MWDJAR12	90		2.95	2.33	0.042	0.029	120		0.67	0.23	8.23		1	\$0			723
MWDJARIZ	90	 	1.95	2.01	0.042	0.032	120	├~—	0.67	0.24	8.23		1	60			7.16
MWDIARI2	90		2.95	1.95	0.042	0.029	120		9.67 9.67	0.20	8.23 1.23			70 80			7.08
MWDIAR12	90		2.95	1.90	0.042	0.027	120		9.67	0.23	123		-	90			7.01 6.88
MWDIARI2 MWDIARI2	90		2.95	1.86	0.042	0.022	120		0.67	0.29	123		1	100			6.83
MWDIARIZ	96		2.93	1.82	0.043	0.027	120		0.67	0.47	121			110			6.79
MINIDIAR 12	90		2.95	1.70	0.042	0.021	120		0.67	0.56	120		1	130			6.76
MWDIARI:	90		2.95	E.71	0.042	0.026	120		0.67	0.52	6.23			140			661
MWDJARI2 MWDJARI2	90 90	-	2.95	1.61	0.042	0.026	120		0.67	0.45	L21		1	130			6.47
MWDJARI1	90		2.95	1.54	0.042	0.027	120	 	0.67	0,49	127		1	160			6.40
MWDIARIS	朝		2.95	1.62	0.042	0.028	120		D.67	130	121		- ;- 	176 195			6.23
MWD/ARI2	男)		2.95	1.57	0.042	0.026	120		0.67	1.30	121		1	190			6.11
MWDIARI3	90		2.95	2.26	0.034	0.052	120		0.67	3.60	121	$-\Box$	1	200			6.12
MWDIARIS	90		2.25	2.08	0.034	0.013	126		0.77	0.77	8,30 8,30		1	10			1.21
MWDIARI3	90		2.25	1.86	9.034	0.021	126		0.77	0.40	2.30			20			7.90
MWDIARI3	90		2.75	2.00	0.034	0.019	126		0,77	a)i	2.30		1	30			7.56
MWDIARIS	90	h	2.25	1.92	0.034	310.0	126	<u> </u>	0.77	0.45	130 130		1	40			7.43
MWDIARI3	50		225	1.80	0.034	310.0	126	_	0.77	0.58	130		1 1	50 60			7.33
MWDIARIJ	90		2.25	1.76	0.034	0.015	126		0.77	0.57	130			70			7.14
MWDIAR13	90		2,25	1.66	0,034	0.013	126		0.77	0.58	2.30			80			7.06
MWDMARIA	90		2.25	1.62	0.034	0.013	126		0.77	0.11	8.30		1	90			6.94
MWDFAR13	#0		225	1.51	0.034	0715 0715	126		0.77	0.67 0.73	8.30			\$00			6.94
MWD/AR14	#0		2.31	2.48	0,033	CEILO	127		0.58	0.54	8.20	\dashv	- - 	tio i			6.88 3.22
MWDIAR14	90		2.31	2,45	0,011	0.725	127		0.58	0.55	8.10		1	19			7.95
MWDIARI4 MWDIARI4	90 90		231	2.31	0.013	D.021	127	<u> </u>	82.0	0,44	8.20			20			7.71
MWDIARI4	90		231	2.09	0.033	0.030	127	-	0.5E	0.41 0.67	E20			30			7.52
MWDIARH	90		2.31	1,94	0.013	810.0	127		0.11	6.39	1.20		+	49 50			7,40
AWDIARI4	90		2.31	1,77	6,033	לוםמ	127		0.18	83.9	L20		. 1	60			7.27
MWDIARI4	90	-	131 131	1.57	6.033 (E0.0	0.017	127		0.51	0.77	£20 [\dashv		70			7.13
MWDIARI4	90		111	1.60	0.013	0.017	127		0.18	0.70	1.20			90			7.06 6.93
MWDJAR14	9(1		2.31	1.55	0.033	9.D15	127		0.51	0.95	1.20		1	100			6.34
MWDJAR14 MWDJAR14	90 90		2.31	1.52	9,033	0.014	127		0.51	1.00	1.20		1	119			6.77
MWDIARI4	90		2.31	1.49	6.033 6.033	0.015	127		0.51 12.0	1,00	1.20		- 1 - 1	120			6.60
MWDIARI4	90		2.31	1.48	0.033		127		0.58	144	1.20		- i - [130			6.53
MWDIARI4	90		7.31	1.42	0.033		127		0.51		1.20		1	150			
MWDIARIS	90 90		2.31	1,33 2,51	0.033	0.041	127		0.58		1.20	_	_ ! _	160			
MWDIAR15	90		3.17	237	D.036	0.034	127		0.47	0,35	8.29 8.29		1 1	10			7.96
MWDIARIS	90		3.17	2.24	0.036	0.031	127	-	0,47	0.39	1.29		- +	20			1.74
MWDIARIS 1	90		3.17	3,06	0.036	0.025	127		0.47	0.27	1.29		1	30			7.52
MWDJARIS	90		3.17	1.86	0.036	0.026 0.028	127		0.47	0.56	1.29			40			739
MWDIARIS	90 .		3.17	1.76	0.036	0.025	127		0,47	0.36	1.29 1.29	-+	1 1	60			7.32
MWDJARIS	90		3.17	1.72	0,016	0.024	127		CL47	0,65	9.29		- 1	70			7.15
MWDIARIS	90		3.17	1.56	0.036	0,024	127		0.47	0.77	1.29		1	ţu .			7.06
MWDIARIS	90		3.17	1.54	0,036	0.024	127		0.47	0.63	£29 £29		1 1	90			7.03
MWDIAR16	70		2.43	2.52	0.041	0.942	117		0.42	9.12	125			0			8,28
MWDIARI6	90	1	2.43	2.50	0.041	0.031	117		0.42	0.35	R25	\Box	1	10			8.01
MWDJARI6	90 PG		2.43	2.32 2.19	0.041 0.041	0.026	117		0.42	0.26	1.25 1.25	{	1	30	Ţ	I	7.50 7.68
MWDJAR16	90		2.43	2.05	9.041	0.024	117		0.42	0.27	125	-	1	40			7.68
MWDJAR16	90		2.43	2.06	6,641	9.624	117		11.12	0.30	125		1	50			7.44
MWDIARI6 MWDIARI6	90		2.43	1,99	0,041	0.022	117		U.42	0.30	1.25	\dashv	1	60			7.36
MWDIAR16	90		2.43	1.87	0.041	0.021	117		0.42	0,35	1.25 1.25		1	To Io			7.16
MWDJAR16	90		2.43	1.12	9.041	0,021	11.3		0.42	0,36	1.25		- ;	90			7,10
MWDJAR16	90		2.43	1.15	0.041	9.021	117		U.42	0,36	121		1	[DK]			7.00
MWDIARI6	90		2.43	1.73	9,041	0.020	117		0.42	8,39 8,66	1,25		- 1	110			6.34
MWDIARIS	90		2.43	1.76	0.041	0.014	117		0.42	8,66	1.25 1.25			120			6.77 6.65
MWDIARIA	90		2.43	1.65	110,0	100	117	1	0.42	0.53	E.25		1	40			6,01
MWDIARI6 MWDIARI6	90		2.43	1,64	0.041	0.017	117		D.42	0.62	123	\Box	1	150			451
MWDIARI6	90	-	2.43	1.60	100.0	0.016 2.11.0	117		0.42	0,00	125	- - [160			6.50
MWD/ARI6	90		243	6,63	0,041	0.014	112	 }	11,42	#.91 .[0	1.25		1	120		 +	6.61
MWDIAR16	9tı		2.43	3.64	D.041	0,013	117		U.42	1.10	1.25		1	190			6.38
MWDIARI6	90		2.43	1.33	1000	D.H14	117		13.42	1.60	1.25		1	200			5,26
MWDJAR16 MWDJAR16	90 90		2.43	1.53	11.041	0.013	117		0.42 0.42	1.14	1.25	 -ļ	1	210			6.18
MWDIARI7	. 50		2.55	2.55	0.061	17,1153	114		1.20	1.10	8.25 B.09	+	1	220 D			6.12 8.04
MWDIARI7	21		2.55	261	11,061	0.048	114		1.20	0.61	8,01		- 1	in			7.62
MWDIARI7	\$6 \$0		2.55	2.55	(LOG)	ILI142	114		1.20	B.41 (90.0	\Box	1	20			7,46
MWDIARI7	10;		2.55	2.39	15,861 11.661	10.04	114		1.20	11,54 ! 11,61 (1,04	-+		40			7,24
MWDJAR 17	St.	+	2.55	213	11.064	9103	114		1.20	8.19	R04 1	_+		50			701
																	

Study ID	W4	iter	I TO	C	<u> </u>	V-254	Älkal	inky	Turb	idity	pł	1		Coare	lation Cond	Stions.	
	% CRW	% SPW	(m)			l/cm)	(mg/L as			U)	0		Coegulant	Dase	Acid	Base	Coag.
			Raw	Filt	Raw	Filt.	Raw	Fill	Raw	Filt	Rane	Filt	5		adjusted?	adjusted?	рH
				ļ	<u> </u>				┝	 	<u> </u>	├	(see above)		(Y/N)	(YAI)	
MWDJAR17	\$0		2.55	2.02	0.061	0.034	134		1.20	0.44	6.09	 	1	60	blank=N	blank=N	6.95
MWDJAR17	50	1	2.55	E.96	0.061	0.042	114		120	1.10	E.O9	 	'	70		[6.60
MWDJARJ7	30	<u> </u>	2.55	1.84	180.0	0.032	114		1.20	0.95	8.09	_	1	90		···	6.51
MWDIAR17	80		2.55	1.74	190.0	0.031	114		1.20	0.85	8.09		1	90			6.43
MWDIARI7	20		2.55	1.64	0.061	0,033	114		1.20	1.40	B.09		1	tgo			6.27
MWDJARI7	80		2.55	1.67	0.061	0.033	114		1.30	1.20	8.09		1	110			6.17
MWDIAR17	\$6		2.55	162	0.061	0.033	114 121		1.30	1.30	E.09	-	1	120	ļ		6.14
MWDIARIS MWDIARIS	\$0 \$0		2.45 2.45	2.51	0.054	0.061	121		0,76	0.66	8.22	 	1	10			7.23 7.25
MWDJARIS	\$0		2.45	2.54	0,054	0.039	121		0.78	0.60	3 22		1	20			7.61
MWDJARIE	20		2.45	2.32	0.054	0.036	121		0.78	0.65	B.22		1	30	 		T,45
MWDJARLE	30		2.45	1.35	0,054	0,041	121		0.71	0.54	1.22		1	40			7.35
MWDIARIE	100		2.45	2.22	0.054	6,0)2	121		0.71	0.67	8.22			50			7.23
MWDIARIS	20	<u> </u>	2.45	1.95	0.054 0.054	0,034	121	_	6.71	0.82	8.22	⊢	1	3	<u> </u>		6,97
MWDIARIE	#0 #1		2.45	1,97	0.054	0.5)1	121		0.71	0.76	1.22			70 20		ļ	7.00 6.90
MWDIARIE	80		2.45	1,83	0.054	0.034	321	· · · · · · · · · · · · · · · · · · ·	6,71	0,75	1.22	_	1	90			6.33
MWDJARIE	190		2.45	1.76	0.054	0.035	121		6.78	0.73	8.22		1.	100			6.92
MWDIARIC	90		2.45	1.75	0.054	0.037	721		0.71	1.00	1.22		1	110			6,77
MWDIARIS	80		2.70	2.87	0,049	0,041	132		057	0.55	131	<u> </u>	1				2.46
MWDIARI9	\$0 ***	 	2.70	2.65	0.049	0.031	122	\vdash	0.57	0.69	8.31	 	1	10	 		7.53 7.64
MWDIARI9	20	 	2.70	2.22	0.049	0,025	122		0.57	0.60	8,38 8,38		1	30	} 		7.64
MWDIARIS	323		2.70	2.04	(LD49	9.023	122		0.57	0.59	838		1	40		-	7.18
MWDIARI9	80		2.70	2.02	0,049	0.021	123		0.57	6.78	8.38			. 50			7,13
MWD/AR19	80		2.70	1.51	0,049	0.021	122		0.57	0.75	232		1	60			6.87
MWD/AR19	2 0		2.70	1.85	0,049	0.018	122		0.57	D.Bi	8.34		1	70			6.79
MWDIARTS	64		1.70	1.71	F100.0	0,010	122		0.57	0.97	\$.38		1	\$17			6.71
MWDIARI9	80	<u> </u>	1.70	i.lid	0.049	0.0(5	123	ļ	0.57	0.89	\$38	H	1	90			6.67
MWD/AR19 MWD/AR19	20 80	<u> </u>	2.70 1.79	1.85	0.049	0.015	122		0.57	1.50	\$.38 \$.3\$	H		110		1	6.55
MWDIAR2	190	 	2.53	1.88	0.042	0,045	133	 	0.25	0.90	8.38		1	0	-		8.45
MWDIAR2	KOO		2.53	1.89	0.043	0.036	133		0.85	0.71	£38		1	10		· · · ·	8.02
MWDIAR2	jao		2.53	2.68	13.042	0.030	133		9.25	0.53	8.38		1	20			7.72
MWDIARZ	fog		2.53	2.51	0.042	0.627	133		0.65	(1,40	8.38		1	30			7.46
MWDIAR2	100		2.53	1.19	0.042	0,027	133		0.85	0.64	2.72		1	40			7,34
MWDIAR2	100		2.53	2.50	0.042	0.028	133		0.85	0.57	8.38			50			7.16 6.96
MWDIARI	jns		2.53	1.99	0.642	0.017 0.018	133		0.85	0.78 1.10	8.38		1	60 70			6.83
MWDIARZ	jue		2.53	1.90	0.942	110,0	133		0.85	1.20	1.38		i	80			6.84
MWDJARZ	100		2.53	1.90	0.042	0.020	133		0.ES	1.30	8.38		1	90		ì	6.81
MWDJAR20			2.79	2.87	0.033	0.035	114		0.54	_ a_a	1.21		1	•			8.15
MWDJAR20	983		2.79	2.46	0.053	0.040	114		0,54	0.37	121			10		ļ	7//5
MWDIAR20 MWDIAR20	10 10		2.79	2.60	0.053	0.044 0.038	114		0.54	0.25	1.21		1	30		<u> </u>	7.58 7.42
MWDIAR20	50		2.79	2.22	0.053	0.035	114		0.54	0.14 0.14	8.21 8.21	-		40		-	7.30
MWDJARZU	\$4)		2.79	2.20	0.013	0.036	114		0.34	0.20	6.21		<u>i</u> 1	50			7.21
MWDJAR20	20		2.79	2.13	0.011	0.036	114		0.54	0.70	1.2)		i	60			7.19
MWDIAR20	30		2.79	2.03	0.013	0.032	114		0.54	0.23	12i		1	70			7.10
MWDIARE	\$0		2.19	1.97	0.053	0.034	114		856	0.76	121		1	\$10			7.0 L
MWDIAREG	#2		2.79	1.95	0.053	0.033	M		0,54	0.17	121		1	90	_		6.97
MWDIARRI	90 \$6		2.79	1.83	0,053 0,053	0.032	114		0.54 0.54	0.27 0.63	8.21 8.21	Н	1	3000 2140			6.92 6.90
MWDUARDO	\$0		2.79	1.74	0,053	0.031	114		0.54	0.59	125		- ;	320			6.74
MWDJARZU	90		2.79	1.70	0.051	0.027	114		0.54	0.43	621	_	1	130			6.62
MWDIARIU	9 ()		2.79	1.62	0.033	0.032	114		0.54	0.53	6.21		1	140			6.48
MWDIARID	8		2.79	1.68	0.053	0.030	114		8,54	D.58	1.21		1	130			6.53
MWDJAR20	20		1.79	1.61	0,053	0,030	114		0.54	0,53	1.21		1	(40			6.42
MWDIAR20 MWDIAR20	\$13 \$12		2.79	1.63	0.053	0,048	114		0.54	1.20	8.21 8.21	Ь	1	170	 	 	6.19
MAZDIARZO	80 80		2.79	1.55	0.053	0.032	[14		0.54	1,40	1.21	Н	1	190			6,10
MWDJARZO	20		2.79	1.52	0.053	0.027	14		R.54	1.30	1.21		1	200			6.03
MWDMR21	\$ (0		2.43	2.42	0.036	0.0712	121		910	0,71	1.22			. 0			1.23
MWDIAR21	\$0		2.43	2.42	0.036	0.028	121		0.13	0.69	I-32	\square	1	10			7.94
MPPOJAR21 MPPOJAR21	30 3)		2.43 2.43	2.09	0.036	0,023	12t 121		0.83 0.83	0.52	8.22			20 10		-	7.60
MWDMILLI	BD .		3.43	2.04	11.00%	0.021	121	-	0.83	0.46	1,23	\vdash	1	40			7.35
MWDIAR21	10		2.43	1,97	D.006	0.019	121		B.E3	0,57	8.22		1	50			7.28
MWDIAR21	REL		2.43	1.10	11,036	0.017	121		R.KS	0.51	8.22		1	60			7.30
MWDIAR2)	80		2.43	1.77	0.036	0.017	121		0.83	0,57	6.22		1	70			7.28
MWDJAR21	\$D		2.43	1.73	11.036	2,015	121		0.83	0.67	8.22		1	80			7.13
MWDJAR2) MWDJAR2)	\$0 \$0		2,43 2,43	1.72	11.036	0.914 0.014	121	— —	0.83	8.72 8.72	8.22		1	90			7.06 6.96
MWDJAR21	50		2.43	1.69	0.636	0.013	121	_	0.83	0.12	6.22	\vdash	1	110			6.95
MWDJAR22	\$40		2.41	2.53	0.038	0.038	121		0,76	0.71	8.15		i	0			125
MWDJAR22	10		2.4(1.31	11.83E	9,039	121		0,78	0.50	£.15		1	10			7.92
MWDJAR22	20		2.4(1.23	0.038	0,627	121		9.78	13.63	LIS		1	20			7.71
MWDJAR22	80		2.41	104	0.032	0.021	121		0.75	Ø.55	6.15	 	- 1	30			7.52
MWDJAR21 MWDJAR21	\$0 \$0		2.41	1.96	0.031	0.019	121		0.78	0.50	R.15	-		40 50		 	7.30
MWDJAR22	942	· · · · · · · · · · · · · · · · · · ·	2.41	[,2]	0.032	110.0	121		0.78	9.73	R.15		-	60	i i		7.03
MWDIAR11	80		2.41	1.74	2,035	7,10.0	121		0.78	0,85	11.15		<u>i</u>	70			6.90
MWDJAR21	to to		2.41	1.68	4.038	Э ВДО	121		0.73	0.86	8.15		1				6.83
MWDJARZZ	50		241	1.64	0.031	910.0	121		0.72	0.76	LIS		1	90			6.76
MWDJAR22 MWDJAR22	RG RG		2.41	1.58	0.032	0.0125	121		0.78	0.21	8.15	\vdash	1	100 110			6.72
MWDJAR23	80		2.41 2.41	1.42	0,033	0,015 210,0	121		0.7% 0.7%	0.93 0.93	R.15			110			6.55
MWDIAR22	10		2.41	1.33	9,032	910.0	121		D.7%	0.95	1.15	·	i	130			6.50
MWDJAR2)	80		2.51	2.56	0.050	Ø#155	121		0.43	0.45	LIL		11	a			1.33
MWDIAR23	20		2.51	2.43	0.050	0.042	121		0,43	0.58	EJ2		1	10			7,92
MOWDIARZ)	80		2.5t	2.25	0.050	0.035	121	<u> </u>	0.43	0.44	1.12		_ ! _	30			7.65
MWINAR23	and t		2,51	2.12	0.050	0,030	121		D41	4.50	K.33		1 1	30			1 49

Study IO	W	ster	1 7	6c	τ	IV-254	Alba	in the		dais.	т—						_
	% CRW	% SPW		g/L)		1/cm)		CaCO3)		Helity	P!	!	Coomdon	Coage	ulation Conc		
<u> </u>	 		Raw	Filt	Raw	Fift	Raw	Fit.	Rew	Fitt	Raw	Fih.	Cosquient	Desa	Asid	Sesse .	Coag.
———	+	ļ								 	1-1-1-1		(Bed above)		adjusted?		pH
4.00001.000	 		<u> </u>		L					\vdash			(000 00000)		(Y/N) btank=N	(Y/N)	<u> </u>
MWDIAR21	No.	ļ	1.11	2.00	0.050	0.021	J21		6.43	0.36	8.32		1	40	DODING	blank=N	
MWDIAR23	lo lo		2.51	1.92	0.050	0.024	121		9.43	9.40	1.32		- i -	50		·	7.39
	100		2.51	1.79	0.010	0.023	121		0.43	0.43	1.32		1	60	 		7.28
MINDLARE)	-	 	2.51	1.75	9,050	0.012	121		6.43	Q.45	8.32	$\overline{}$	1	20	 		7.21
MWDMRI	30	╄	2.51	1.62	6020	0.022	121		0.43	11.48	LU2		-	M	i		7.16
MWDIA323	1 20]	2.51	1.56	0.050	0.019	621		9.43	u.55	LJ.		1	90	 		7.00
MWD/AR24	10	 	2.51	1.56	(1,050	0.011	121		0.43	0.56	6.11		. 1	LOO			6.95
MWDJAJI24	1 10		2.57	2.45	11.045	9,046	113		0.65	0.59	LIL			u		1	3.20
MWDIAR24	10		2.57	2.32	U.045 D.045	0.033	113		0.65	0.32	8.11		1	10		T	7.95
MWDIAR24	30		1.57	2.07	0,041	0.031	113		0.65	0.39	1.11			20			7.80
MWDIAR24	90	 -	2.57	2.05	9,041	0,027	113		0.65	0.21	1.11	<u></u> ,	1	30			7,62
MWD/AR24	80		257	1,90	9.045	8.026	113		0.65	(1.21			1	46			7,50
M(WDJAR34	80		2.57	1.90	0.7MS	0.015	113		0.65	0.27	8.11			50			7.39
MWD/AR24	80	1	257	2.03	0,045	0.021	133		0.65 0.65	0.27	R.11			69			7.19
MWDIAR24	80		2.57	1.92	0,045	0.021	113		0.65	0.27	E.II	\dashv	1	70			7.11
MWDIAR24	\$20		2.57	1.90	0.045	1,001	113	$\overline{}$	0.65	0.40	8.13			80		ļ	7.0)
MWDJAR24	140		2.57	1.69	0.045	0.02L	113		9.65	0.44	1.11			. 90		L	6.93
MWDJAR24	\$40		157	1.61	0,045	9.020	113		0.63	0.45	1.11	∤		100			6.90
MWDIAR24	20		2.57	1.61	0.045	0.000	133		22.0	0,54	8.11			110			6.16
MWDIAR14	20		257	1.64	0,043	0.020	111		0.65	0.62	\$-11	\dashv	- i -	120			6.73
MWDJAR24	80		2.57	1.55	0.045	0.019	113		0.65	0.20	LJi	1		130		——	6.67
MWDJAR24	80		2.57	1.69	0,845	0.018	(13		24.0	1.20	L11		-;- -	140			6.5k
MWDJAR24	80		2.57	1.57	0.045	410.0	113		0.65	120	EII I					 	6.53
MWDJAR24	80		2.57	1.44	0.045	0,017	10		0.65	0.89	5.13			160			6.45
MWDIAR24	RU .		2.57	1.46	0,045	0.017	113		0.65	1.53	LU	- +		182			637
MWDJARZM	10		2.57	1.36	0.045	0.016	113		0.65	0.76	LII	-+		190	 		6.30
MWDJAR24	to to		2.57	1,35	0.015	0.015	. 113		6,63	0.77	1.11	-+		200			632
MWDJAR24	340		2.57	1,40	0.045	0,015	113	$\neg \neg$	0,65	0.75	1.(1			210			6.13
MWD2AR24	20		2.57	(2)	0.045	0,015	163		0.65	0.95	1.11	\dashv		220			6.04
MWDIARES	70		2.67	2.67	6,00,9		109		0.84	0.75	7.84	- +	-;-	- 120 U			5.91
MWDJAR25	70		2.67	2.59	0.065	0.054	109		Q.M	9.65	7.84	\dashv		115			7.93
MWDJAR2S	70		2.67	149	0.065	0.049	(09	$\neg \neg$	0.14	0.65	784	-+	;	20	-		7.64
MWD/AR25	70		2.67	120	D.065	6,039	tos		0.84	0.43	7,84		- ; 	30		}	
MWDIAR25	70		2.67	2.10	6.065	4.0)7	109		0.34	0.50	7.84	_	;	40			7.13
MWDIAR25	70		2.67	1.97	0.065	0.037	109		0,94	0.76	7.84		+ +	50			6.25
NWDIAR25	70		2.67	1.92	0.065	0.035	109		11.24	0.77	7.84			60			6.72
MWDIAR25	70		167	1.87	0.065	0,028	09		0.24	0.90	7.84		1	- 70			6,5%
NWDJAR25	70		2.67	1.82	0.065	0.026	109		0.84	0.85	784	_	1	RO I			6.50
MWDIAR25	70		2,57	1.66	0.065	0,026	109		0.84	0.37	7.84	\dashv	1	90			6.42
MWDIAR25	70	<u> </u>	2.67	1.68	0.065	0.024	109		0,14	0.95	7.84	_	1	100			6.22
MWDIAR26	70		2.50	2.56	0,055	0.038	₹15	- {	0,64	0.82	1.22		7	0			122
MWDIARIA	70		2.50	253	0.055	9.046	115		0.68	11.76	8.22		1	10	$\overline{}$		7.79
MWDIAR36	70		2.50	2.39	0.055	9,041	185		0.AL	9.78	8.22		1	20			7.57
	70		2.50	129	0.035	9036	115		0.61	0.75	1.21		1	30			7.43
MWDIAR26	70		2,50	2.01	0.055	0.035	115		9.68	9.73	8.22		1	40			7.28
MWDIAR26	70		2.50	2.02	0.055	0.035	115		67.0	1.00	1.22		1	50			7.18
	70		2.50	1.96	0.055	0.033	115	$ \Box$	83.0	1.67	1.22		1	60			6.97
MWDIAR26	70		2.50	1.75	0.055	11.034	UI5		11,68	0.70	1.22	. 1	1	70			7,00
MWDIAR26	70		2.50	1.75	0.055	0.036	115		0.68	0.76	3.22		1	20			6.81
MWDJAR26 MWDJAR26	70		2.56		n.nss	0.031	HS		0.62	0.41	#21	$\overline{}$	1	90			6.78
MWDIAR26	70		2.50	162	0.051	0.034	m		0.62	0.57	1.22		1	100			6,77
MWDJAR26	7u 7u		2.55	1.72	0.055	9.011	E15		0.62	0.72	8.22		1	1)0			6.56
MWDJAR26	70		2.50		0.055	0.032	[15		0.61	1.20	8.22		1	120			6.46
MWDIAR26	70		2.50		0.055	0.033	113		0.61	1,40	R.22		1	130	1		6.39
MWDIAR27	70		1.14		9.064	6,061	115		0.68	1.70	1.22		1	140			6.33
MWD/AR27	70		3.14		0.064	0,027	115		0.69	0.62	R.32	_					8.19
MWDJAR27	70		3.14	2.62	0.064	0.030	115		0.69	0.43	8.32			10			7.24
MWDIAR17	70		3.14	_	0.064	0.019	115	-+	0.69	0.43	133		!	20			7.33
MWDIART?	70		3.14		0.064	D,917	113	 -	0,69	0.41	8.32 8.32	-+	1	30			7.35
MWDIAR27	70		3.14		0.004	0.014	115		0.69	11.55	8.32	-	-}	47			7.05
MWD/AR27	70		2.14		0.064	0,029	113		0.69	11.61	8.32	-+	1 1	50		<u> </u>	4.99
MWDIAB27	70		3.M	2.81	0.064	0.020	115		0.49	11.71	131		- i 	70	-+		6.71
MWDIAR2?	70		3.14	1.93	0.064	0.020	115		0,69	0.62	8.32	\dashv		80			6.63
MWD/AB27	70		3.14		0.064	0,014	115		0.67	0.74	8.32	$\neg +$	1	90	$\overline{}$		6.56
MWDIAR27	70		3.14		9,064	0.029	115		0.69	0,14	8.32		1	HOO	- 		6.62
MWDIAR27	70		3.14		0.064	T	115		9.69	1.00	0.32	\neg	1	110		- 1-	6.33
MWDIAR27	70		3.14		1,000	0.025	115		0.69	1.70	132	\neg	1	120			6.19
MWDIAR17	70		3.14		0.064	0.019	115		0.69	2.10	0.32		1	130			6.15
MWDJAR17	70		3.14		0.064	0.017	115		0.64	1.70	1.32		7	140			6,05
MWDJAR27	70		3.14		0.1)64	0.016	115		N.64	3.10	1.32		1	150			5.B5
MWDIAR21	70		2.74		0.058	0.057	111		0.47	0.17	8.12		1	- 100			£17
MWDIAR21 MWDIAR21	70		174		0.059	DUKT	111		0.47	U.22	8.12	\Box	1	10			7.91
	70		2,74		0.052	0.043	111		0.47	0.20	£ 12		1	20			7.80
MWDIAR21 MWDIAR21	70		2.74		0.05E	0.039	151		9,47	n.17	8.12		1	30			7.59
MWDJAR2E			2.74		0.058	0.033	int	<u>_</u>	0,47	H.16	8.12	T	1	40			7.47
MWDJAR2S	70		2.74		0.058	0.039	nı		0.47	0.21	L12		1	50			7.37
MWDJARZE	70		2.74		0.058	0,932	111	—-	0,47	D.22	1.11	\perp	1	60			7.25
MWDIARES	70	+	2.74		0.058	0.0,14	111		0.47	0.22	L.12		1 7	70			7.09
MWDJARZE	70		2.74		0.058	0.027	101		0.47	0.24	6,12		1	20			7.04
MWDJARIS	70		174		0.05B 0.05B	0.027	111		0.47	0.21	1.12			90			6.59
MWDIAR28	70		2.74		0.058	8.03E	111		0.47	0.28	1.12		1	100		_ · _ [6.29
MWDIAR28	70	-+	2.74		0.05E	0,030 0,025	111		0.47	0,27	1.12	\dashv	1	£10			4.71
MWDJAR28	30	j-	2.74		2,012	0.029	121		0.47	Q.33	1.12	\rightarrow	1	120			5.73
MWDIARZE	70		2.74		0.038	61130 61134	113		0.47	0.50	1.12	$-\!\!\!+$		(30			6.63
MWDIAR18	70		2.74		0.051	6TIX:	113	 }-	0.47	0.53	1 12 1 12		1	140			0.55
MWDJA928	70		2.74		9.058	0.026			0.47	U.43	8.12	-		150			6.41
MWIHAR28	76		2.74		0.058	0.1344	111		0.47	4.5E	S.12		1	179			6.JS
MWDJAR28	76		2.74		0.038	11.1723	111		9.47	0.6.1	2.12	-+-	- 1	180			6.40
MONTHARDS	70		2.74	1.67		0.041	iii i	· ····	047	DAT.	R 12	- +-	1 1	190			6.33
			_							~				1791 1			6.23

Study (D	1912	iter	. 47	oc .		V-254	Alkal	dain.	Yust	Idian					iala Gara	***	
3100710	% CRW	% SPW	(ms			l/cm)	(mg/L as		(N)		<u>pl</u>		Coagulant	Dose	Acid	Base	Coag.
			Raw	Fin.	Raw	Filt.	Raw	Filt		Fitt.	Raw	Fist,	10		adjusted?	adjusted?	piłł
				_			 	ļ				├	(See above)		(Y/N) blank=N	(Y/N) blank=N	. (7
MWDIARES	70		2.50	2.51	0.1340	0.040	1135	1	9.68	9.68	1.20	 		0	UMBER-15	SANCE P	1.20
MWDJARZY	70		2.50	2.44	0.040	0.030	115		0.68	0.51	1.30		1	10			7.92
MWDIAR29	70		2.50	2.25	0.640	0.026	135		11.68	0.52	1.20			_ 20			7.69
MWDAR29	70	<u> </u>	2.50	2.13	0.040	0.023	113	 	0.68	0.44	1.20	├	1	40			7.51
MWIJAR29	70		2.50	1.91	0.040	0.020	115		0.64	0.72	8.20		- i -	50			7.39
MWDIAR29	70		1_10	1.80	Q.CI40	0.019	LIIS		0.68	6.77	1.20		1	66			7.06
MWDIAR29	70	ļ	2.50	1.76	0,040	0.018	115		0.68	0.16	1.20	┡—	1	70			6.99
MWDIAR29	70		1.50	1,76	0.040	0.018	115		0.63 10.0	0.61	1.20	├	1	90			6.93
MWDFAR29	70		1.90	1.62	0,040	8016	115		0.48	0.60	1.20	 	- i	100			6.87
MWDIAR29	70		1.50	1.60	0.040	0.015	115		0.62	0.78	1.20			130			6.30
MWDIAR29	70		2,50	1.49	0.040	0.015	115		0,62	L.00	2,20			120			6.72
MWDIAR29 MWDIAR29	70 70		2.50	1.47	040.0 040.0	0.017 0.016	113		0.68	1.10 1.00	\$.20 \$.20		1	130 140			6.51
MWDIAR29	70	 	210	1.41	0,040	0.018	115		0.63	(.)0	9.21		1	150		··	6,40
MWDIAR29	70		2.50	1.19	9,040	0.014	115	L	0.63	1.20	1.20		1	160			6.33
MWDIAR29	70		2.50	1,37	0.040	0.0 4	185		0,68	1.20	1,30			170			6.27
MWDIAR3 MWDIAR3	100		2.50	2.55 2.30	0.040	0,037	134	-	0.42	0_35 0_49	8.41 8.41	⊢		9	ļ		3.40 7.84
MWDIARS	100		2.50	2.10	0.140	0.029	134	-	0.42	0.49	8.41	\vdash		1D 20			7.63
MWDIARI	100		2.50	2,00	0,1140	0.025	134		D.42	0.61	8,41		1	30			7.39
MWDIARS	100		2.50	1.94	01,040	0.023	134		0.42	9.60	8.6L			44)			7.32
MWDJAR3 MWDJAR3	100	 	2.50	1.05	0.040	0.022 0.022	134	 	0.42	0.51	8,41 8,41	 	1	50 60	-		7.13 6.93
MWDJARS	100		2.50	1,65	9,040	0.019	134	 	842	0.96	241		+	70			6.90
MWDJARJ	100		2.50	1,60	0.040	0.020	134		0.42	1.10	8.41		. 1	10			6.54
MWD/ARJ0	70		2.44	2.51	0.042	0,042	316		P.0	0.58	8.14	<u> </u>	1	0			LIZ
MWDIAR30 MWDIAR30	70		2,44 2,44	2.36 2.20	0.043	0.032	136		0.1	0.61 0.50	8,14 1,14	├	. 1	10			7.81 7.53
MWDJARJ0	76	 	2.44	2,04	0,042	0.024	116	 	0.5	0,50	1,14	 		30			7.36
MWDIARID	70		2.44	1.96	0,043	0.022	116		0.8	9.70	8.14		1	40			7.29
MWDIARIO	70		244	1.23	D.N42	0.021	116		0.1	0.52	14.8			50			7.23
MWDIAR30	70		2.44	1.92	0.042 0.042	0.019	1116	 	0.3	0.58	4.4	 	1-	70			7,00 6.86
MWOJARJO	70		2.44	1,80	0.042	0.017	116		0.5	0.72	14.1 14.2	┢	i	80			6.82
MWDIAR30	70		2.44	1,84	O.(MZ	0.016	116		0.1	9.84	LM	 	1	90			6.79
MWDIAIUG	70		2,44	1,43	0.042	0.015	116		0.1	1.10	8.14		1	100			6.74
MWDIAR30 MWDIAR30	70		2.44	1.79	0.042	0.015	116		0.1	9.95 9.75	8.14 8.14		1	110			6,70
MWDIARM	70		2.44	1.26	0,042	0.019	136	 	0.8	1.10	L.14			150	 		6.43
MWDJARJU	70		2.44	1.24	0.042	0.017	t 14	_	0.9	0.27	8.14			140	<u> </u>		6.36
MWDIARIO	70		2.44	1.24	0.042	0.016	116		0.0	[,50	1,14		1	150			631
MWDIARNI	70		2.60	1.13 2.56	0.042 0.053	0.015 0.053	116	<u> </u>	0.8	1.20 8.40	1.14 1.29		1	160 G			6.27 8.30
MWDIARUI	70		2.60	2.44	0.053	0.052	114	 	0.45	9.55	1.29		i	10	.		7.91
MWDIARNI	70		2.60	222	0.053	0.036	114		0,45	0.50	L29		1	30			7.66
MWDIARSI	70		2.50	2,10	0,053	0.033	114		0.45	9.35	1.29			38			7.52
ICEALCHM ICEALCHM	70 70		2.60	2,00 E,54	0.053 0.053	0.031	114	-	0.45	0.33 0.53	1.29		1 1	49 			7.32
KWDIABUI	70		2.60	L.57	0.053	0.028	114	<u> </u>	0.45	0.43	1.29		i	60			7.20
MYDIARUI	70		2.60	1,31	0.053	0.026	114		0.45	0.41	1.29		1	70			7.88
MWDMSUI	70		2.60	1.72	0,053	0.024	114	ļ	0.45	0.41	1.29		1	#0			7.00
MWDIARUI	70:		2.60	1.62	0.053	0,023	134		0.45 0.45	0.63	1.29	-	- 1	90			6.96
MWOJARJI	70		2.60	1.58	0.053	0.021	124		0.45	0.50	1.29		1	110			6.72
MWDIARUI	70		2.60	1.52	1,053	0.021	194		0.45	72.0	1.29		1	(25)			6.68
MWDIARII	70		2.60	1.47	0.053	0.020	114		0.45	6,63	129	<u> </u>		130			6.59
MWDIARII	70		2,60	1.50	0.053	11.020	184	 	0.15	0.73 0.77	1.29	 	- 1	150	ļ		6.46
MWDIARII	70		2.60	1.40	0.053	0.0(2	114		0.45	0.77	1.29		- ;	160			6.39
MWDIARII	Ph Ph		1.60	1.16	CLUST	0.012	184		9.45	1,131)	129		1	170			6.55
MWDJARJI	70 70		1.60	1.30	0.053	0.017	184		0.43	1.10	1.29		- 1	(30)			6.63
NWDIARJI	7u 7u		1.60 2.60	1.17 1.12	U.053	0.017	184		0.45 Q.45	L.(U	129			190 200			6.23
MWDJARJ2	70		2.49	2.51	H.048	0.047	ID6		0.52	9.84	1.06		<u> </u>	0			2.07
MWD/ARJ2	70		2.49	2.36	DUM	11.047	106		0.12	0.37	1.06		1	90			7,90
MWDIARIZ MWDIARIZ	70		2,49	1.96	0.048 0.048	0.040	106		0.52	#.26 0.32	8.06 1.06	 	1	30 30			7.73 7.51
MWD/ARJZ	70		3.49	2.09	P.D48	0.035	106		0.52	0.29	1.06	1	i	40		-	7.48
MWDJAR32	70		2.49	2.04	0.044	0.030	106		9.51	0.29	1.06		1	50			7.41
MATUARIZ MONTHARIZ	70		2.49	[1]	U.148	0.027	106		0.52	0.25	1.06	_	1	60			7.27
MWDJARJ2 MWDJARJ2	70 70		2.49	1.34	(LOA)	0.022	106	 	0.52	0.30	1.06	 	1	70 \$0			7.j4 7.84
MWD/ARJ2	70		2,49	1.77	0.04	0.022	106		0.52	0.30	LO6		1	90			6.97
MWDIARD	70		2.49	1,67	0.041	0,023	(76		0.52	0.37	1.06		1	100			6.86
MWDIARII MWDIARII	70		2.49	1.67	0.04E	0.023	106		0.52	0.42	1.06	<u> </u>	1	110			6.83
NWDIARIZ	70	<u> </u>	2.49	1.59	0.048	0.021	106	 	0.52 0.52	0.39	1.06	-		130			6.75
MWDJAR32	70		2.49	1.62	9.04	0.012	106		9.53	0.53	1.06		1	140			6.66
MWDJARJZ	TO		2.49	1.52	0.041	0.012	106		0.52	0.56	1.06		1	150			6.65
MWDJARJE		<u> </u>	2.49	1.55	0.041	0.018	106	<u> </u>	0_52	0.70	1.06	-	1	160			6.51
MWDIARJ2 MWDIARJ2			2.49	1.56	0.048	9,017	106		0.52 0.52	18.0 28.0	1.06		1	170			6.34
MWDJARJ2			2.49	1.39	0.041	0.017	106	i	0.52	0.73	8,06	<u> </u>	1	190			6.13
MWDJARJI	70		2.49	1.50	0.04\$	0.015	(4)6		0.53	0.25	ILDG.		1	200			6,06
MWDIARII MWDIARII	70		2.49	1.37	EQ41	0.015	(06	<u> </u>	0.57	0.95	8,06	<u> </u>	1	210			5.50 5.56
MWDIARI)	70 60		2.49	1.13	0,64E 0.974	0.015	104	 	0.52 1.70	1.10	#116	 		220			7.91
MWDJAR33	60		2.72	2.62	0.074	0,062	104		1.70	0.53	1.03			10			7,59
MWDIARI3	60		2.72	2.50	0.474	0.055	(04		1.70	0 64	1,01		1	20			7.18
MWHIAR13	AC)		2.72	2 40	D 074	4.042	104	l	1.70	614	1.03		1	પા	· _		7.17

Study (D	We	ter	To	œ	u	7-254	Alket	inity	Turb	ditv	pi			Corn	lation Cond	W	
	% CRW		(mg	/Li	ľ	/cm)	(mort as	CeCO3)	(NT		l 		Coagulant	Dose	Acid	Basa	Coag.
			Raw	Fift	Raw	Filt	Raw	Filt	Rew	Filt.	Raw	Fit.	10		adjusted?	adjusted?	pH
			_	-				-					(See above)		(Y/M)	(Y/N) blank=N	0
MWDIARS	60		1.72	2.15	0.074	0.043	104		1,70	II.75	8.63	 	1	40	bienk=N	CHBRE-M	6,94
MWDIARU	60		2.72	2.09	0.074	0.042	104		5.70	0.84	LO3			50			6.92
MWDIARS	60		1,72	2.04	0.074	0.048	104		1.70	0.86	8.01	_	1	60			6.77
MWDIARJS	60 60		1.71 1.71	1.92	0.074	9tn.p	104		1.70	1.10	E.03		1	- 70 80	ļ		6.49
MWDIAX33	60		2.72	1.75	0.074	0.035	104		1.76	0.97	1.01			10			6.33
MWDIAR33	60		1.72	1.67	0,074	7,000	104		1.70	2.00	£03		1	100			6.11
MWDIARS	60		2.51	2.67	0.048	0,043	109		9.77	0.67	1.27		1	0			8.27
MWDIAR34 MWDIAR34	60 60		2.51	2.66	0,045	0,035 100.0	109	_	0.77	0.70	1,17 1,27	ļ	1		ļ		7,79
MWDIAR34	60		2.51	2.32	0.048	0.025	109		0.77	041	1.27	-	 -	30			7.57
MWDIARM	60		2.51	7.24	0,048	0.025	109		0.77	0.57	8.27			40			7.28
MWD/AR34	60		2.51	2.22	0.048	0.024	109		0.77	0,72	1.27		1	50			7,18
MWDJARM	60 60		2.51	1.99	0,048	0.021	109 109		0.77	0.57 0.11	E27			70			7.09
MWDIAR34	60	_	251	1.52	0.048	0.019	109		0.77	0.66	8.27	-		30			6.98
MWDJARH	60		251	1.76	0,048	0.027	109		0.77	0,73	8.27		_ i	90			6.81
MWDIARM	60		2.51	1.69	8141.0	0.023	109		0.77	0.71	8.27		1	1(00)			6.76
MWDIARH MWDIARH	60		25L	1,48	0,041	0.022	109		0.77	0.11	8.27	<u> </u>	1 1	110			6.68
MWDIARH	60		251	1,47	0,741	0.035	109		0.77	1,40 1.50	8.27			120	<u> </u>		6,45 6,41
MWDIARIS	60		3.44	3,13	0.021	0.077	111		0.74	0.65	8.36	\vdash	i	0	\vdash		8.34
MWDIAR11	40		3.44	3.27	0.031	0.0\$4	111		0.74	0.51	8.36		1	10			7.86
MWDIARIS	60		3.44	2.92	180.0	0.044	101		0,74	0,56	1.36		1	20			7.57
MWDIAR15	60 60		3,44	2.66	180.0	0.038	111		0.74	0.56 0.47	1.36	 		30	ļ		739
MWDIAR15	60	 	3,64	2.33	181.0	11,1131	1(1	 	0.74	0.47	1.36	 		40 50	-		7.10
MWDIARUS	60		3.44	217	0.041	11,043	111		0.74	B.6T	1.36		;	60			6.83
MWD/ABLIS	60		3,44	2.15	0,011	ri,034	III		0.74	0.72	1.36		1	70			6.78
MWDIAR15	60		3,44	2.02	0.011	0.025	111		0.74	Q.M.	1.36		1	(k)			6.69
MWDIARIS	-60		3.44	2.06	6,081	0.1/28	111		0.74	0.76	1,36	\vdash		90			6.61
MWDIAR35	60 60		3,44	1.88 7.81	0.081	0.1126 0.1128	111		0.74	0.58 0.64	8.36	 	1	100			6.54
MWDIARUS	60	-	3.44	1.77	9,021	0.1124	111		0.74	1,10	8.36	-	- i -	120			6.17
_MWDIAR15	60		3.44	1.64	0.081	0.027	. [1]		0.74	1.10	1.36		1	130			6.06
MWDIANS	40		3.44	1.65	0.011	0.031	111		0.74	1.30	1,36		1	140			6.00
MWDIAR35 MWDIAR36	60 60		3.44	1.64	0.041	0.1128	111		0,74	1.58	L36	<u> </u>	1	150			5.93
MWDIAR36	60	 -	322	3.20 2.98	0.064 0.064	0.051	107		0.43	D.48	E.10		1	10			7.70
MWDIAR36	G		3.22	2.60	0.064	0.047	107		9.43	U.30	K.10		· · · · · ·	20			7.58
MWDIAR36	和		3.22	2.69	9.064	0.1344	107		0.43	0.27	R.10		1	30	i		7.43
MWDIAR36	60		3.23	2.52	0.064	0.040	107		0.43	0.18	6.10		-	49			731
MWDIAR36	60 60		3.22 1.22	236	9.064	0.038	107 107		0.43	0.32	£10		1	50 60			7,19
MWDJAR36	60		3.22	224	0.064	0.035	107		9.43	0.25	E.10	_	- i -	70		-	7.25
IMWEDJAR36	60		122	2.17	0,064	0,034	107		0.43	0.27	R.10		1	#0			7.06
MWDIAR36	60		122	2.07	9,064	0.033	107		0.43	0.26	8.10			#0			6.95
MWDJAR36 MWDJAR36	60		3.22	2.02 1.98	0,064	0.035	307		0.43	0.27	£10	<u> </u>	-	300	ļ		6.86
MWDIAR36	60	\vdash	1.22	1.75	8.964	0.026	107		0.43	0.45	8.10 8.10	 -		110 120			6.78
MWDIAR36	60		1.22	1.74	0.064	0.026	107		0.43	0.36	1.10			130			6.56
MWDIAR36	60		1.22	1.73	10,064	0.027	107		0.43	4.38	8.10		1	140			6.58
MWDIAR36	60		1.22	1.75	0.064	0.026	107		9.43	0.42	8.10		1	150			6.49
MWDIAR36 MWDIAR36	60		3.22 3.22	1.20 1.70	0,964	0.025	107 107		0.43	0.35	1.ta 1.ta	-		160			651 634
MP/DIARJ6	60		3.22	1.71	0.004	0.037	lat		0.43	0.87	1.10	 	- i	180	 - 		621
MOVDMARIS	60		3.22	1,64	0.064	0.050	107		0.43	1.13	A.10		_	190			6,13
MWDIARS?	60		2.56	2.63	0.939	0.6)1	109		0.41	0,70	L)5	<u> </u>	-	0			2.35
MWDIAR37 MWDIAR37	60 60	 	2.56	2.49	0.039	0.036	109	 	0.12	0.56 0.52	LIS LIS	-	1-1-	20	 		7,95
MWDIAR17	60		2.56	2.33	0.039	0,000	109		DAR.	0.3Z 0.3ti	K.IS	 		30	 		7.57
MWDIAR37	60		2.56	2.22	0,039	0.024	109		0.14	0.51	E.15		1	40			7,40
MWDIAR37	60		2.56	1,07	0.039	0,023	109		0.03	0.54	K.15		1	\$0			7.29
MWDJARJ?	60		2.56	1.14	0.039	0.021	109		O.BS	0.56	8.15 8.15	1	1	70			7.25
MWDIAR37	60	 	2.56	1.81	0.039	0.019	109	 	0.68	0.65	E.15	 	1	#0 #0	 		7.01
MWDJAR37	60		2.56	1,63	0.039	0.015	109	L	0.88	0.67	E.15		1	90			6.96
MWDJAR37	60		2.56	1.61	0.039	0.016	109		13.00	0.16	8.15		1	100			6.88
MWDIAR37	60	<u> </u>	1.56 2.56	1.58	0.039	0.015	109		38.0	0.86	8.15	-	3	110	 		6.76
MWDIAR37	50 60		2.56	1.42	0,039	0,017	109	 	28,0	0.95	1.15	1	 ; -	130	 	·	6.56
MWDJAR37	60		2.56	1.38	8,039	0.015	109		0.22	ILB?	1.15		1	140			6.39
MWDJAR37	6N		2.56	1,37	(1.1139	6,613	103		0.53	1.00	1.15			150			6.36
MWDJAR37	60	 	2.56	1.39	0.039	0.015	109	├	0.32	1,00	1.15 1.15	1	1	150	 		6.23 6.23
MWEHARIT	60	 	2.56	1.33	Q,039 Q,049	0,014	109	 	0.24	9.76	4.13	 		0	 		3.14
MWDIARS	60		2.49	2.35	6.049	0.035	110	i	0.14	6.53	LD		1	10			7.74
MWDIARIS	60		2.49	2.12	0.049	0.027	110		0.84	0,39	1.13			20			7,44
MWDIARIE	60		2.49	1.92	9.047	0.023	110		0.84	0.33	8.13	1	1	30			7.29
MWDIARIE	60	ļ	2.49	1.86	0.049	0.020	110	-	0.84	0.45	8.13	-		- ¢0 - 50	 		7,31
MWDIARJE	60	 	2.49	1.80	0.049	0,010	LID	 	0.84	0.41	8.(3 8.13	+	 }	60	 	 	6.91
MWDIARUE	60	1	2.49	1.62	0.049	0.018	110		0.84	0.63	8.13		i	76			6,87
MWDIARIR	60		2.49	1.51	0.149	0.017	110		U.S.4	0.49	8.0		1	30			6.15
MWDIARJE	60		2.49	1,47	0.049	0.017	110		0.84	0.54	2,()	-	1 -1 -	90			6.79
MWDIARUS	60		2.49	1.31	0.049	0,014	110	-	0.84	D.83	L13	+	1	110		 	6.59
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MWDDARRS 50 2.55 2.14 0.057 0.041 94 0.34 0.19 7.99 1 30 7.39 MWDDARRS 50 2.53 1.07 0.057 0.033 94 0.34 0.20 7.99 7 40 40 7.39 MWDDARRS 50 2.55 1.56 0.027 0.032 94 0.34 0.20 7.99 1 50 1 50 7.39 MWDDARRS 50 2.55 1.66 0.057 0.039 94 0.34 0.20 7.99 1 0.10 7.39 MWDDARRS 50 2.55 1.66 0.057 0.039 94 0.34 0.30 7.99 1 0.19 7.39 1 70 7.34 MWDDARRS 50 2.55 1.66 0.057 0.039 94 0.34 0.19 7.99 1 70 0.19 7.39 1 70 7.34 MWDDARRS 50 2.55 1.66 0.057 0.039 1 0.03 1																		
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MWIDMARS 50 2.55 1.86 0.037 0.032 94 0.34 0.20 7.93 1 50 7.29 MWIDMARS 50 2.55 1.74 0.037 0.030 94 0.34 0.20 7.93 1 0.0 0.0 7.24 MWIDMARS 50 2.55 1.69 0.097 0.028 94 0.34 0.19 7.93 1 0.0 7.24 MWIDMARS 50 2.55 1.69 0.097 0.028 94 0.34 0.19 7.93 1 7.0 7.24 MWIDMARS 50 2.55 1.67 0.097 0.028 94 0.34 0.19 7.93 1 7.0 7.24 MWIDMARS 50 2.55 1.67 0.097 0.026 94 0.34 0.10 7.93 1 80 7.15 1 7.0 7.24 MWIDMARS 50 2.55 1.60 0.097 0.026 94 0.34 0.20 7.93 1 9.0 7.15 1 7.0 7.24 1 7.0 7.25 1 7.0 7.25 1 7.0 7.25 1 7.0 7.0 7.25 1 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0 7.0																		
MWDDARAR 50 2.55 1.68 0.037 0.030 94 0.34 0.20 7.93 1 0.1 7.38 MWDDARAR 50 2.55 1.68 0.037 0.038 94 0.34 0.30 7.93 1 70 7.27 7.27 MWDDARAR 50 2.55 1.66 0.037 0.038 94 0.34 0.34 0.39 7.93 1 70 7.27 7.27 MWDDARAR 50 2.55 1.67 0.057 0.024 94 0.34 0.22 7.93 1 70 7.93 7.93 7.93 7.93 7.93 7.93 7.93 7.93																<u> </u>		
MYDIARRS 50 2.55 1.68 0.057 0.028 94 0.34 0.19 7.53 1 70 2.27 MYDIARRS 50 2.55 1.67 0.057 10.06 94 0.34 0.19 7.53 1 80 7.15 MYDIARRS 50 2.55 1.61 0.057 10.06 94 0.34 0.22 7.59 1 90 7.13 MYDIARRS 50 2.55 1.69 0.057 10.02 94 0.34 0.22 7.59 1 1 0.00 7.13 MYDIARRS 50 2.55 1.50 0.057 10.02 94 0.34 0.34 0.38 7.51 1 100 7.22 MYDIARRS 50 2.55 1.50 0.057 10.02 94 0.34 0.38 7.51 1 110 0.00 7.22 MYDIARRS 50 2.55 1.56 0.057 10.02 94 0.34 0.34 0.38 7.51 1 120 6.55 MYDIARRS 50 2.55 1.56 0.057 10.02 94 0.34 0.34 0.37 7.51 1 120 6.55 MYDIARRS 50 2.55 1.56 0.057 10.00 94 0.34 0.34 0.32 7.51 1 120 6.55 MYDIARRS 50 2.55 1.56 0.057 10.00 94 0.34 0.34 0.32 7.51 1 120 6.55 MYDIARRS 50 2.55 1.56 0.057 10.00 94 0.34 0.34 0.32 7.51 1 100 6.51 MYDIARRS 50 2.55 1.56 0.057 10.00 94 0.34 0.34 0.34 7.53 1 1 100 6.51 MYDIARRS 50 2.55 1.57 0.057 10.00 94 0.34 0.34 0.75 7.51 1 100 6.51									<u> </u>				\vdash			ļ		
MWDDARRR 50 2.55 1.61 0.057 0.024 94 0.34 0.22 7.93 1 50 7.15 MWDDARRR 50 2.55 1.61 0.057 0.024 94 0.34 0.22 7.93 1 50 7.13 1 50 7.13 MWDDARRR 50 2.55 1.59 0.057 0.027 0.023 0.44 0.34 0.22 7.93 1 1000 7.13 MWDDARRR 50 2.55 1.59 0.057 0.027 0.42 0.40 1.038 7.91 1 1000 7.12 1.									ļ							<u> </u>		
MWDDARR8 50 2.55 1.61 0.057 0.024 94 0.34 0.22 7.51 1 90 7.13 MWDDARR8 50 2.55 1.49 0.057 0.023 94 0.34 0.40 7.91 1 100 7.02 MWDDARR8 50 2.55 1.55 0.057 0.022 94 0.34 0.34 0.42 7.91 1 100 7.02 MWDDARR8 50 2.55 1.56 0.057 0.022 94 0.34 0.42 7.91 1 120 6.30 MWDDARR8 50 2.55 1.56 0.057 0.02 94 0.34 0.42 7.91 1 120 6.30 MWDDARR8 50 2.55 1.56 0.057 0.02 94 0.34 0.42 7.91 1 130 6.30 MWDDARR8 50 2.55 1.66 0.057 0.057 0.050 94 0.34 0.42 7.91 1 130 6.35 MWDDARR8 50 2.55 1.66 0.057 0.057 0.050 94 0.34 0.47 7.95 1 130 6.35 MWDDARR8 50 2.55 1.67 0.057 0.057 0.050 94 0.34 0.47 7.95 1 1.00 6.35									<u> </u>									
MWDDARRS 50 2.55 1.69 0.957 0.033 0.4 0.34 0.40 7.91 1 100 2.02 MWDDARRS 50 2.55 1.55 0.037 0.022 0.4 0.34 0.34 0.38 7.91 1 130 0.455 0.45																		
MWDIARR 50 2.55 1.55 0.037 1827 94 0.34 0.38 7 97 1 110 4.95 MWDIARR 50 2.55 1.58 10.97 10.922 194 0.34 0.42 7.93 1 130 4.50 MWDIARR 50 2.55 1.56 0.057 10.90 94 0.34 0.42 7.93 1 130 6.51 MWDIARR 30 2.55 1.47 0.057 0.920 94 0.34 0.44 7.95 1 130 6.53 MWDIARR 50 2.55 1.47 0.057 0.920 94 0.34 0.42 7.95 1 130 6.53 MWDIARR 50 2.55 1.47 0.057 0.920 94 0.34 0.20 7.95 1 100 6.63 MWDIARR 50 2.55 1.47 0.057 0.920 94 0.34 0.20 7.95			ļ						<u> </u>							 		
MWDIARAH 50 2.55 1.58 0.037 0.022 04 0.34 0.42 7.91 1 120 6.50 MWDIARAH 50 2.55 1.56 0.037 0.021 0.04 0.34 0.42 7.92 1 130 6.50 MWDIARAH 50 2.55 1.56 0.037 0.002 0.000									-				 					
MWDIARAR 50 2.55 L54 0.057 0.101 94 0.34 0.42 7.93 1 130 6.61 MWDIARAR 50 2.55 1.49 0.057 0.000 94 0.34 0.44 7.93 1 1min 6.55 MWDIARAR 50 2.55 1.47 8.037 0.020 94 0.34 8.70 7.93 5 150 6.44			<u> </u>										 -					
MWDIARAN 50 2.55 (49 0.057 0.000 94 0.34 0.44 7.93 1 1mm 6.55 MWDIARAN 50 2.55 (47 0.037 0.020 94 0.34 0.70 7.93 9 150 6.44			—										\vdash				ļ	
MWDIAR68 50 2.55 1.47 0.657 0.020 94 0.34 0.70 7.93 1 150 6.44									 									
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Stores 10	144	4	TO	·		V-254	276-1	ain.	Tarab.	of inc.				2		41aaa	
Study ID	% CRW	% SPW		p/L)		Y-254 (/cm)	Aikai (mg/L as		Turb		- pt	•	Coagulant	Dose	tation Cond	itions Base	Cosg.
			Rime	FIR.	Rew	Filt.	Raw	Filt	Raw	Filt.	Raw	Pitt.	10		ed usted?	adjusted?	pН
· ·											<u> </u>		(see above)		(Y/N) blankeN	(YAN)	0
MWDJAR49		100	2.13	1.36	0.977	0,074	73			0.85	8.07	_	1	a	CERTIFICATE	blankeN	1.07
MWDJAR49		LOC	1.11	2.20	0.077	0.064	73			0.57	\$.07		1	10			7.65
MWDIAR49		100	1,33	2.19	0.077	0.050	73			11.75	\$.07		1	20			7.41
MWDIAR49		100	2.33	1.54	0,077	0.046	7)	-		0.56 11.72	8.07 8.07		1	<u>10</u>			7.24
MWIJIAR49		100	133	1.75	0.077	0,040	. 73	_		11.72	8.07		 	50			7.15
MWDIAR49		100	2.33	1.72	0.077	0.040	Ħ			0.53	11.07		1	60			7.gn
MWDIAR49		100	2.33	1.78	לדעח	0.037	77			0.47	8.07		1	70			6.87
MWDJAR49 MWDJAR49		100	2.33	1.42	0.077	0.035 0.035	73			R.47 D.57	8.07 8.07		1	90			6.73
MWDIARAS		100	2.33	1.54	0.077	0.1130	73			12.56	8.07		1	100			6.58
MWDIAR49		100	2.33	131	0.077	п.п28	7)			12,60	8.07	, i	1	LID			6.45
MWDIAR49		100	2.33	1.30	0,077	0.1134 0.1131	73			0.45	8.07 8.07		1	130			6.38 6.23
MWDIAR49		100	2.33	1.20	0.077	U.D21	73			0.65	E.OT		1	140			6.14
MWDIARS	100		2.37	2.40	0.043	CLIMI	(3)		0.76	0.51	8.23		1	6			8.23
MWDIARS	100		1.37	2.27	0.048	CLIMS	131		0.76	0.57	123	_		30			7,59
MWDIARS	[6U 003	 	2.37	2.19	0.048	0.U34 U.036	131		0.76	0.47	123		1	20 30			7.66
MWDIARS	100		2.37	2.07	D.049	0.033	[31		0.76	0.61	1.1)		- i	40			7.52
MWDIARS	190		2.17	1.96	0.044	0.029	131		0,%	0.46	1.2)			50			1.44
MWDIARS	100	 	1.17	1.94	(1,648	0.028	131	 	0.76 0.76	0.71	123 123	├	1 1	70		-	7.36 7.25
MWDIARS	100	l	1.37	1.77	0.041	0.025	131		11.76	0.82	123		1	20 20		-	7.16
MWDIARS	100	<u> </u>	1.37	1.75	0.041	0.004	131		0.76	0.65	123		1	90			7,05
MWOJARS	100	-	2.37	1.68	0.042	0.015	131		1.76	0.84	1.2)	H	1	100			7.06
MWDJARS	100	100	2.37 3.99	1.65	Q.1148	0.109	131 77		0.76 1.7	1.50	8.00	-	1	110		ļi	6.97 8.00
MWDIARIO		100	3,90	169	1110	0.072	77		1.7	4,79	8,00		-	LO .			7.44
MWDIARIO		LOO	3.90	3.17	0,110	0,049	77		1.7	11,39	2,00		1	20			7.15
MWDIARIO MWDIARIO		100	3.90	2.81	0.110 0.110	0.037	TT TT		1.7	11,78	2,00	\vdash		30			6.99
MWDIARSO		100	3,90 3.90	1.25	11,110	0,032	77		1,7	U.31	\$.00 \$.00		1	40 50			6.92 6.89
MWDIARSO		tgo	3.99	2.16	0.110	0.924	π		1.7	0.40	E(00)			60			6.66
MWDJARSO		100	3,90	2.06	0,110	0.020	77		1,7	D.\$B	8.00		1	7.1			6.45
MWDJAR50 MWDJAR50		Ino	3.90 3.90	1.99	U110	0.021	77		1.3	0.63	8.00		1	90 90			6.14
MWDIARSO		100	3.90	2.03	0.110	4.014	77		13	1.10	8.0D	-	1	100			5.93
MWD/AR50		[00	3.90	1.50	0.110	11,1126	77		1,7	(1,90	1,00		1	110			5.70
MWDJARSI		100	3,09	3.17	0.097	0.103 0.077	81		0.83	2.30	7,10		1	0			1.86
MWDIARSI		100	3.09	2.94 3.18	0.097	11177	EL EL		0.85 0.85	0.33	7.80 7.80		1	1D 20			7.3E
MWDIARSI		100	3.09	2.97	0.097	(L)I/6	1		0.85	0.40	7.80			30			7.14
MWDIAIGI		100	3.09	2.42	0.097	TLU54	u		CLES	0.29	7.20		1	40			T,06
MWDIARSI		100	3.09	2.15	0.097	0.849 0.851	EI EI		0,85 0,85	9.45	7,30	-	1	50 65			7,00 6,97
MWDIARSI		100	3.09	2.32	0.097	0.044	81	-	0.85	034	7.90	\vdash		79			6.77
MWDJARSL		100	3.09	2.31	0,097	U,040	\$ì		0.05	0.31	7.90		1	\$0			4.66
MWDJARSI		100	3,09	2.33	0.097	1.039	BI		0.85	9.31	7,80	_	1	8			6.57
MWDIARSI		100	3.09	2,62 1.94	0.097 0.097	0.036	\$1 		0.85	0.31	7,80 7,80	-	1	100			6.43 6.35
MWIMARSI		100	3.09	1.74	9,097	0.038	11		0.965	0.35	7,20			120			6.33
MWDIARS		100	3.09	1.91	0.097	0.035	L)		0.85	0.30	7.80		1	130			6.25
MWDIAR52 MWDIAR53		100	2.78 2.78	2.94 2.31		0.0KU			0.71	0.77	7.72 7.72		1	10°			7.91
MWDJARS2		[00	2.78	1,40		0,051			11.79	0.36	7.72			30			7.33
MWD2AR52		(00)	2.72	2,09		0.042			0.71	0.31	7.72		1	30			7.14
MWDIAR52		100 100	2.78 2.78	1.95		6.04D 0,014			0,78	0.33	7.72	\Box	1	40			7.11
MWDIARSZ		100	2.72	L.75		0.031			0.78	0.32 0.37	7.72	H	1	50 60			6.92
MWDJAR52		100	2.78	1.64		0.02 ₹			山78	0.47	7,72		1	70			6.84
MWDIARS2		100	2.78	1.52		0.026 0.024			0.78	0.64	7.72	\Box		\$13 20			6,71
MWDIABS2		590 691	2.78	1.49		оддз 0.025			0,78	0.50	7.72		1	98			6.63 6.58
MWDIARS2		100	2.78	1.43		0,1124			1173	0.50	7.73		i	110			6.43
HWDIARS2		100	2.78	1.36		0,023			0.78	4.52	7.72		1	120			6.34
MWDIARS2 MWDIARS2) (00 100	2.78	1.29	<u> </u>	0.023 0.024	·		11.78 11.78	0.65 1.00	7.72	H	1	130			6.21
MWDJAR53		100	2.25	2.40	U.065	OH)	79		(.10	0.33	7.93		1	۵			7,94
MWDIAR53		IQI	2.25	2.24	0.065	6.046	79		1.10	6.41	7,94		1	18			7.54
MWDJAR53		100	2.15	1.98 2.06	0,065	0.031 0.021	79		1.10	Q.40 0.31	7,90 7,91	\square	1	30			7.33 7.13
MWDJAR53		100	125	1.59	0,065	0,021 0.017	79		1.10	0.42	7.91	H	1	48	-		7,13
MWDJAR53		100	1.25	1.75	0.065	ðiu.o	79		1.(0	0.44	7.98		1	50			6.97
MWDJAR53		100	3.25	1.45	0.065	11110	79		1,49	0.59	7.91	ш	1	4			6.67
MWDIARS)		100 180	2.25	1.38	0.065	OTKIA	79 79	 -	1.10 1.10	0.74	7,98	$\vdash\vdash$	1	79 U2			6.61 6.34
MWD3AR13		100	2.25	1.43	0.065	thing?	75		1.10	0.59	7.91			90			6.46
MWDJAR13		100	2.25	1.21	0.065	0.006	79		1.10	ti.90	7.94		1	100			6.33
MWDIARS1		100	2.25	1.19	0.065	10,0006	79		1.10	0,90	7.98	\vdash	1	110			6.29
MWDJAR54 MWDJAR54		100	2.92	3.21 2.91	0.087	11,170	72		0.52 0.52	0.35 0.70	7.27	├─┤	1	() (9			7,90
MWDJAR54		(90	2.92	1.33	0.087	(LOS)	72		Ц.52	8.54	7.57		i	20			7.54
MWDIARS4		100	2.92	1.55	0,007	0,843	72		ILS2	0.52	7,57		1	30			7.35
MWDJAR54 MWDJAR54		100	2.92	2.05	11.087	0.039	72 72		0.52 FL52	0.47	7.87	┝┯╡	1	48 56			7,15 7.11
MWDJAR54		100	2.92	1.63	0.047	0.037	72		ILSZ	0.45	7.57	\vdash	1	60			6.87
MWDJAR54		100	2.92	1.41	11.007	0.025	72		0.52	0.49	7.57		1	70			6.85
MWDJAR54		100	2.92	1.55	11.007	0.022	72		61.52	0.45	7.77	ЩĪ	1				6,72
MWDJAR54		100	2.92	1.44	0.087	0.015	72 72		0.52	0.57	7,57		1	96			6.49
MWDJAR54		Inci	2.72	1.38	J1 1987	0.014	72	\vdash	11 52	0 54	137	\vdash	- i -	110			6.37

Study (D		ther'	10	C	U	V-284	Alte	limity	Turt	idity		H		Cone	ulation Cond	WI	
	% CRW	% SPW	(m	راره ا	1 .1	Ucm)	(dig/L as	Caccas		TUI	1-5		Congulant	Dese	Acid	Base	*
			Raw	Fill	Raw	Fik.	Raw	FBL	Raw	Filt.	Rew	File	10		adjusted?	adjusted?	Coag
										1		1	(Bee shove)		CYAN	(Y/N)	P 7
							1					 			blankeN	Diank-N	v_
MWDIAR54		100	1.72	1.36	0,007	0.014	72		0.52	0.61	7.57	 	 	120	Dentify-14	federif-44	
M9TDIARS4		100	2.12	1.27	0.007	£10.0	73	——	0.52	0.64	7.87	 	-	136	 		6.12
MWDIARS		100	191	1.22	0.017	0.014	72		0.52	0.11	7.57		 	140	-		6.00
MWDIAES		100	2.92	1.25	0.097	0.014	72	$\overline{}$	0.52	0.91	7.87	╄	 	150			5.93
MWDIARSI		100	1.92	1.23	0.047	0,021	72		0.11	1.30	727	+	 	160	 		5.69
MWDIARSS		100	2.61	2.65	0.006	0.083	62		0.72	0.55	722	_		190	-		5.51
MWDIARS		100	26	2.43	0.006	0.061	- 62		0.72	0.42	732	┼—	 	10			7,77
MWDIAR55		100	2.64	2.24	0.086	0.051	62		0.72	0.74	792			20			7.52
MWDIAILS		loc .	2.68	1.06	0.066	0.040	62		0.72	0.24	7.82	 			 		7.35
MWDMAR15		100	2.63	1.76	0.006	9.036	- 0		0.72	0.29	732	┼──					7.18
MWDIARIS		100	2.61	L76	0.006	0.012	62		0.72	0.30	722	-		40 50			7.12
AIWDIARIS	-	100	2.63	1.59	0.006	0.030	0		9.72	0.23	7.02	┪┈─			 		7.20
MWDIALLS		100	2.63	1.40	9.086	0.029		_	9.72	0.24	7.52		 } 	60			7,03
MWDJAR45		100	2.68	1.45	0.086	0.027	-		0.72	0.25	7.12	 	 	70	<u> </u>		6.97
MWDJAR35		too	2.62	1.40	0.086	0.024	- 62		0.72	0.31	7.12	ļ	 				6.84
MWDIARSS		1.00	2.62	1.34	0.096	0.003	62		0.72	021	7.82	 -	├── ┆──┥	100			6.67
MWDIARSS		too	2.61	LA7	0.086	0.024	62		0.72	0.74	720	_					6.50
MWDIARSS		100	2.61	1.31	0.086	0.024	6	-	0.72	6.44	7.82	 		110			6,45
MWDIARS		100	2.69	1.34	0.006	0.021	42	_	0.72	0.63	7.55	-	 	130			6.10
MWDIARIS		100	2.64	133	0.086	0.032		_	0.72	9.50	7.53			140	 		5.95
MWDJAR55		100	2.64	1.30	0.086	0.022	- 62	-	0.72	0.72	731			150	ļ		5.13
MWIMARSS		100	2.69	1.32	0.096	0.021			0.72	0.72	7.81			160			5.52

Utility ID:																	
~~~~ 1			·		MW	D		(ACWD, C	CWD, E8	MUD, M	ND, SCV	WD)					
				1						·							
1. Study ID:					C Stud	y Data		(Optimizal	ion Study	9/95, etc.	.)						
2. Source water	C.				SPW/	CRW		(River, lak	e, ground	water, etc	٤.)						
										لـــــــــــــــــــــــــــــــــــــ							
3. Source water	r ID:					L,		(State Pro	ject water	, blend of	etc.)						
																	<u> </u>
5. Describe lev	el of stud	y:		Bench-	cale		in this dau										<u> </u>
(indicate with a	in 'X')			Pilot-sc	ale .		efter coage	ulation, fic	occulation	ı, sedime	ntation,	and					
<del>'                                      </del>			×	Full-sc	ıle :		filtration.										<u> </u>
<del> </del>																	
6. Indicate with	an X if c	ata repo	rted as "	Filt." an	from s	amples co	lected after	sedimen	tation on	γ.							
							or afte	e sedime	ntation <u>ar</u>	<u>id</u> filtratio	on:					<u> </u>	<u> </u>
WATER QUA	ALITY D	ATA: C	ONVEN	ITION	\L												
BEX ICIT GOV																	
Study ID	Wa	er	TO	ic	11	V-254	Aikai	inity	Turb	idity	pl	-	Temp	erature			1
Study ID	SPW	CRW	(mg			l/cm)	(mg/L as		(N)		- 1		(de	ig. C)			Fi
	3741	URIT	Raw	FUL	Raw	File	Raw	FIL	Raw	FUL	Raw	FIL	Raw	Filt.	dicate di	sinfectant	Chlorine
			1/4/4	100	1444				7,227	1					used v	dth an 'X'	dose
				<del> </del>		<u> </u>	<del>                                     </del>										(mg Cl2/L
MWDODPI	×		2.45	1,88	0.073	0.026	74	· -	2.10		8.90		11.2		0.5 mg/L (	72 thru floc t	esin; I.7 mg/
MWDODPI	<del>x</del>		2.41	1.86	0.069	0.020	74		2.10		8.20		10.3		0.5 mg/L (	12 thru floc t	atin; 1.7 mg/
MWDODPI	<del>-</del> î		2.11	1.71	0.068	0.026	74		2.30		1.10		10.1		0.5 mg/L (	12 thru floc b	esin; 1.7 mg
MWDODPI	x-	<del></del>	2.28	1.70	0.064	0.024	74	1	2.00	T	E.00		10,9	L	0.5 mg/L (	12 thru floc i	esia; 1.7 mg
MWDODPI	- x	<del>                                     </del>	2.48	1.80	0.073	0.026	74		1.80		8.50		10.8				busin; 1.7 mg
MWDODP1	x	<del> </del>	1.26	1.35	0.070	0.027	78	<u> </u>	0.93	1	7.95		11.5			12, 1 hr @ 2	
MWDODP2	x		231	1.43	0.068	0.028	78		1.60		7.96		10.8			12. l hr@2	
MWDODP2	x		2.34	1.59	0.065	0.030	78		1.50		8.03		11.0			12.1 hr@2	
MWDODP2	×		2.21	1.42	0.069	0.028	78		1,20		7.92		11.2			12, Ihr@/2	
MWDODP3	X		2.47	231	0.036	0.036	131		0.98		8.30		12.0			112, lbr@2	
MWDODPI	X		2.51	2.08	0.036	0.027	131		0.80	<u> </u>	8.41		12.0			312, Ibr@i2	
MWDODPI	X		2.31	1.90	0.033	0.024	131		0.88		B.34		11.5	<u> </u>		⊐2,lbr@:2	
MWDODP4	Х		2.05	1,10	0.033	0.014	131		0.76		B.33		12.0	ļ <u> </u>		112,1 br@12	
MWDODP5	Х		2.27	2.24	0.076	0.071	\$1		1.40		8.60	<u> </u>	11.7			112, 1 hr @ 2	
MWDODP5	X		2.42	1.98	0.078	0.070	<b>\$1</b>	1	1.30	ļ	8.63	<u> </u>	11.7			.12, 1 hr @ 2	
MWD0DP!	X		2.78	1.95	0.087	0,044	70		1.90		7.97		9.3	<u> </u>		C12, 1 hr @ 2	
MWDODPS	X		2.43	1.82	0,074	0.044	81	T	1.40	<u> </u>	8.69		11.7			C12, 1 hr @ 2	
MWDQDP5	X		2.71	1.81	0.079	0,036	75		1.48		8.46		10.9	<u> </u>		CD2, 1 hr @ 2	
MWDODPS	×		2.64	1.65	0.074	0.028	75	<u> </u>	1.20	<u> </u>	8.41	<u> </u>	11.2	<u> </u>		C12, 1 hr @ 2	
MWDODP5	X		2.76	1.63	0.083	0.023	70		1.80	<u> </u>	7.91		9.1	<u>                                     </u>	<del></del>	C12, 1 hr @ 2	
MWDODPS	X	Ι	2.28	1.59	0.068	0.039	81	<u> </u>	1.60	ļ	8,70	<u> </u>	11.8	<b>!</b>		C12, [hr@/2	
MWDODPS	X		2.62	1.62	0.077	0.027	75	<u> </u>	1,30	<u> </u>	8.53	<u>.                                    </u>	11.1	<u> </u>		C12, Ihr@ 2	
MWDODP6	X		2.65	1.8B	0.072	0.030	76	<u> </u>	2.10	-	8.44	<del> </del>	11.0	<del>                                     </del>			i hr@ 25oC
MWDODP6	X	<u> </u>	2.62	1.68	0.080	0.024	76	<u> </u>	2.00	<del> </del>	8.37	<del> </del>	10.9	<del>├</del>			I har @ 250C
MWDODP6	X		2.67	1.51	0.078	0.01\$	70	ļ .	2.10	<del>  .    </del>	8.01 8.37	<del> </del>	11.0	<del>                                     </del>			1 hr @ 25oC
MWDODP6	X	ļ	2.70	1.25	0.066	0.012	76		1.90	+	8.46	<del> </del>	11.1				1 hr @ 25oC
MWDODP6	X		2.62	1.38	0.074	0.019	75	<del> </del>	1,20	<del> </del>	7.97	<del>                                     </del>	9.2				1 hr @ 25oC
MWDODP6	X	<u> </u>	2.76	1.24	0.076	0.014	70 76	-	2.20 1.80	<del> </del>	8.31	+	10.9	<del>                                     </del>			1 hr @ 25oC
MWDODP6	X		2.67	1.19	0.080		76	<del> </del> -	0.55	┽──	7.90	<del>                                     </del>	11.7	<del>                                     </del>		C12, 1 hr@ 2	
MWDOPI	92-99%	<b>_</b>	2.94	2.71	0.084	0.064	<del>  '8</del>	+	0,50	+	7.83	†	12.1	<del>                                     </del>		C12, 1 hr @ 2	
MWDOPI	92-99%		2.77	2.37	0.088	0.062	71	<del>                                     </del>	2.20	+	8.05	<del>                                     </del>	9.2	1		C12, 1 hr @ 2	
MWDOPI		<del> </del>		2.17	0.043	0.060	<del>  ''-</del>	-	1.50	1	7.96	†	10.2			C12, 1 hr @ 2	
MWDOPI	92-99%	-	2.59 2.84	1.46	0.084	0.022	71	-	1.60	<del>1"</del>	8.27	1	10.6	1		CI2, i hr@2	
MWDOPI MWDOPI	92-99%		2,60	1.42	0.083	0.027	72	<del>1</del>	1.50	<del>                                     </del>	8.14	1	11.3			C12, 1 hr @ 2	
MWDOPI	92-99%	+	2.74	1.53	0.078	0.022	<del>                                     </del>	1	1.80	1	8.55	T	12.6			C12_1 hr@:2	
MWDOPI	92-99%		3.30	2.02	0.091	0.036	1	1	3.10	1	9.22		14.9			C12, 1 hr @ 2	
MWDOPI	92-99%		3.20	1.99	0.099	1	75	1	2.10		8.60		13.5			C12, 1 br@ 2	
MWDOPI	92-99%		3.43	2.03	0.103	0.039	77	1	1.75		8.51		14.3			C12, i hr@ 2	
MWDOP1	92-99%		2.73	1.58	0.072		73		0.72		7.83		11.3	1		Cl2, I hr@:	
MWDOP2	92-100%		3.46	3.01	0.108		80		1.60		8,36	<u> </u>	17.4			C12, 1 br @ 2	
MWDOP2	92-100%		3.37	2.99	820.0	0.063			2.00		8.14	<u> </u>	17.5	↓		C12, 1 br @ 2	
MWDQP3	92-100%		3.26	1.93	0.111				1.55		8.34	ļ	16.6	<del> </del>		C12, 1 br @ 2	
MWDOP3	92-100%		3,49	2.07	0.120		78	1	1.60	<del></del> .	8.24	4	16.1	<del> </del>		CD2, 1 hr @ 2	
MWDOP3	92-100%		3.53	2.07	0.111		79		1.80	<del></del>	8.18	╄	16.6			C12, 1 hr @ : C12, 1 hr @ :	
MWDOP3	92-100%		3,67	2.12	0.115			1	1.60		8.24	<del> </del>	16.2			Ciz, I hr @ .	
MWDQP3	92-100%		3.05	1.85	0.100			<del> </del>	2,10	-	7,99	<del> </del>	21.1			Ciz, I hr@	
MWDOP3	92-100%		3.29	1.81	0,104		80	<del> </del>	2.70	+	8.03	<del> </del>	18.9			Cl2, 1 hr @:	
MWDOP1	92-100%		3.20	1.85	0.102		1	<del> </del>	2.90	+	8.09	+	18.8			C12, 1 hr @	
MWDQP3	92-100%	4	3.17	1.85	0.103		81	-	2.70	+	7.15	<del> </del>	21.7			esid, 1 hr, 25	
MWDOP4	X	Ļ	3,54	3.60	0.106		85	+	1.49	+-	7.85	+-	21.7			sid, 1 hr, 25	
LALMON.	X	↓	3.54	3.80	0.106		85	<del> </del>	1.49	+	7.85	+	21.7			sid. 1 hr. 25	
MWDOP4	-		3.54	3.50	0.106	0.091	85	1	1.49								
MWDOP4	X	<del> </del>			-		- 44		1 34	T	705		1 717		[ ] gre/) v	estin Inr. 23	UL
	X X		3.54 3.54	2.86 3.0i	0.106		\$5 \$5	1	1,49		7.85 7.85	╁—	21.7			esid, 1 hr. 25 esid, 1 hr. 25	

Study ID	Wa		T	ÖC -	Ü	V-254	Alka	inity	Turk	idity						
	SPW	CRW	(m	g/L)	(1	/cm)	(mg/L as			TU)	<u>PI</u>			HERATUKE		
	l		Raw	Füt.	Raw	Filt.	Raw	Fig.	Raw	Filt.				g. C)	<del> </del>	
	<u>.</u>	·					<del>                                     </del>	<del></del> -	- CAW	FIR.	Raw	Filt	Raw	Filt.	dicate disinfectant	Chloris
				_					├	<del> </del>	<b> </b>		<b>-</b>		used with an X'	dose
MWDOP4	X		3.54	3.07	0.106	0.077	85	-	1.49						chlorine hioramin	
MWD084	X		3.54	3.02	0.106	0.069	85		1.49	<del></del>	7.85		21.7		1 mg/L resid, 1 hr, 25 o(	
MWDQP4	X		3,54	2.55	0.106	0.055	85	<del> </del> -	1.49		7.85		21.7		1 mg/L resid, 1 hr, 25 of	
MWDOP4	Х		3,54	2.50	0.206	0.052	85		1.49		7.15		21,7		1 mg/L resid, 1 hr, 25 of	<u>:</u>
MWDOP4	Х		3,54	237	0.106	0.051	85		1.49		7.85		21.7		1 mg/L resid, 1 hr, 25 of	
MWDOP4	Х	-	3,54	2.23	0.106	0.045	85		1.49		7.85		21.7		1 mg/L resid, 1 hr, 25 oC	
MWDOP4	X		3.54	2.74	0.106	0.059	85	<del></del>	1.49		7.85		21,7		1 mg/L resid, 1 hr, 25 oC	
MWDOP4	Х		3.54	2.62	0.106	0.060	85				7.25		21.7		1 mg/L resid, 1 hr, 25 oC	
MWDOP4	Х		3.54	231	0.106	0.048	\$5		1.49		7,15		21,7		I mg/L resid, I hr, 25 oC	
MWDOP4	X		3.54	2.51	0.106	0.048	25		1.49		7.85		21.7		I mg/L resid, I hr, 25 oC	
MWDOP4	X		3.54	2.12	0.106	0.042	85		1.49		7.85		21.7		I mg/L resid, I hr, 25 oC	-
MWDOP4	X		3.54	214	0.106	0.037	85		1.49		7.85		21.7		I mg/L resid, I hr, 25 oC	
MWD0P4	X		3.54	2.18	0.106	0.059			1.49		7.85		21.7		i mg/L resid, 1 hr, 25 oC	
MWD0P4	X		3.54	2.57	0.106		85		1.49		7.85		21.7		1 mg/L resid, 1 hr, 25 oC	
MWDOP4	X	-	3.54	2.20	0.106	0.052	25		1.49		7.85		21.7		1 mg/L resid, 1 hr, 25 oC	
MWDOP4	X		3,54	2.05		0.046	<b>85</b>		L.49		7,25		21.7		i mg/L resid, I hr. 25 oC	
MWDOP4	x		3.54		0.106	0,037	85		1.49		7.85		21.7		I mg/L resid, I hr, 25 oC	
MWDOP4	- î		3.54	2.01	0.106	0.041	85		1.49		7.85		21.7		I mg/L resid, I hr. 25 oC	
MWDOP4	Ŷ			1.92	0.106	0.046	25		1.49		7.85		21.7		I mg/L resid, 1 hr, 25 oC	<del></del> -
MWDOPS	^-	x	3.54	1,78	0.106	0.033	85		1.49		7.85		21.7		1 mg/L resid, 1 hr, 25 oC	
MWDOPS		<del>- 2  </del>	2.44	2.12	0.039	0,031	131.5		0.65		7.7		24.6		1 mg/L resid, 1 hr, 25 °C	
MWDOPS		<del>-</del> Ĉ-	2.44	2.16	0.039	0.028	131.5		0.65		7.7	$\neg$	24.6		1 mg/L resid, 1 br. 25 °C	
MWDOPS			2.44	1,97	0.039	0.024	131.5		0.65		7.7		24.6		I mg/L resid, I hr. 25 °C	
MWDOPS		×	2.44	1,85	0.039	0.021	131.5		0.65		7.7		24.6		I mg/L resid, I hr, 25 °C	
MWDOPS		<del>- Ĉ  </del>	2.44	1,80	0.039	0.023	131.5		0.65		7.7		24.6		I mg/L resid, I hr. 25 °C	
MWDOPS			2.44	1.81	0.039	0.020	131.5	T	0.65		7.7		24.6		I mg/L resid, I far, 25 °C	
MWDOP5		X	244	1.99	0.039	0.024	131.5		0.65		7.7		24.6		I mg/L resid. I br. 25 °C	
MANOES	1	_ X	244	1.73	0.039	0.020	131.5		0,65		7.7		24.6		1 mg/L resid. 1 hr. 25 °C	

Contract to											-		
Utility ID:													<b>——</b>
								— — -					<b></b>
1. Study ID:													
											<u> </u>		
2. Source wat											ļ		
3. Source wat													—— <u> </u>
								Indicate coagu			<u> </u>		
5. Describe le								ID	oagula		l formula	Units	
(indicate with								1	Alum	Al _z (SO ₄ )		mg/L	LI
								. 2	Femc	FeCl ₁ *	6 H ₂ O	mg/L	l
								3					$\Box$
6, Indicate wit								4					
				<u></u>					Polymer	added: 2, 3	, 0.5 mg/L	T	
WATER QU								TREATMEN'	CONE	OITIONS			
	-				1	-							
Study ID				Diek	fection	Ву-ргос	lucte	<del>                                     </del>	Coagula	tion Coadi	tions	<del></del>	
audy io	ered			TTI			A5	Coagulant	Dose	Acid	Base	Coag.	Coag.
	mmoni	bubation t	Perkinal	(μg			g/L)	ID			adjusted?		temp.
	dose	(h)	140340000	Raw	Fift	Raw	FIR.	(see above)		(Y/N)	(Y/N)	0	(deg. C)
	g NH3-N		(mg Cl2/L)		1		1 //	(000		(vive)	1	<u> </u>	, , , , , , , , , , , , , , , , , , ,
MWDODPI	CI2 thru fi		thus come		40.6			1	40			7.00	
MWDODPI	C12 thru fi			-	70.0	<del>                                     </del>	<b>-</b>	<u> </u>	40			7.00	
MWDODPI	CI2 thru fi			<del>                                     </del>	35.1	ļ	30,1	<del> </del>	40		<del> </del>	7.00	<b></b>
MWDODPI	C12 thru fi		-		23.1		30.1	i	40		<del>  "</del>	7.00	<del> </del>
MWDODPI	C12 thru fi				37.2		31.7	i	40	<del> </del>	<del>                                     </del>	6.90	$\vdash$
MWDODP2	CJZ DIEB LI	I CELS			30.7		12.4	<del>                                     </del>	30	Y	<u> </u>	6.40	<del>                                     </del>
MWDODP2					32.9	<del> </del>	12.0	1	35	Y Y	<del></del>	6.46	$\vdash$
MWDODP2				<del></del>	35.8		14.4	i	40	Ŷ		7.03	
MWDODP2		<del></del>		<del></del>	29.9	<del>                                     </del>	12.2	<del> </del>	40	Y		6.56	<del></del>
MWDODP3				1	29.0	<del></del>	12.4	1-2	5	<u> </u>	<u> </u>	7.91	
MWDODP3	-	<del></del>			24.8	├──	11.0	2	10		<del> </del>	7.97	
MWDODP3	<del>                                     </del>			<del> </del>	20.5	<del></del>	10.6		25	<del></del>	<del> </del>	7.14	-
MWDODP4	<del> </del>	<del></del>			14,0		7.7	2	25	Ϋ́	<del></del>	5.59	
MWDODPS	<del> </del>			<del> </del>	45.5	-	19.3	2	5	<del></del>		7.90	
MWDODPS		<del></del>	<del></del>	┼	40.9	<del> </del> -	15.4	2	10			7.54	
MWDODP5	-	<del></del>	<del> </del>		35.4	<del> </del>	16.1	2	15			7.13	<del> </del>
MWDODP5	<del> </del>	<del> </del>	<u> </u>	-	33.9	<del>                                     </del>	14.0	2	20			7.23	<del>   </del>
MWDODP5		<del>                                     </del>		-	31.7	<del> </del>	19.3	2	20	<del> </del>	-	7.20	$\vdash$
MWDODPS	<del> </del>	<del> </del>	<del></del>		29.4	-	20.2	2	25		<del> </del>	6.97	
MWDODP5		<del> </del>	<del></del>		28.4	<del>                                     </del>	15.6	2	25			6,95	
MWDODPS	<del>                                     </del>	-	<del> </del>	<del> </del>	33,8	1	14.6	2	30		<del> </del>	7.18	
MWDODP5		<del></del>	<del>                                     </del>	<del>                                     </del>	26.1	<del>                                     </del>	15.3	2	30			6.26	
MWDODP6	<del> </del>	<del> </del>	<del>                                     </del>	<del> </del>	33.2	<del> </del>	17.8	- 2	10	Y	<del> </del>	6.98	
MWDODP6					28.4	<del>!                                    </del>	12.2	2	10	Y		6.24	
MWDODP6	<del> </del>		<del> </del>	<del> </del>	27.7	<del>                                     </del>	12.7	1 2	15	Y	<del></del>	6.25	
MWDODP6	<del> </del>	<del></del>	<del> </del>	<del>                                     </del>	21.2	<del> </del>	8.9	1 2	20	Ÿ		6.25	
MWDODP6		<del></del>	<del> </del>	<del> </del>	24.1		15.6	2	20	Y		6.15	
MWDODP6	<del>                                     </del>		-	<del>                                     </del>	22.3	<del>                                     </del>	11.8	2	25	Ÿ		6.15	<del> </del>
MWDODP6	<del>                                     </del>		-	<del>                                     </del>	20.3	<del>                                     </del>	9.0	<del></del>	30	Y		6.22	
MWDOPI	<b>†</b>		<del> </del>		50.8		25,9	1 2	3	<del> </del> -	<u> </u>	7.60	
MWDOPI	<del> </del>		<del> </del>	1	49.8	<del>                                     </del>	29.2	1	3		<del>                                     </del>	7.53	<b> </b>
MWDOP1		<del></del>		<u> </u>		1		1 2	5	<del> </del>	$\vdash$	7.56	
MWDOP1		<del>                                     </del>		1	48.6	1	22.8	2	5	i	1	7,53	
MWDOPI			<del>                                     </del>		28,3	1	16.2	1 2	30	· · · · · ·	1	6.86	
MWDOPI	<u> </u>		<u> </u>	<del>                                     </del>	28.2	1	14.5	2	30	<b>—</b> —		6.80	
MWDOPI					32.0		16,1	2	30	T	Ш,	6.77	
MWDOPI	<u> </u>		T	T	37.B	Г	16.9	2	30	L		7.09	
MWDOPI	· · · · ·			1	36.1	1	17.1	2	30			6,94	
MWDOPI			1		36.0		17.8	2	30			6.92	
MWDOPI	<u> </u>				31.4	Ī	14.3	2.	30		I	6.88	
MWDOP2			1		68.2		30.3	1	12	I		7,71	l
MWDOP2	J				66.5	L	29.5	1	12		l	7.65	
MWDOP3	I				43.0		16.9	1	40	Y		6.41	
MWDOP3	L				38.3	1	17.9	1	40	Y		6.41	
MWDOP3					41.4		17.0	l	40	Y		6.37	<u> </u>
MWDOP3					38.0	1	17.1		40	Y		6.33	ļ
MWDOPI				L	41.6		16.5	l l	40	Y	<u> </u>	6,43	1
MWDOP3					39.4		16.4		40	Y		6.34	
MWDOP3					39.9		18.2	ı	40	Y		6.33	<u> </u>
MWDOP3	<u> </u>			<u> </u>	36.7		16.4	l l	40	Y	ļ	6.31	1
MWDOP4					77.9	1	34.0	1	10	Y	<u> </u>	7.82	ļ
MWDQP4	1				75.7	Į <u> </u>	33.7	1	10	Y	ļ	7.71	<b>_</b>
MWDOP4					71.1		31.6	1	10	Y	<b> </b>	7.00	ļ
MWDOP4	1				59.6		25.1	1	10	Y	ļ	6.23	<del> </del>
MWDOP4	L				67.7	L	26.7	l	IQ.	Υ	<b></b>	5.41	ļ
MWDQP4	1	I	·	1	70.8		< 32.5	1 1	20	Y	1	7.65	<u> </u>

Study ID	1			Disir	ifection	Ву-ргос	tucts	-	Coagui	etion Condi	tions		_
	pred			П	HM _	H/	<b>A</b> 5	Coagulant	Dose	Acid	Base	Coag.	Coag.
	mmoni	bubation t	Residual	(PQ	/L)	<b>(</b> µ	1/L)	ID		adjusted?	adjusted?	pH	temp.
	dose	(h)		Raw	FIIL	Raw	Filt	(see above)		(Y/N)	(Y/N)	0	(deg. C
	g NH3-N	chlorine	(mg Cl2/L)										<u> </u>
MWDOP4					67,4		29.4	1	20	Y		7,17	i i
MWDOP4					62.7		< 23.9	1	20	Y		7.11	
MWDOP4					54.9		< 22.3	i	20	Y		6.34	T
MWDOP4					49,9		21.0	ı	20	Y		6,40	
MWDOP4					53.1		20.9	1	20	Y		5.52	
MWDOP4					52.2		22.4	1	20	Y		5.71	
MWDOP4					62.1		23.8	1	30	Y		7.26	
MWDOP4					63.5		<b>Q4.7</b>	i	30	Y	· · · · · · · · · · · · · · · · · · ·	7.05	<del></del>
MWDQP4					53.0		< 21.1	ī	30	Y		6.25	
MWDOP4	T				53.8		<20.1	<u> </u>	30	Y		6.50	
MWDOP4					48.1		<17,8	ı	30	Y		6.23	
MWDOP4					46.7		<b>41.5</b>	ı	30	Y	<del></del>	5.43	
MWDOP4	T				56.4		24.9	1	40	Y		6,97	
MWDOP4	1 -				57.3		25.3	ı	40	Y	i i	7.24	l
MWDQP4					52.4	,	< 21.5	<del></del>	40	Y		6,30	
MWDOP4	1				43.9		< 8,7	1	40	Y		6.19	
MWDQP4	1				45,9		< 18.0	1	40	Y		5.65	
MWDOP4	1				46.1		< 18.6	<u> </u>	40	Y	ii	5.74	
MWDOP4					43.6		<15.8	1	40	Y		5.42	
MWDOPS					22.2	1	11.7	]	18	Y		5.88	
MWDOPS			. •		22,0		14.7	1	20	Y		7.55	1
MWDQPS					18.7		11.1	1	20	Y		5.89	
MWDOP5	1				16.6		9,5	1	20	Y		6.50	1
MWDOPS	1		1		17.4	1	9.2	- 1	20	Y		5.75	
MWDOPS			<del>                                     </del>		17.5		< 10,6	1	20	Y		5,31	<del>                                     </del>
MWDOPS	<del> </del>				18.7		9.1	1	40	Y		6,90	
MWDOPS					16.3	<del> </del>	9.2	1	40	Y	<del>i 1</del>	5.53	

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0.00	4/25/04			0.63	17.3		0.57	12.24	7.16	
17.5   2.5   0.4   12.24     0.64   19.7   2.5   0.4   12.24     0.65   10.7   2.5   0.4   12.24     0.65   10.7   2.5   0.4   1.5     0.65   17.2   0.5   1.5     0.65   17.2   0.5   1.5     0.65   17.2   0.5   1.5     0.65   17.2   0.5   1.5     0.65   17.2   0.5     0.65   17.2   0.5     0.65   17.3   0.6     0.65   17.4   1.5   0.75     0.65   17.7   0.6     0.65   17.7   0.6     0.65   17.7   0.6     0.65   17.7   0.6     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.65   17.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.7     0.7   0.7   0.	4025/84			9	17.31		0.57	12.24	7.16	
10	P/16/14			7	17.5		0.4	12.24	7.85	
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