RISK SCIENCES

Strawman Proposals to Guide the Policy Discussion at the CV-Salts Executive Committee Meeting on 7/19/2012

Please review the white paper entitled: "Salinity Effects on MUN-Related Uses of Water" prepared by Dr. Richard Meyerhoff of CDM-Smith, Inc.

1) The existing numeric water quality objectives for TDS, chloride and sulfate should be deleted from the current Basin Plan.

A) These objectives are based on the recommended Secondary Maximum Contaminant Levels (SMCLs) and are only intended to address aesthetic concerns such as taste and odor.

B) These SMCLs were accidentally included (by reference) when the Basin Plan was amended to adopt water quality objectives for constituents with established Primary Maximum Contaminant Levels (PMCLs).

C) Most other Regional Water Quality Control Boards (#1, 3, 5, 6, 7 & 9) have not adopted the SMCLs as binding water quality objectives in their respective Basin Plans.

D) The Basin Plan already contains narrative standards regulating the discharge of wastes to prevent nuisance conditions including objectionable tastes or odors in drinking water supplies.

E) The degree to which specific levels of TDS, chloride or sulfate are acceptable to consumers depends on the specific form of the constituent (e.g. sodium sulfate vs. calcium-sulfate) and the presence or absence of other major anions and cations that may mitigate or aggravate the objectionable qualities.

F) The TDS, chloride and sulfate levels "recommended" in California's Secondary Drinking Water Standards are based on the lower threshold of detectable changes in taste.

G) The SMCLs were originally intended to govern the quality of delivered drinking water not discharges to receiving waters that may serve as raw water supplies for municipal distribution systems.

2) The Implementation chapter of the Basin Plan should be revised to indicate that the SMCLs will be used as one of several factors that the Regional Board will rely on to assess attainment of and compliance with the narrative objectives prohibiting nuisance (based on the following table):

Constituent	**Preferred Range**	**Acceptable Range** *(long-term consumption)*	**Tolerable Range** *(short-term consumption)*
TDS or Specific Conductance	≤500 mg/L or ≤900 uS/cm	501 - 1,000 mg/L or 901 - 1,600 uS/cm	1001 - 1,500 mg/L or 1,601 - 2,200 uS/cm
Chloride	≤250 mg/L	251 - 500 mg/L	501 - 600 mg/L
Sulfate	≤250 mg/L	251 - 500 mg/L	501 - 600 mg/L

A) Preferred Range =

B) Acceptable Range =

C) Tolerable Range =

3) Where the constituent concentrations in a discharge are greater than the Preferred Range but lower than the average concentration in the affected receiving waters, such discharges should be permitted on the basis that it would result in a net improvement to water quality.

4) Where the constituent concentrations in a discharge are within the Preferred Range, such discharges should be permitted, pursuant to the Recycled Water Policy, even if higher than the average concentration in the receiving water because doing so would not adversely affect existing or probable MUN uses and would provide maximum benefit to the people of California.

Salinity Effects on MUN-Related Uses of Water
White Paper Executive Summary
July 6, 2012

Purpose

- Summarize current state of knowledge regarding the effects of elevated conductivity, salinity or TDS and hardness on drinking water supply and other domestic purposes for water use.
- Identify/summarize unique concerns related to specific ions (e.g. sodium, chloride, boron, etc.).

Regulations to Protect MUN-Related Uses

Federal Regulations

- No enforceable Maximum Contaminant Levels or Goals have been promulgated for any salinity related constituents.
- Three salinity-related non-enforceable Secondary Maximum Contaminant Levels (SMCLS) established: TDS (500 mg/L), chloride (250 mg/L), sulfate (250 mg/L). SMCLS established to address aesthetic (taste, odor, color) not human-health concerns. They were first promulgated in1979 and have never been modified.

California Regulations

- No enforceable Primary Drinking Water Standards promulgated for salinity related constituents.
- Four Secondary Drinking Water Standards (SDWS) established (Table ES-1); compliance requirements established in Title 22 §64449(b).

Table ES-1. Summary of California Salinity-Related Secondary Drinking Water Standards

Constituent	Recommended	Upper Level	Short-Term or Intermittent Use
Total Dissolved Solids mg/L	500	1,000	1,500
or			
Specific Conductance (µS/cm)	900	1,600	2,200
Chloride (mg/L)	250	500	600
Sulfate (mg/L)	250	500	600

- Most California regions have adopted SDWS in Basin Plans as objectives applicable to all waters with an MUN use; many Basin Plans also include site specific objectives for salinity-related constituents (surface water and groundwater).

Salinity Effects on MUN-Related Uses

Human Health Effects

- Key salinity-related constituents, e.g., those with SMCLS or SDWS, are not known to be the cause of human health concerns. Promulgated values intended to address aesthetic considerations: odor, taste and color. Some specific ions may cause minor health effects at very high concentrations (e.g., laxative effect from high levels of calcium or magnesium), but the effects are not toxic.
- WHO (2011) notes that the degree to which taste is impaired varies with the associated cation, e.g., taste thresholds can range from 250 mg/l for sodium sulfate to 1000 mg/l for calcium sulfate. Similarly, the cation associated with the chloride anion also may influence taste acceptability (WHO 2011).

Other Domestic Use Effects

Overview

Primary effects of elevated salinity in municipal and domestic water supplies are increased corrosivity or staining and increased scaling or sedimentation:

- *Residential* - Salinity reduces the life expectancy of household appliances (water heaters, faucets, garbage disposals, clothes and dish washers, toilet flushing mechanisms, galvanized water pipes, evaporative coolers, etc.). Increasing salinity may increase public demand for bottled water or home treatment devices."
- *Commercial* – Impacts from elevated salinity expected to be similar to residential impacts.
- *Urban Irrigation* – Elevated salinity impacts turf/landscaping of golf course, parkland; impacts are similar to what would be expected in agricultural circumstances.
- *Industrial* – Potential salinity effects are industry type or process-specific; depends on source water quality needs for manufacturing process; larger concern appears to be the need to minimize variability in source water salinity.

Salinity-Related Impact Assessment

- Impact assessments generally date back to the 1960's; emphasis on two areas: (1) salinity effects on life expectancy of water-using appliances and translation of these findings into increased replacement costs; and (2) costs for investments in bottled water or home water treatment systems.
- Salinity impact studies primarily rely on TDS as the measure of salinity. Occasionally some discussion regarding specific ion or hardness effects, but these are the exception and none have been completed recently.
- Regression relationships established to relate TDS concentration to appliance life expectancy (first published in 1974; updated in 1988). Recent studies primarily rely on 1988 equations.
- Most recent study that directly evaluates salinity impacts on water-using appliances using an alternative method was published in 2000. This study found reduced economic impact from increased salinity – likely a result of alternative method of analysis and increased use of plastics or composite materials in appliances.
- Most recent studies evaluating salinity impacts to economic sectors (including UC Davis Central Valley Report [2009] and Hilmar Report [2007]) do not re-evaluate direct impacts of salinity to water-using appliances; instead, these studies rely on 1988 developed regression equations.
- Information regarding specific impacts to non-agricultural industry generally limited to summary developed in 1988; potential impacts are industry specific, related to equipment and process needs. Most recent studies regarding salinity impacts to industry are area or industry specific economic analyses.

Memorandum

To: *CV-SALTS*

From: *CDM Smith*

Date: *July 6, 2012*

Subject: *Salinity Effects on MUN-Related Uses of Water*

Background

The CV-SALTS Executive Committee identified the following focus area for policy discussion: (Focus Area #5): "Define what constitutes 'Reasonable protection of existing and probable future MUN [Municipal and Domestic Supply] uses' with respect to electrical conductivity (EC) and some specific individual ions. Determine whether and when to use secondary MCLs [maximum contaminant levels] as water quality objectives." To support the discussion, the Executive Committee requested the development of technical information in the following two areas:

- Summarize the current state of knowledge regarding the effects of elevated electrical conductivity (EC) (salinity or total dissolved solids [TDS]) and hardness concentrations on drinking water supply and other domestic purposes.
- Identify and summarize unique concerns related to specific ions (e.g. sodium, chloride, boron, etc.)

This Technical Memorandum (TM) represents the findings from research completed to date on each of these two technical areas. In addition to the specific areas of research posed above, we provide a summary of federal and California water quality standards currently applicable to MUN-related uses. For comparative purposes, information from other selected states and international sources is also provided.

All California Regional Boards define MUN as follows: "Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply". This definition is broad, encompassing uses of public water supplies for purposes other than drinking. Accordingly, both drinking water and non-drinking water uses of municipal and domestic water supplies are evaluated in subsequent sections of this memorandum.

Consistent with Westcot (2012), this review considered total dissolved solids (TDS), EC and the principal cations and anions in water salinity:

- Principal cations: Sodium, (Na^{+}), Calcium (Ca^{2+}), Potassium (K^{+}), Magnesium (Mg^{+2}); and
- Principal anions: Chloride (Cl-), Sulfate ($SO_4{}^{2-}$), Carbonate ($CO_3{}^{2-}$), Bicarbonate ($HCO3^{-}$).

In addition to the above, this review will also include some information on a minor cation, Boron (B^{3+}), which can be associated with dissolved solids.

Development of this memorandum relied extensively on the work completed by Dennis Westcot: *Drinking Water Quality Criteria for Evaluation of Water Quality Objectives for the Lower San Joaquin River*, prepared for the Lower San Joaquin River Committee of the CV-SALTS Program (June 20, 2012, hereafter referred to as Westcot [2012]). The full draft of this document is provided as Attachment A. The information in Westcot (2012) was supplemented where appropriate, especially with regards to the use of municipal and domestic water supplies for non-drinking water purposes. References used in this TM are provided at the end of this memorandum; additional extensive references are available in Attachment A.

Regulations to Protect MUN-Related Uses

This section includes a summary of (a) federal requirements for the protection of waters used as a public water supply; (b) California drinking water standards; and (c) requirements from other selected states or international organizations.

Federal Requirements

State adopted surface water quality standards are typically based on Environmental Protection Agency (EPA) guidance developed under Section 304(a) of the Clean Water Act (CWA). However, for protection of waters designated as MUN the EPA has not adopted 304(a) criteria specific to the protection of MUN-related uses[1]. Instead, states typically rely on the primary maximum contaminant levels (MCLs) and secondary maximum contaminant levels (SMCL) promulgated by the EPA under the Safe Drinking Water Act (SDWA) to protect surface waters designated as a municipal or domestic water supply.

EPA has established both MCLs (enforceable) and Maximum Contaminant Level Goals (MCLGs, non-enforceable) for drinking water. MCL means the maximum permissible level of a contaminant in water which is delivered to any user of a public water system. An MCLG means the maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur. MCLs and MCLGs are found at 40 Code of Federal Regulations (CFR) 141, in particular parts 141.11 (MCL - inorganic compounds), 141.13 (MCL - coliform) and 141.61 (MCL - organics), and 141.50 through 141.5 (MCLGs) (or see, http://water.epa.gov/drink/contaminants/index.cfm). No MCLs or MCLGs have been promulgated for any salinity-related constituents.

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[1] It is important to note that the EPA has developed human-health based criteria, which do protect for direct consumption of untreated water from a waterbody; however, these criteria assume direct consumption of raw water and also include protection for exposure to pollutants from other pathways, e.g., consumption of harvestable aquatic life.

EPA has also promulgated SMCLs, which are non-mandatory or voluntary water quality standards[2] (**Table 1**). Although adopted in 1979, the SMCL for TDS dates back to standards recommended by the U.S. Public Health Service in 1942 and by the National Technical Advisory Committee to the Secretary of the Interior in 1968 (FWPCA 1968; aka, "Green Book").

The federal SMCLs provide guidance to public water systems for managing their drinking water to take into account aesthetic considerations, such as taste, color, and odor. The SMCLs include several salinity related constituents, e.g., chloride, sulfate, and TDS. At the SMCL threshold, none of these contaminants is considered to present a risk to human health (also, see Table 5 below regarding specific salinity-ion effects).

The EPA promulgated the first SMCLs in 1979 (after publishing proposed regulations in 1977). These standards have never been modified; the only changes since 1979 have been the addition of three more SMCLs for fluoride, aluminum and silver. The SMCLs are published at 40 CFR 143.3 or see the EPA's website: http://water.epa.gov/drink/contaminants/index.cfm#SecondaryList.

California Requirements

The federal MCL and SMCL regulatory structure is mirrored in California through the promulgation of primary and secondary drinking water standards. Two California agencies are involved in establishing standards to protect drinking water:

- *California Office of Environmental Health Hazard Assessment (OEHHA), Toxicology Unit* – Agency responsible for establishing California Public Health Goals (PHGs). A PHG is the level of a contaminant in drinking water that does not pose a significant risk to public health; it is not a regulatory standard, but instead provides guidance for the California Department of Public Health (CDPH) to consider when setting a drinking water MCL. No PHGs have been established for salinity-related constituents.
- *California Department of Public Health, Division of Drinking Water and Environmental Management* - CDPH drinking water-related regulations are found in Titles 22 and 17 of the California Code of Regulations (CCR) commonly known as the California Safe Drinking Water Act & Related Statutes:
    - *Primary Drinking Water Standards (PDWS)* - Under §116275, MCL means the maximum permissible level of a contaminant that may be present in water and not have an adverse effect on human health. §64431 establishes the PDWS for inorganic chemicals administered by CDPH. No PDWS have been adopted for salinity-related compounds in California.

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[2] In the original federal promulgation of SMCLs (1979), EPA provided the following basis for SMCLs: "At considerably higher concentrations, these contaminants may also be associated with adverse health implications…they are intended as guidelines for the States. The States may establish higher or lower levels as appropriate to their particular circumstances dependent upon local conditions such as unavailability of alternate raw water sources or other compelling factors, provided that public health and welfare are adequately protected. However, odor, color and other aesthetic qualities are important factors in the public's acceptance and confidence in the public water system; thus, States are encouraged to implement these SMCLs so that the public will not be driven to obtain drinking water from potentially lower quality, higher risk sources (44 FR 42195, July 19, 1979)."

Table 1. Federally Promulgated SMCLs – All Constituents[1,2]

Constituent	SMCL	Federal Register (FR) Publication	Noticeable Effects above the SMCL[3]
Aluminum	0.05 to 0.2 mg/L	56 FR 3597, Jan 30, 1991	Colored water
Chloride	250 mg/L	44 FR 42195, Jul 19, 1979	Salty taste
Color	15 color units	44 FR 42195, Jul 19, 1979	Visible tint
Copper	1.0 mg/L	44 FR 42195, Jul 19, 1979	Metallic taste; blue-green staining
Corrosivity	Non-corrosive	44 FR 42195, Jul 19, 1979	Metallic taste; corroded pipes/ fixtures staining
Fluoride	2.0 mg/L	51 FR 11396, Apr 2, 1986	Tooth discoloration
Foaming Agents	0.5 mg/L	44 FR 42195, Jul 19, 1979	Frothy, cloudy; bitter taste; odor
Iron	0.3 mg/L	44 FR 42195, Jul 19, 1979	Rusty color; sediment; metallic taste; reddish or orange staining
Manganese	0.05 mg/L	44 FR 42195, Jul 19, 1979	Black to brown color; black staining; bitter metallic taste
Odor	3 TON (threshold odor number)	44 FR 42195, Jul 19, 1979	Rotten-egg, musty or chemical smell
pH	6.5 - 8.5	44 FR 42195, Jul 19, 1979	*Low pH:* bitter metallic taste; corrosion *High pH:* slippery feel; soda taste; deposits
Silver	0.1 mg/L	56 FR 3597, Jan 30, 1991	Skin discoloration; graying of the white part of the eye
Sulfate	250 mg/L	44 FR 42195, Jul 19, 1979	Salty taste
Total Dissolved Solids	500 mg/L	44 FR 42195, Jul 19, 1979	Hardness; deposits; colored water; staining; salty taste
Zinc	5 mg/L	56 FR 3597, Jan 30, 1991	Metallic taste

Notes:

[1] Prior to publishing its 1977 rule proposal, the EPA also considered proposing SMCLs for hardness, alkalinity, phenols, sodium and standard plate count (bacteria-related measure of aesthetics, not human health-related protection). None of these constituents was included in the published rule proposal.

[2] Original federal proposal (42 FR 17143, Mar 31 1977) also included a proposed SMCL for hydrogen sulfide; this constituent was removed in the final promulgation (44 FR 42195, Jul 19, 1979) based on public comment.

[3] Source: http://water.epa.gov/drink/contaminants/secondarystandards.cfm

- *Secondary Drinking Water Standards (SDWS)* – These standards specify a secondary maximum contaminant level that, in the judgment of CDPH, is necessary to protect public welfare. SDWS are not enforceable but set guidance on how public water systems should be operated. An SDWS may apply to any contaminant in drinking water that may adversely affect the odor or appearance of the water and may cause a substantial number of persons served by the public water system to discontinue its use, or that may otherwise adversely affect the public welfare.

  Inorganic chemical SDWS are found in §64449 (Tables 64449-A and 64449-B). Those constituents that are salinity-related are found in Table 64449-B. For the most part, these standards are similar to the federal SMCLs; however, differences include the inclusion of upper limit and short-term/intermittent use levels for TDS, chloride, and sulfate concentrations (**Table 2**), and the inclusion of a standard and levels for specific conductance (µS/cm) (or EC), for which there is no federal SMCL.

Table 2. Summary of California Salinity-Related Secondary Drinking Water Standards

Constituent	Recommended	Upper Level	Short-Term or Intermittent Use
Total Dissolved Solids (mg/L)	500	1,000	1,500
or			
Specific Conductance (µS/cm)	900	1,600	2,200
Chloride (mg/L)	250	500	600
Sulfate (mg/L)	250	500	600

CCR §64449(b) describes how the SDWS for these constituents are managed:

- Constituent concentrations lower than the recommended contaminant level are desirable for a higher degree of consumer acceptance.
- Constituent concentrations ranging to the upper contaminant level are acceptable if it is neither reasonable nor feasible to provide more suitable waters.
- Constituent concentrations ranging to the Short Term contaminant levels are acceptable only for existing community water systems on a temporary basis pending construction of treatment facilities or development of acceptable new water sources.

The upper limit and short-term levels reflect the lack of evidence of any health affects below these values and the findings that consumer acceptance is diminishing above these levels. **Table 3** provides a comparison between California requirements and federal requirements or international guidelines.

California Regional Board Basin Plans

As noted above, all California Regional Boards have adopted the same MUN definition. However, although the same definition applies statewide, variability exists across regions with regards to the adoption of salinity-related water quality objectives in each region's Basin Plan (**Table 4**).

Table 3. Comparison of U.S. Federal, California and International Standards or Guidelines to Protect MUN-Related Uses (NA – no standard or guideline established)

Constituent	**Federal MCL and MCLGs (40 CFR §141)**	**Federal SMCLs (40 CFR §143.3)**	**California Primary Drinking Water Standards (CCR §64431)**	**California Secondary Drinking Water Standards (CCR §64449)**	**WHO International Drinking Water Guidelines**	**Canadian Guidelines (MAC or AO/AG)(8)**	**Australia/New Zealand (HB or AeB)(9)**
Total Dissolved Solids	*NA*	*500 mg/L*	*NA*	*500 mg/L (1)*	*(2)*	*500 mg/L (AO/AG)*	*600 mg/L (AeB)*
Electrical Conductivity	*NA*	*NA*	*NA*	*900 µS/cm (3)*	*NA*	*NA*	*NA*
Bicarbonate (HCO_3^-)	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Boron (B)	*NA*	*NA*	*NA*	*1.0 mg/L (4)*	*2.4 mg/L*	*5 mg/L (MAC)*	*4 mg/L (HB)*
Calcium (Ca^{2+})	*NA*	*NA*	*NA*	*NA*	*(2)*	*(5)*	*NA*
Carbonate (CO_3^{2-})	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
Chloride (Cl^-)	*NA*	*250 mg/L*	*NA*	*250 mg/L (6)*	*(2)*	*250 mg/L (AO/AG)*	*250 mg/L (AeB)*
Magnesium (Mg^{2+})	*NA*	*NA*	*NA*	*NA*	*(2)*	*(5)*	*NA*
Potassium (K^+)	*NA*	*NA*	*NA*	*NA*	*(2)*	*NA*	*NA*
Sodium (Na^-)	*NA*	*NA*	*NA*	*NA*	*(2)*	*200 mg/L (AO/AG)*	*180 mg/L (AeB)*
Sulfate (SO_4)	*NA*	*250 mg/L*	*NA*	*250 mg/L (7)*	*(2)*	*500 mg/L (AO/AG)*	*250 mg/L (AeB)*

(1) 500 mg/L is recommended for continuous use with an upper limit of 1,000 mg/L. Short-term or intermittent use is allowed up to a TDS of 1,500 mg/L.
(2) Some chemical and physical parameters have been identified as not requiring a numerical guideline, because currently available data indicate that it poses no health risk or aesthetic problem at the levels generally found in drinking water.
(3) 900 µS/cm is recommended for continuous use with an upper limit of 1,600 µS/cm. Short-term or intermittent use is allowed up to an EC of 2,200 µS/cm.
(4) State Action Level that requires notification of the water users. Boron is not a regulated contaminant but is considered a contaminant of concern.
(5) Some chemical and physical parameters have been identified as not requiring a numerical guideline, because currently available data indicate that it poses no health risk or aesthetic problem at the levels generally found in drinking water.
(6) 250 mg/L is recommended for continuous use with an upper limit of 500 mg/L. Short-term or intermittent use is allowed up to a Cl of 600 mg/L.
(7) 250 mg/L is recommended for continuous use with an upper limit of 500 mg/L. Short-term or intermittent use is allowed up to a SO4 of 600 mg/L.
(8) MAC = Health based Maximum Acceptable Concentration; AO/OG = Aesthetic Considerations/Operational Guidance Value.
(9) HB = Health based; AeB = Aesthetic-based.

Table 4. Summary of Salinity-Related Objectives Adopted by California Regional Boards

Regional Board	**Salinity-Related Constituents Explicitly Applicable to Entire Region**				**Narratives**	**Site-Specific Objectives**	**Other Considerations**
	TDS	**EC**	**Cl^-**	**SO_4**			
Region 1	NA	NA	NA	NA	NA	Selected waterbodies have TDS and EC site specific objectives (SSO) using 90% and 50% percentile upper limits for a calendar year	Propose to incorporate all provisions of Title 22 of CA CCR (2012 proposal)
Region 2	500	900	250	250	Controllable water quality factors shall not increase the total dissolved solids or salinity of waters of the state so as to adversely affect beneficial uses, particularly fish migration and estuarine habitat	None identified	Title 22 regulations applicable to MUN use
Region 3	NA	NA	NA	NA	Controllable water quality factors shall not increase the total dissolved solids or salinity of waters of the state so as to adversely affect beneficial uses, particularly fish migration and estuarine habitat	SSOs for TDS, chloride, sulfate, boron and sodium established in selected surface waters and groundwaters	NA
Region 4	500 – applied if no SSO		250 – applied if no SSO	400-500 – applied if no SSO	NA	SSOs for TDS, chloride, sulfate, boron and Sodium Adsorption Ratio (SAR) established in selected surface waters. SSOs for TDS, sulfate, chloride and boron established for selected groundwaters	Portions of Title 22 regulations applicable to MUN use
Region 5 – Sacramento and San Joaquin River Drainages	500		250	250	NA	Sacramento/San Joaquin - Selected waterbodies have TDS, EC, and chloride objectives	Title 22 regulations applicable to MUN use

Table 4. Summary of Salinity-Related Objectives Adopted by California Regional Boards

Regional Board	**Salinity-Related Constituents Explicitly Applicable to Entire Region**				**Narratives**	**Site-Specific Objectives**	**Other Considerations**
	TDS	**EC**	**Cl^-**	**SO_4**			
Region 5 – Tulare Lake Basin	NA	NA	NA	NA	• For inland surface water, waters shall be maintained as close to natural concentrations of dissolved matter as is reasonable considering careful use of the water resources. • For ground waters, all waters shall be maintained as close to natural concentrations of dissolved matter as is reasonable considering carful use of the water resources. No proven means exist at present that will allow ongoing human activity in the Basin and maintain ground water salinity at current levels throughout the Basin. Accordingly, the water objectives for ground water salinity control the rate of increase.	Selected waterbodies have site-specific EC objectives	Title 22 regulations applicable to MUN use
Region 6	NA	NA	NA	NA	NA	Selected waterbodies have TDS, EC, chloride, sulfate, boron, SAR or adjusted SAR, % sodium objectives	Title 22 regulations applicable to MUN use
Region 7	NA	NA	NA	NA	Discharges are not allowed to increase the receiving water concentrations unless there is no adverse impact to affected beneficial uses.	TDS SSOs for specific reaches; any discharge (except agricultural) shall not cause TDS in surface waters to exceed annual average of 2000 mg/L or 4000 mg/L (waterbody dependent) and no discharge shall exceed 4,500 mg/L; SSOs applicable to the Salton Sea.	Apply only some of the Title 22 regulations

Table 4. Summary of Salinity-Related Objectives Adopted by California Regional Boards

Regional Board	**Salinity-Related Constituents Explicitly Applicable to Entire Region**				**Narratives**	**Site-Specific Objectives**	**Other Considerations**
	TDS	**EC**	**Cl^-**	**SO_4**			
Region 8	NA	NA	500 (Ground Water)	500 (Ground Water)	Groundwater - Hardness of receiving waters shall not be increased as a result of waste discharges to levels that adversely affect beneficial uses.	SSOs for TDS, hardness, chloride, sulfate, and sodium for selected inland waters, both surface water and groundwater	Groundwater – As a result of controllable factors, sodium shall not exceed 180 mg/L; boron shall not exceed 0.75 mg/L
Region 9	NA	NA	NA	NA	NA	SSOs for TDS, chloride, sulfate, % sodium, iron, manganese, boron for selected inland waters, both surface water and groundwater	Title 22 regulations applicable to MUN use

Other State Requirements

Westcot (2012) prepared a brief review of selected state drinking water standards requirements with regards to salinity-related constituents. Information was originally developed for the California Urban Water Agencies (CUWA) (2007). CUWA chose states to survey based on known incidences of water quality concerns related to the constituent of interest, presence of unfiltered drinking water supplies, historically progressive regulatory arena, and presence of large number of impacted source waters for the CWA Total Maximum Daily Load program. Examples from the CUWA survey include:

- Florida has a surface water salinity criterion with a monthly average of 500 mg/L, not to exceed 1,000 mg/L. Groundwaters used for potable supplies are classified by their TDS levels, either Class G-1 less than 3,000 mg/L or Glass G-II less than 10,000 mg/L;Michigan regulations state that the addition of any dissolved solids shall not exceed concentrations which are or may become injurious to any designated use. Point sources containing dissolved solids shall be considered by the commission on a case-by-case basis and increases of dissolved solids in the waters of the state shall be limited through the application of best practicable control technology, except that in no instance shall total dissolved solids in the waters of the state exceed a concentration of 500 milligrams per liter as a monthly average nor more than 750 milligrams per liter at any time, as a result of controllable point sources.
- Mississippi and North Carolina regulations state that there shall be no substances added that will cause the TDS to exceed 500 mg/L in freshwater streams;
- New Jersey has a standard which prohibits an increase in background levels of TDS which may adversely affect the survival, growth or propagation of the aquatic biota or 500 mg/L, whichever is more stringent;
- New York has two standards based on the classification of the waterway. For A-Special (pristine waterways) the amount shall not exceed 200 mg/L and for other classes of potable waters it shall be kept as low as practicable to maintain the best usage of waters but in no case shall it exceed 500 mg/L;
- Oklahoma has a TDS narrative criterion stating that the waters will be maintained so as to be essentially free of substances of a persistent nature, from other than natural sources; and
- Utah set their TDS criteria at 1,200 mg/L although they have many site-specific salinity criteria because of the naturally high salinity levels in several parts of Utah. Site-specific salinity criteria range from 1,800 mg/L to 9,700 mg/L.

International Requirements

Westcot (2012) provides a summary of key international sources of MUN-related water quality standards (see Table 3 for jurisdictional comparison of MUN-related standards).

- *World Health Organization (WHO)* – Currently has no established guideline for TDS, based on a recent review that found no reliable data on health effects associated with water ingestion and TDS concentrations. Previously WHO provided the following guidance regarding elevated concentrations: TDS concentration below 1,000 mg/L is usually acceptable to consumers although acceptability may vary according to circumstances. In addition, WHO has not established guidelines for other salinity-related constituents for which EPA or California has established SMCLs or SDWS, respectively, including chloride and sulfate (see Table 3). The only relevant constituent of concern for which WHO has established a guideline is Boron, which is health-based.
- *Canada National Guidelines* – Canada has established guidelines of three types: (1) health-based standards listed as Maximum Acceptable Concentrations (MAC); and (2) Aesthetic Considerations, which are listed as aesthetic objectives (AO), or operational considerations listed as Operational Guidance Values (OG). Table 3 provides a comparison between California and US federal requirements and Canadian guidelines. With the exception of boron, Canada has not established health-based standards for any salinity related constituents; other guidelines are based on aesthetic considerations.
- *Australia and New Zealand* – Australia/New Zealand jointly established national guidelines under the National Water Quality Management Strategy for ambient and drinking water. Salinity-related guidelines have been established for aesthetic reasons, not for any human-health-based concerns. Table 3 compares California and US federal requirements and Australia/New Zealand guidelines. Not shown in the table are Australia/New Zealand hardness guidelines. These guidelines provide a scale of < 60 mg/L $CaCO_3$ (soft but possibly corrosive) to > 500 mg/L $CaCO_3$ (severe scaling) with an optimum of 200 mg/L $CaCO_3$.

Salinity Effects on MUN-Related Uses

This section focuses on the effects of salinity-related constituents on (1) human health – through water consumption; and (2) other domestic, commercial and industrial uses of water.

Human Health – Water Consumption

Westcot (2012) and the supplemental information developed for this memorandum show that human health concerns associated with salinity-related compounds are minimal. Concerns regarding these compounds are almost entirely related to aesthetic considerations. One key exception is boron. No federal MCL or SMCL has been established for this constituent. Although not regulated, California considers boron a contaminant of concern and has adopted a SDWS action level of 1.0 mg/L. Exceedance of this level requires notification of water users.

Salinity-related constituents with SMCLS, including chloride, sulfate and TDS, are not known to be the cause of human health concerns. However, guidelines for these constituents, as well as other salinity-related compounds, are intended to address aesthetic considerations, including:

- *Odor and Taste* – Odor and taste of finished water varies with total salinity and concentration of salinity related-ions, e.g., chloride, sulfate and TDS. Bruvold and Daniels (1990) summarize the results of the California Mineral Taste Study which established a relationship between TDS concentration and taste quality as assessed by consumers and a taste panel. WHO (2011) notes that the degree to which taste is impaired varies with the associated cation, e.g., taste thresholds can range from 250 mg/l for sodium sulfate to 1000 mg/l for calcium sulfate. Similarly, the cation associated with the chloride anion also may influence taste acceptability (WHO 2011).
- *Color* – While increased color is often indicative of the amount of dissolved organic material, inorganic contaminants including TDS can be a potential cause of increased of color.

Table 5 summarizes health-related concerns associated with the most common salinity-related constituents as well as the other principal cations and anions included in this review. Some of these ions may cause some minor health effects at very high concentrations, but even at these high concentrations the effects are not toxic. For example, high levels of calcium and magnesium in water are believed to have a laxative effect. The information in Table 5 includes a compilation of information developed by Westcot (2012) (also see Attachment A) supplemented by other sources.

Other Domestic Uses of Drinking Water

Overview

There are numerous other residential, commercial, and industrial uses of municipal and domestic water supplies unrelated to drinking water. Salinity-related effects on these uses generally fall into two key areas (also see Table 1):

- *Corrosivity/Staining* – Increased corrosivity or staining may affect the aesthetic quality of water and have significant impacts on water distribution system pipes and household fixtures. In addition, increased corrosivity can result in an objectionable metallic taste and cause a red or blue-green color to the water. Salinity-related constituents that relate to corrosion and staining include chloride and TDS.
- *Scaling/Sedimentation* - Scale is a mineral deposit which builds up on the insides of hot water pipes, boilers, and heat exchangers, restricting or even blocking water flow. Sediments are loose deposits in the distribution system or home plumbing. Both processes can have a significant impact on the life expectancy of mechanical devices.

Table 5 summarizes potential effects of most of the various salinity-related ions on other uses of water. For non-drinking water uses, this information primarily comes from Todd (1980), which was adapted and used by the Central Arizona Salinity Study (CASS 2003). Increased salinity (i.e., TDS) can impact water use as follows (adapted from CASS [2003], Hilmar [2007], and UC Davis [2009]):

Table 5. Principal Salinity Related Cations and Anions

Constituent	Concentration in Natural Water (Todd 1980 unless otherwise noted)	Federal or State Standard[1]	Potential Health-Related Impacts	Other Potential Water Use Impacts (CASS 2003; Todd 1980)[3]
Bicarbonate (HCO_3^-)	Commonly less than 500 mg/L; may exceed 100 mg/L in water highly charged with carbon dioxide.	NA	Concentrations up to 700 mg/L of bicarbonate in drinking water considered harmless (McKee & Wolff 1963); concentrations of less than 150 mg/L recommended for domestic water use (Hibbard 1934).	Upon heating, bicarbonate is changed into steam, carbon dioxide, and carbonate (see carbonate below)
Boron (B)	Typically low in freshwaters (e.g., median of 0.01 mg/L in British Columbia waters; seawater averages 4.5 mg/L (Moss & Nagpal 2003).	1.0 mg/L[2]	Constituent has a long history of study (see Attachment A). The most recent drinking water guideline recommendation is 2.4 mg/L (WHO 2009a, 2009b, 2011). Canadian Guidelines are 5.0 mg/L.	None identified for domestic water uses. Primary concern is agricultural related.
Calcium (Ca^{2+})	Generally less than 100 mg/L; brine may contain as much 75,000 mg/L.	NA	Concentrations up to 1,800 mg/L of calcium in drinking water have been reported to be harmless. Hibbard (1934) recommended level in domestic water be less than 30 mg/L.	Calcium and magnesium combine with bicarbonate, carbonate, sulfate and silica to form heat retarding, pipe clogging scale in boilers and in other heat-exchange equipment. Calcium and magnesium combine with ions of fatty acid in soaps to form soap scum
Carbonate (CO_3^{2-})	Commonly less than 10 mg/L in groundwater. Water high in sodium may contain as much as 50 mg/L of carbonate.	NA	Not considered to be detrimental to public health	Upon heating, bicarbonate is changed into steam, carbon dioxide, and carbonate. The carbonate combines with alkaline earth – principally calcium and magnesium – to form crust like scale of calcium. Carbonate can retard flow of heat through pipe walls and restricts flow of fluids in pipes. Water containing large amounts of carbonate alkalinity is undesirable in many industries.
Chloride (Cl^-)	Commonly less than 10 mg/L in humid regions but up to 1,000 mg/L in more arid regions. About 19,300 mg/L in seawater; and as much as 200,000 mg/L in brine.	250 mg/L (SMCL, CA SDWS)	Generally not harmful to human beings until high concentrations reached, although chlorides may be injurious to some people suffering from diseases of the heart or kidneys. Restrictions based primarily on taste rather than on health, with a salty taste observed at concentrations as low as 100 mg/L. For average person, the taste threshold is 400 mg/L (McKee and Wolf 1963). WHO has not proposed a health-based guideline for chloride but note that concentrations above about 250 mg/L affect taste (e.g., WHO 2011).	Food processing industries usually require less than 250 mg/L. Some industries – textile processing, paper manufacturing, and synthetic rubber manufacturing – desire less than 100 mg/L.

Table 5. Principal Salinity Related Cations and Anions

Constituent	Concentration in Natural Water (Todd 1980 unless otherwise noted)	Federal or State Standard[1]	Potential Health-Related Impacts	Other Potential Water Use Impacts (CASS 2003; Todd 1980)[3]
Magnesium (Mg^{2+})	Generally less than 50 mg/L; ocean water contains more than 1,000 mg/L, and brine may contain as much as 57,000 mg/L.	NA	Considered relatively non-toxic and not a public health hazard because before toxic concentrations are reached, the taste is unpleasant (McKee and Wolf 1963). At elevated concentrations, magnesium is a strong laxative (Marier et al, 1979)	Magnesium combines with bicarbonate, carbonate, sulfate and silica to form heat retarding, pipe clogging scale in boilers and in other heat-exchange equipment. Magnesium combines with ions of fatty acid in soaps to form soap scum
Potassium (K^+)	Generally less than about 10 mg/L; as much as 100 mg/L in hot springs; as much as 25,000 mg/L in brine.	NA	Potassium is an essential element for humans; seldom, if ever, found in at levels that could be a concern for human health; considered relatively non-toxic to man and not a public health hazard (e.g., WHO 2011).	More than 50 mg/L sodium and potassium in the presence of suspended solids causes foaming which accelerates scale formation and corrosion in boilers. Sodium and potassium carbonate in re-circulating cooling water can cause deterioration of wood cooling towers. More than 65 mg/L of sodium can cause problems in ice Manufacturing.
Sodium (Na^-)	Generally less than 200 mg/L; about 10,000 mg/L in seawater; about 25,000 mg/L in brine.	NA	No firm conclusions drawn concerning possible association between sodium in drinking water and occurrence of hypertension; no WHO health-based guideline value proposed (e.g., WHO 2011). WHO does recognize that sodium may affect drinking water taste above about 200 mg/L.	
Sulfate (SO_4^-)	Commonly less than 300 mg/L except in water supplies influenced by acid mine drainage. As much as 200,000 mg/L in some brine.	250 mg/L (SMCL, CA SDWS)	Taste threshold of about 250 mg/L; major physiological effect is diarrhea and in extreme cases, dehydration (Gutherie 1989). Water containing 600 mg/L of magnesium sulfate acts as a laxative (WHO 1996); however, sulfate is not toxic at this concentration (WHO 2003).	Sulfate combines with calcium to form an adherent, heat-retarding scale. More than 250 mg/L is objectionable in water in some industries.

Notes:

[1] NA – No applicable standards; MCL and SMCL – federal primary and secondary maximum contaminant levels, respectively; CA PDWS and CA SDWS – California primary and secondary drinking water standards, respectively

[2] – This value represents an action level; it has not been translated into a drinking water standard. If exceeded, requirement to notify water users.

[3] – The focus of this information is on non-drinking water uses of municipal and domestic water supplies other than use of such water for urban irrigation, e.g., golf course or park watering. However, these potential impacts are discussed below.

- *Residential* - Salinity reduces the useful life or life expectancy of household appliances through accelerated depreciation of appliances. Salinity also may result in the need for increased investment in other sources of water or water treatment devices:
    - *Galvanized Water Pipes* – While concerns existed in the past with regards to salinity impacts to galvanized pipes, these concerns have been reduced over time because new houses use copper or plastic pipes and older houses replace existing galvanized pipe with copper or plastic over time. Hilmar (2007) states that several studies did not find evidence of reduced life of copper or plastic pipes due to increased TDS.
    - *Water Heaters* – Several studies have found a correlation between TDS and the life expectancy of water heaters.
    - *Faucets and Garbage Disposals* – Several studies have shown a relationship between salinity and the life expectancy of these devices, but there are indications that changes in technology (e.g., increased use of plastic) has reduced the potential impact. However, no empirical data have been identified to quantify benefits of changes in technology.
    - *Toilet Flushing Mechanisms* – These devices are now primarily made with plastic and a small number of metal parts. While there may have been significant salinity impacts in the past, no statistical relationship now exists between TDS levels and the life expectancy of toilet flushing mechanisms.
    - *Clothes Washers and Dishwashers* – Previous studies have found a statistically significant relationship between TDS levels and clothes washing machine life. Results for dishwashers have been variable – some studies identified a relationship, others did not. The increased use of plastic parts in both devices is believed to have reduced salinity impacts, but no studies have been identified that quantify these assumed benefits.
    - *Water Treatment* – Numerous studies show that a positive relationship exists between increased salinity and investment in water treatment devices in households (e.g., water softeners). However, the impetus for installing the treatment system likely has to do more with taste concerns than with corrosion concerns on pipes and appliances.
    - *Bottled Water* – Similar to water treatment devices a positive relationship exists between increased use of bottled water and increased salinity.
- *Commercial* - The commercial sector (schools, hospitals, retail stores, etc.) encounters impacts similar to homeowners with water-intensive operations bearing higher costs. Large commercial buildings commonly utilize cooling towers to provide air conditioning. Cooling towers operate by evaporating water-using the same principle as evaporative coolers for individual homes, but employ a more sophisticated process in which the cooled water is passed through a heat exchanger to cool the air. As water evaporates it leaves behind salts, which inevitably accumulate in the remaining water. After a few cycles, depending on the source water, salinity and other factors, the water has to be discharged or the salts will precipitate out or scale on the copper tubing of the heat exchanger or the tower itself, reducing the efficiency of the system.

High TDS water can be used through fewer cycles (than would be expected from low TDS water) before that water is discharged and freshwater or makeup water must be brought into the tower. The use of this additional water has an associated cost.

- *Urban Irrigation* – Many golf courses and parks use reclaimed water for irrigation purposes. If this water has a salinity content of more than 1,000 mg/L TDS, it is more difficult to grow turf. The result can be additional costs to a golf course. The impacts are similar to what is seen in agricultural circumstances. High TDS tends to limit the ability of certain species of turf grasses to grow. Salt buildup in the root zone can become endemic and must be flushed with additional water. High-TDS water also stains those facilities that receive any overspray. High sodium also causes clay soils to disperse, resulting in a relatively impermeable layer and poor subsequent infiltration. With aggressive maintenance regimens, golf course managers can maintain the greens and fairways but at a substantial increase in cost for chemicals and labor.

  Industrial - Some industries, such as food and beverage manufacturers and semiconductor manufacturing, require de-mineralized water, other industries require water softening. In such cases, relative costs are directly tied to the TDS content of their source water. However, as will be noted below, the larger concern may be the salinity variability of the source water rather than the salinity concentration. Waters with consistently high salinity may be pre-treated to levels needed for the industrial process. In contrast, source waters with high variability in salinity can be more difficult to manage. Cooling towers used in the industrial sector are usually larger and more robust than the commercial sector cooling towers, but have the same problems described above for commercial facilities. Chemical suppliers publish a recommended maximum of six cycles, but data from Arizona show that in practice the actual number of cycles is considerably lower, between 2.5 and 4.5, because of the high TDS. Corrosion in water and wastewater facilities is a concern and is primarily the result of elevated sulfides and chlorides. However, corrosion can be controlled at the water and wastewater facilities by using corrosion resistant construction materials such as stainless steel.

Salinity-related Impact Estimates

Studies regarding the impacts of increased salinity on residential, commercial and industrial concerns date back to at least the 1960's. Studies generally combine expected impacts to residential and commercial interests together given that for the most part the types of concerns, i.e., impacts to water-using devices, applies to both residential and commercial properties. Few studies specifically applicable to industrial processes were identified; however, the reason may be that industrial facilities often take into account source water quality as it may affect their industrial process and install pretreatment devices where needed to ensure a consistent quality to their source water.

The following sections summarize the state of knowledge with regards to economic impacts to residential water users and specific types of industries. Older studies tended to focus on the specific impacts to appliances in terms of life expectancy of the device. More recent studies tend to be focused more on the economic cost to a given area in terms of total dollars/time unit or annual cost/household. For the most part, we only discuss the former types of studies since the latter tend to be area-specific in their application and interpretation.

Residential

Studies regarding residential impacts can be broken up into two general periods: 1967-1982 and 1988-2009. Up until 1982 if a study needed data regarding the relationship between TDS concentration and impact to a household water-using device, the studies tended to rely on regression equations published by Tihansky (1974). Following 1982, these equations were updated in Lohman et al. (1988) (Note: some publications reference Lohman et al. 1988 as Milliken Chapman Research Group 1988), and, to the best that can be determined at this time, these same equations remain in use today.

Residential Impact Studies, 1967 – 1982

Salinity impacts to infrastructure (e.g., pipes) and mechanical devices (e.g., appliances, plumbing fixtures) were the subject of several studies from the 1960's to early 1980's. Based on a review of these studies or using summaries prepared by others (e.g., Tihansky [1974]; d'Arge and Eubanks [1978]; Lohman et al. [1988]; and Ragan et al. [2000]), general study methods and findings include:

- *Black and Veatch (1967)* conducted surveys of 38 communities in the Midwest. Water quality data were restricted to TDS. Estimates were made of the average lifetimes of galvanized water pipes, wastewater pipes, water heaters, faucets, toilet flushing mechanisms, garbage disposals, washing machines, and dishwashers. Water utility companies, plumbing contractors, and hardware and appliance dealers provided information for the survey. The lifetime for various fixtures was estimated as a function of TDS in the water at TDS levels of 250 mg/L and 1750 mg/L. Operation and maintenance (O&M) costs including repairs to infrastructure, soap and detergent purchases, bottled water purchases, and over-watering of lawns were also estimated. Costs/household were calculated but per the opinion of Ragan et al. (2000) the usefulness of the results is low because of study characteristics, in particular only widely different TDS concentrations were evaluated, and the results are not easily extrapolated beyond the communities studied.
- *Patterson and Banker (1968)* gathered data from 38 communities in 11 states including Arizona, Colorado, Kansas, Missouri, Montana, New Mexico, Oklahoma, South Dakota, Texas, Utah and Wyoming. Field investigations primarily consisted of interviews with utility officials, plumbing contractors, and hardware and appliance dealers. TDS varied from 100 to 3,000 mg/L in the communities surveyed. Community-specific results are provided in Patterson and Banker (1968); Lohman et al. (1988) summarized the findings from this study (See below).
- *Metcalf and Eddy (1972)* interviewed consumers in 10 communities, primarily in the southwest; these data were supplemented by industry data. The study statistically tested various measures of water quality for significance. The most important observed data relationships were bottled water purchase versus TDS, softening costs and soap demand versus hardness, and the frequency of water heater replacement versus chloride levels. No significant effects were identified for lawn watering, clothing expenses and plumbing repairs. Ragan et al. (2000) noted that the findings contradicted findings in other studies. Problems identified with the study included costs were derived only in terms of hardness levels, interviews were conducted "primarily with housewives, most of whom lack awareness of damaging minerals other than

hardness, which most recognize as affecting soap costs." Thus, cost estimates are biased towards hardness and omitted other important water quality factors.

- *Orange County Water District (OCWD) (1972)* prepared a report regarding water quality and consumer costs (impacts included use of water softeners or bottled waters or damage to water heaters, plumbing, water-using appliances and swimming pools) based on a literature review and a personal interview questionnaire administered to 1,100 area residents. Orange County assumed a linear relationship between increased salinity and impacts. The analysis was based on a TDS concentration of 746 mg/L and hardness of 349 mg/L. The study concluded that increased salinity (as related to the TDS concentration and hardness of the water) caused significant economic damage.
- *Metropolitan Water District (MWD) of Southern California (1973)* responded to the OCWD (1972) report by disputing the OCWD approach that showed a linear relationship between TDS and water quality impacts. MWD did not dispute the finding that increased TDS caused impacts, but only that there was a direct link between TDS or hardness and all types of impacts.
- *Tihansky (1974)* attempted to integrate the findings of previous efforts, including some of those described above and developed regression equations for the relationship between TDS and the expected life expectancies of various water-using devices, e.g., washing appliances, garbage disposals, water heaters, water piping, wastewater piping, toilet facilities, and sewage facilities. O&M cost functions were also derived for all of the above except cooking utensils and washable fabrics. **Figure 1** provides two examples of the observed relationships between increasing TDS and water heater life expectancy and increasing TDS and water heater O&M costs.
- *d'Arge and Eubanks (1978)* prepared "probably the most careful study of residential salinity damages" (Ragan et al. 2000) in a study conducted in collaboration with the Bureau of Reclamation and a Colorado River Basin multi-university group. They surveyed appliance service and plumbing businesses in three locations in the Los Angeles Metropolitan area. Each location had different TDS levels in their water supply ranging from 210 mg/L (San Fernando Valley) to 728 mg/L (Costa Mesa-Newport Beach) and 457 to 759 mg/L (two locations in Long Beach). The life expectancy of appliances as related to salinity was measured. **Figure 2** shows a set of results from this study. The study found a statistically significant difference in estimated mean lifetimes of various appliances among locations. The Costa Mesa-Newport Beach area had a shorter estimated mean lifetime for dishwashers, washing machines, garbage disposals, brass faucets, water heaters, and galvanized pipes at the 10 percent level of significance. No significant difference was found for toilet flushing mechanisms, copper or plastic water pipes, or copper or cast iron wastewater pipes at that same level of significance.
- *California Department of Water Resources (1978)* used a residential survey to gather salinity impact data, including impacts to household appliances and use of bottled water. They agreed that impacts to household appliances were related to increased TDS and hardness; however the "report contained several pages of discussion and caveats against the presumption of a linear relationship of damages to TDS and even, to some extent, to hardness"(Lohman et al. 1988).

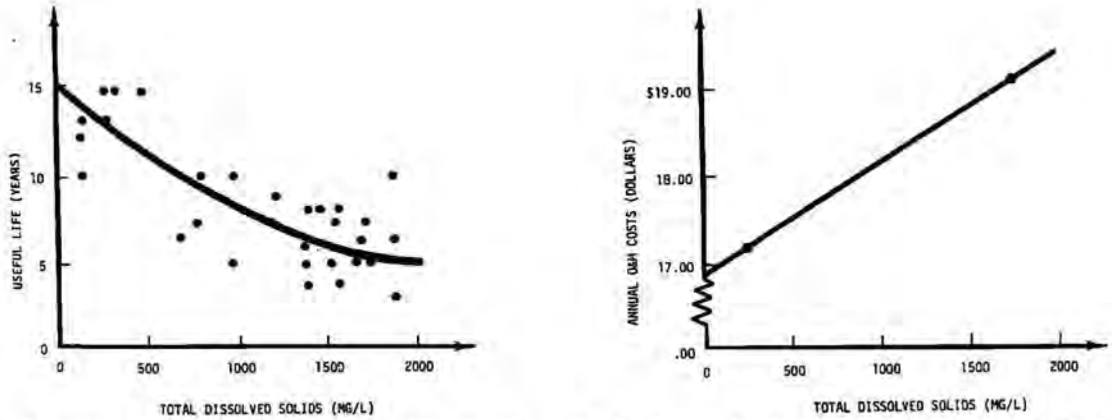

Fig. 1. Damage function for service life of water heater versus TDS levels.

Fig. 2. Damage function for annual operation and maintenance costs of water heater versus TDS levels.

Figure 1. Example results from Tihansky (1974)

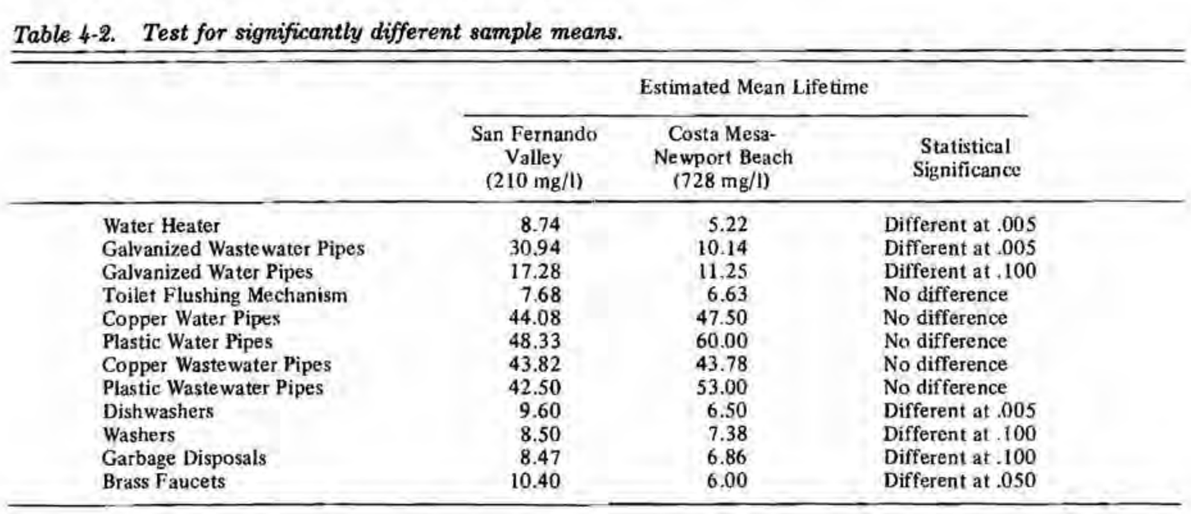

Table 4-2. Test for significantly different sample means.

	Estimated Mean Lifetime		
	San Fernando Valley (210 mg/l)	Costa Mesa-Newport Beach (728 mg/l)	Statistical Significance
Water Heater	8.74	5.22	Different at .005
Galvanized Wastewater Pipes	30.94	10.14	Different at .005
Galvanized Water Pipes	17.28	11.25	Different at .100
Toilet Flushing Mechanism	7.68	6.63	No difference
Copper Water Pipes	44.08	47.50	No difference
Plastic Water Pipes	48.33	60.00	No difference
Copper Wastewater Pipes	43.82	43.78	No difference
Plastic Wastewater Pipes	42.50	53.00	No difference
Dishwashers	9.60	6.50	Different at .005
Washers	8.50	7.38	Different at .100
Garbage Disposals	8.47	6.86	Different at .100
Brass Faucets	10.40	6.00	Different at .050

Figure 2. Example results from d'Arge and Eubanks (1978)

- *Coe (1982)* conducted a mail survey of households in four southern California communities with varying mineral content in their water supply. The highest salinity in the study was 700 mg/L TDS. Coe attempted to evaluate ionic composition as part of the study, but in the end related findings to TDS and hardness. Ragan et al. (2000) notes statistical errors in the analysis that may have resulted in missed significant statistical relationships between specific ion concentrations and life expectancy of appliances. Coe (1982) also looked at the percentage of respondents that invested in bottled water as related to elevated TDS.

Figure 3 summarizes the findings for impacts to household appliances from the above studies completed between 1967 and 1982. **Figure 4** provides a similar summary for use of bottled water (although data were much more limited). These figures were developed using summary tables published by Lohman et al. (1988). While results vary from one study to another, the general negative relationship between increasing salinity and various types of water-using appliances or increased use of bottled water is apparent.

Residential Impact Studies, 1988 – 2009

- *Lohman et al. (1988)* updated and extended previous studies using a different approach to assess salinity effects. They note that prior studies describe salinity effects based on an assumption that there exists an "ideal" salinity level at which no salinity effects occur. This situation is not common given the naturally varying salinity content of water. Instead, evaluations of salinity effects need to consider not only the water source, but the cause of the salinity, the use of the water, and how the water is managed. Accordingly, Lohman et al. (1988) stated that studies evaluating salinity effects should be made using a baseline salinity level that can be justified for the study area. For their particular study which involved evaluating salinity impacts of Colorado River water, two baseline values were used: TDS = 334 mg/L (considered to be the Colorado River's natural TDS level at Hoover Dam based on 1942-1961 data) and the SMCL of 500 mg/L TDS. The study evaluated TDS only; no attempt was made to identify impacts from specific ions.

  Lohman et al. (1988) developed their own economic model for estimating damages associated with increased salinity, which resulted in the development of new regression relationships between TDS and life expectancy of water-using devices (**Figure 5**). The study included costs associated with avoiding salinity impacts, e.g., bottled water purchases and home water treatment system purchases (not considered in the earliest studies), impacts to automotive radiators (not previously considered in any other study) and other expenditures that increase with higher salinity concentrations, including soaps and detergents and clothes replacement as a result of textile wear caused by water hardness.

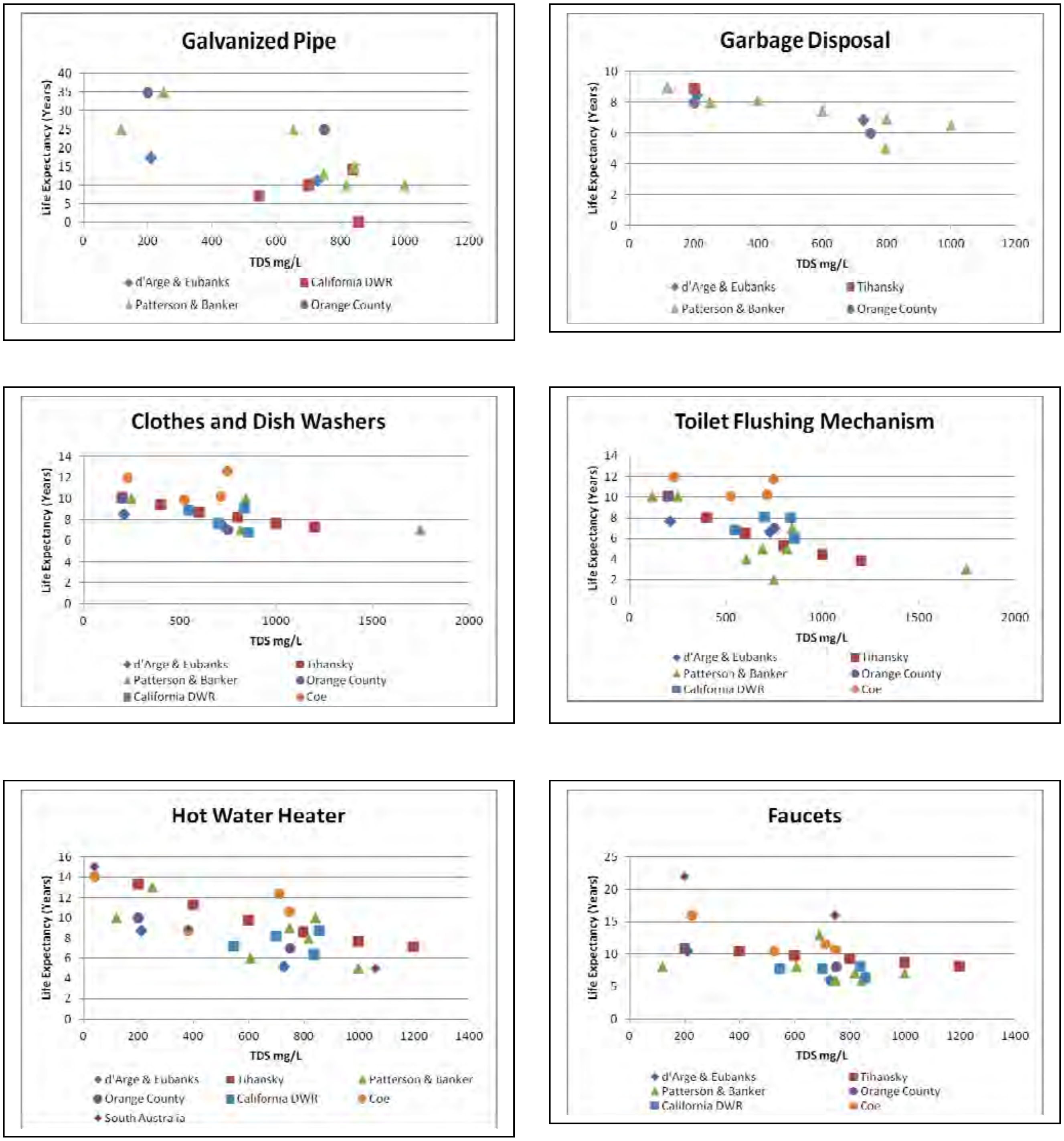

Figure 3. Summary of relationship between salinity (TDS mg/L) and life expectancy of various types of water-using devices. Symbols represent various study results (1967-1982); data as summarized in Lohman et al. (1988).

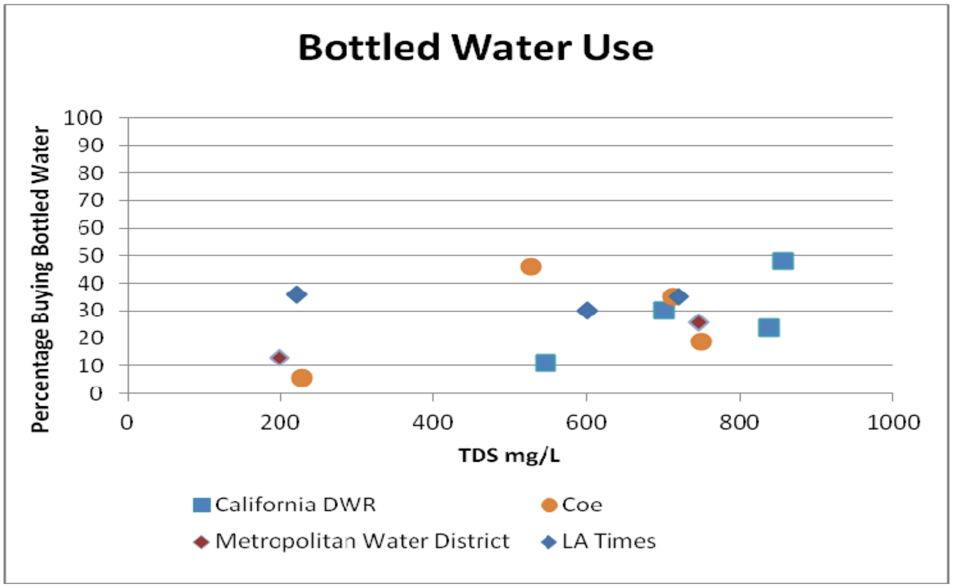

Figure 4. Summary of relationship between increased TDS (mg/L) and percentage of survey respondents that buy bottled water (adapted from Lohman et al. 1988)

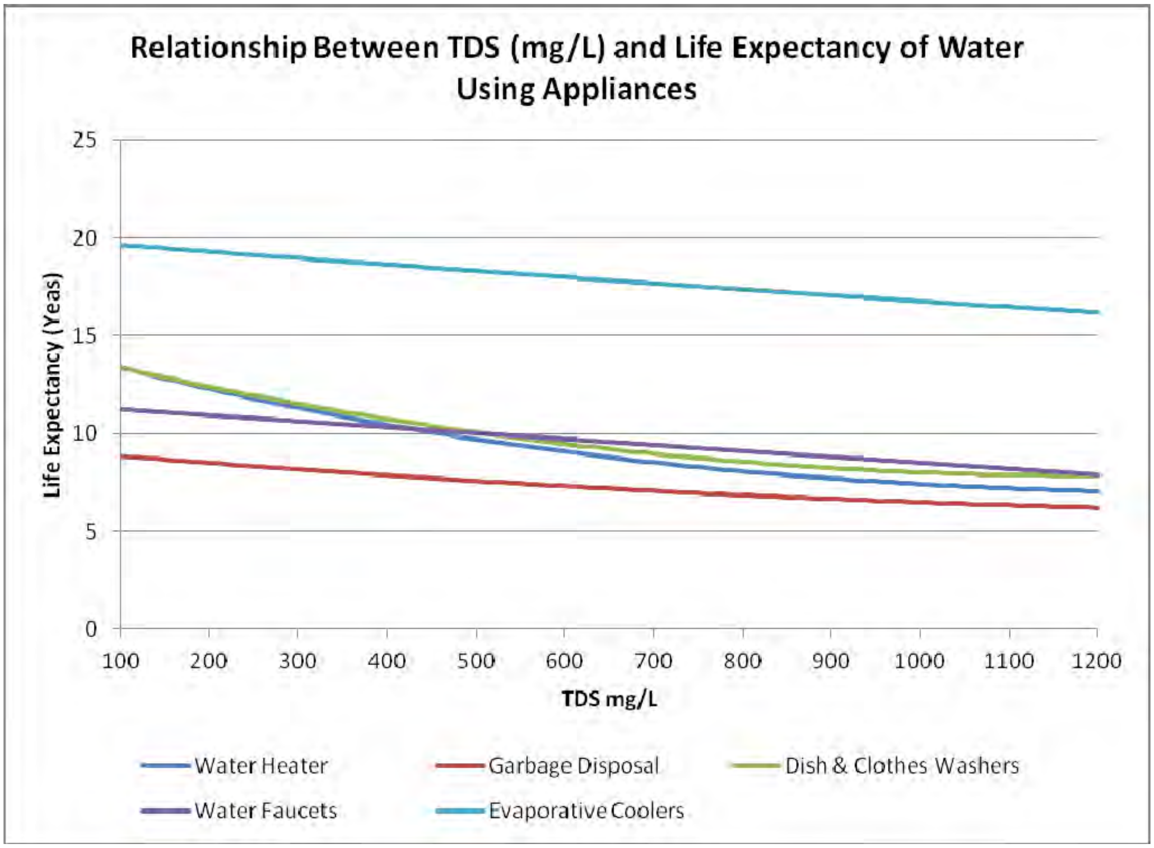

Figure 5. Relationship between salinity (TDS mg/L) and life expectancy of water using devices based on revised equations developed by Lohman et al. 1988.

Overall, estimated household salinity damages (inflation-adjusted) were much higher than reported in previous studies. However, according to Ragan et al. (2000) the primary cause of the elevated estimate was the inclusion of salinity effects on automobile radiators. Ragan et al. (2000) state that these estimates may have been inappropriate because it was assumed that all car owners only use local tap water in their automobiles. No data were gathered to verify this assumption; de-ionized water could have been used and potential costly damages avoided.

- MWD of Southern California (1999) (Note: also referenced as Bookman-Edmonston Engineering 1999) reviewed and revised previous salinity study impacts to estimate costs of elevated salinity to southern California households. This study also evaluated the regression equations for various water-using devices developed by Lohman et al. (1988); no revisions were made. This study also developed regression relationships between increased TDS and use of home water softeners or home treatment systems (**Figure 6**).
- Ragan et al. (2000) developed an alternative method for evaluating economic impacts. Their purpose in developing a new method was, in their opinion, to avoid biases prevalent in previous studies. The location of the study was the Colorado portion of the Arkansas River Basin. TDS in tap water ranged (generally from upstream to downstream) as follows: Buena Vista, 91 mg/L; Leadville, 142 mg/L; Canon City, 158 mg/L; Florence, 279 mg/L; Salida, 258 mg/L; Pueblo, 319 mg/L; Pueblo West, 343 mg/L; St. Charles Mesa, 451 mg/L; Park Center, 957 mg/L; Rocky Ford, 988 mg/L; La Junta, 1253 mg/L; Lamar, 1440 mg/L; and Las Animas, 3,603 mg/L. Data were gathered for TDS, sulfate, chloride and hardness. The concentrations of these constituents were highly correlated; therefore, it was not possible to look at ion-specific impacts. All analyses

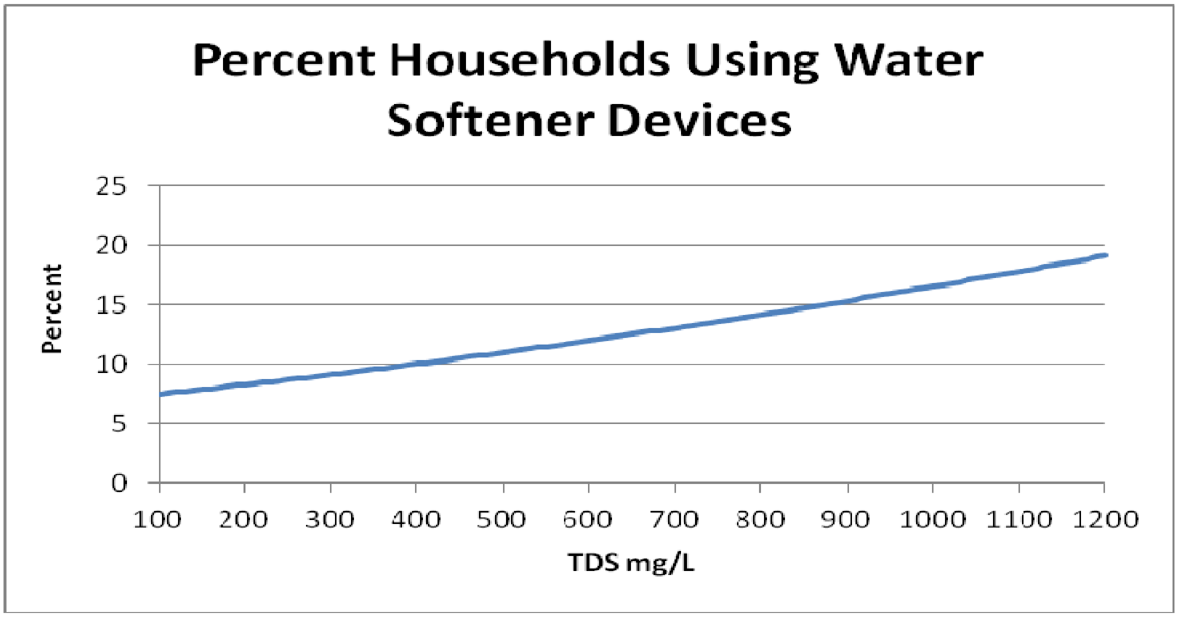

Figure 6. Relationship between percent household use of water softening devices and TDS (mg/L). Adapted from MWD (1999).

relied on TDS as the measure of salinity. **Figure 7** illustrates the relationship between TDS concentration and the total excess annual cost ($/year) of appliance replacement per household (Ragan et al. 2000). Specific study findings included:

- Evidence of statistically significant effects of salinity identified for five types of appliances: dishwashers, water heaters, food waste disposers, water softeners, and evaporative coolers. No statistically significant effects found for other appliances.
- Based on a reduction in TDS from 600 to 500 mg/L, results from the earlier literature, which are based on data from the 1960's and 1970's, suggest that the savings on appliance replacement costs (water heaters, clothes washers, and food-waste disposers) is more than three times greater than what was observed in this new study (**Figure 8**).
- Two factors may account for the observed differences between this study and past studies:
    - Inclusion of data on in-service appliances and use of methods appropriate to censored data (survey/statistical methods of previous studies ignored appliances that were still in use at the time of the survey), which may have led to previous overestimates of salinity damage; and

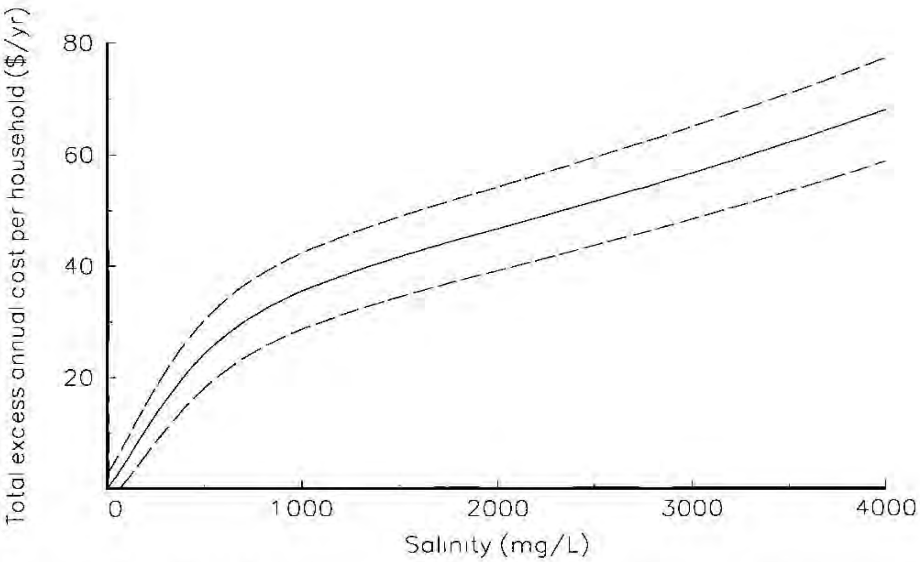

Figure 3. Total excess annual cost of appliance replacement per household.

Figure 7. Example results from Ragan et al. (2000) converting increased TDS impacts to cost per household/year.

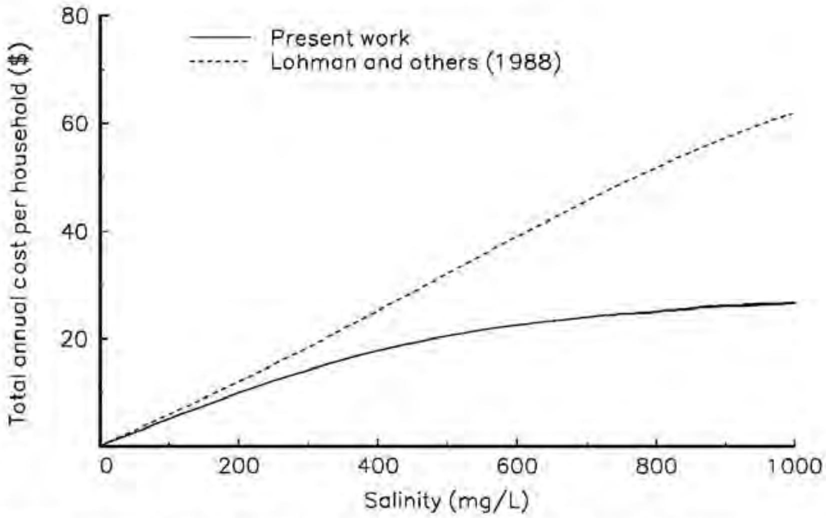

Figure 5. Cost of replacing water heaters, clothes washers, and food-waste disposers according to present and previous studies.

Figure 8. Comparison of annual cost/household between Ragan et al. (2000) and Lohman et al. (1988) (see discussion in text for explanation)

    - Technological improvements in appliances have probably reduced the potential benefit from salinity reduction. For example, use of plastic and composite materials rather than metal for some appliance parts has likely reduced susceptibility to salinity damage.

  - Continuing technological innovation and the gradual phasing out or retiring of old appliances is likely to result in a continued decline in observed adverse effects of salinity on household appliances.

  - Study was not able to account for potentially disparate effects of various ions: "...it is possible that a similar study in a different basin, with a different mixture of ionic concentrations would yield significantly different results. In view of the large differences between our findings and those in the earlier literature, a similar study in another river basin, such as the Colorado, would be desirable to shed more light on the sources of the differences".

- *CASS (2003)* - To develop life expectancy values for water-using appliances, CASS (2003) relied on the data originally developed by Lohman et al. (1988). The report develops estimated costs associated with the difference between a baseline TDS value (based on Central Arizona Project and Salt River Project water sources) and a new salinity level expected in the future. The presented results combine impacts to all sectors (residential, commercial, industrial and agricultural) in terms of millions of dollars with regards to increased TDS concentrations.

Because the results are not presented in a manner that is useful for comparison to other studies, no additional information is provided here.

- *The Hilmar Report (Hilmar 2007),* prepared as a Supplemental Environmental Project (SEP) authorized as part of a settlement agreement between Hilmar Cheese and the Regional Board, was developed to increase understanding the food processing industry's role in salinity discharge in the San Joaquin Valley. The study also provided a framework, methods, and data to support analyses of salinity alternatives. Volume Three of the report includes information regarding data sets and models for evaluating salinity impacts to non-domestic uses of water. A review of this section finds that this study relies on the same life expectancy data developed by Lohman et al. (1988) and water softener/home treatment system data developed by MWD (1999).
- *University of California Davis (2009)* recently evaluated the economic impacts of salinity in the Central Valley out to the year 2030 assuming no change in current policy regarding how salinity is managed. The portion of the report that evaluated impacts to residential water customers relied on the water-using device life expectancy and water softener/home treatment system data originally developed by Lohman et al. (1988) and MWD (1999), respectively. The analysis assumed a baseline urban TDS value of 264 mg/L (average of values used by Ragan et al. [2000] and Coe [1982]). The 2030 TDS value used for comparative purposes was 343 mg/L. This value is based on an analysis of 1967-1997 water quality data which showed that over a 30-year period TDS had increased approximately 30% (generally linear increase over the 30 year period). **Table 6** summarizes the expected change in appliance life expectancy based on this study.

Table 6. UC Davis (2009) Summary of Expected Change in Appliance Life Expectancy Based on Expected Increase in Salinity in the Central Valley Over 30-Year Period

Appliance	Life Expectancy at Baseline TDS (years)	Life Expectancy at Increased TDS (years)
Galvanized Water Pipes	30.63	28.16
Water Heaters	10.72	9.36
Faucets	10.74	10.50
Garbage Disposal	8.29	8.04
Washing Machine	11.73	11.05
Dishwashers	11.73	11.05

- *Michelsen et al. (2009)* recently prepared a report for the Rio Grande Salinity Management Coalition that estimates the economic impacts of salinity for water users in the Rio Grande Basin in portions of New Mexico and Texas. Using a baseline of 500 mg/L TDS, the study estimated per household costs resulting from delivered water with a salinity of 835 mg/L. This study did not attempt to re-evaluate the relationship between life expectancy of water-using devices and TDS. Instead, the study used the equations developed by Tihansky (1974).

Information regarding costs/household is provided; however, such data is local in nature and cannot be directly compared to other studies.

Industrial

Most studies that estimate impacts of increased salinity on non-drinking uses of water focus on impacts to residential households. Some of these studies suggest that residential and commercial impacts are similar given that similar water-using appliances are used in both. A few sources provide additional information with regards to impacts to specific types of industrial facilities. This information is summarized below.

Lohman et al. (1988) discusses impacts of increased salinity on water and wastewater utilities. For example, for water utilities over time production, distribution and storage systems can be impacted by salinity-related corrosion that reduces the life expectancy of these systems. Similarly, impacts occur to a wastewater collection system and the mechanical equipment in a wastewater treatment facility. To estimate the impacts, Lohman et al. (1988) used regression equations developed by Tihansky (1974) to calculate the relationship between TDS concentration and life expectancy of water supply production and distribution systems and wastewater collection systems. **Table 7** summarizes the findings. These data were also used by Lohman et al. (1988) to estimate per capita capital investment costs for water supply systems.

Table 7. Life Expectancy of Various Water/Wastewater Systems as Related to Increased TDS (mg/L)

TDS (mg/L)	Water Utility Production Systems (Years)	Water Utility Distribution Systems (Years)	Wastewater Utility Systems (Years)
0	30.83	110	40.83
100	30.5	105.7	30.5
200	30.17	101.76	30.17
300	29.84	98.17	29.84
400	29.51	94.88	29.51
500	29.18	91.88	29.18
600	28.85	89.14	28.85
700	28.52	86.63	28.52
800	28.19	84.34	28.19
900	27.86	82.24	27.86
1000	27.53	80.33	27.53
1100	27.2	78.58	27.2
1200	26.87	76.98	26.87

Lohman et al. (1988) also summarizes the findings from various studies that identified recommended TDS criteria for different types of industrial processes (McKee & Wolff 1976; Office of Water Research and Technology [OWRT] 1981; Culp et al. 1979; EPA 1976) (**Table 8**).

Table 8. Recommended TDS Concentration Ranges or Maximum Values Based on Various Studies

Industrial Process	TDS (mg/L) (maximum or range of recommended values)
Primary Metals	1,500
Clear Plastics	200
Confectionary Products	100
Cooling Water	35,000
Textile Manufacture	100 to 200
Canning	500 to 850
Carbonated Beverages	500 to 850
General Food Processing	500 to 850
Ice-Making	170 to 3000
Pulp and Paper	80 to 1080
Chemicals	1000 to 2500
Petroleum	1000 to 3500

Lohman et al. quotes OWRT (1981), "From the industrial viewpoint, the primary criterion is that the primary water supply be of consistent quality so that pretreatment [is]... maintained routinely.'' That is, salinity usually can be treated but constantly changing levels of salinity, or any other constituent can cause the industrial water user serious problems.

UC Davis (2009) estimates the costs of increased salinity on industrial water users but presents them in terms of cost per acre foot of water per 1 mg/L increase in salinity for three types of processes: cooling tower operations, boiler operation and water treatment (**Table 9**). The study calculated costs using a methodology established in Wilson (2000) (not reviewed) and assumes industry in the Central Valley can be considered uniform, that is no differentiation exists between various industrial structures. As such the study states that the cost per acre foot of water is overestimated for some types of buildings, understated for others, but as a whole the average is appropriate. Since no other studies were found that used this method to present results, these data cannot be compared with other studies reported in this document.

Table 9. Cost per Acre Foot (AF) of Water Resulting from a 1 mg/L Increase in Salinity (TDS)

Business Item	Cost per AF
Cooling Tower Operation	$9.88
Boiler Operation	$5.38
Process Water Treatment	$21.41

Summary of Impacts to Non-Drinking Water Uses of Municipal and Domestic Water Supplies

- Based on the literature reviewed, it is apparent that evaluations of impacts of increased salinity on non-domestic water uses is based on two key sources – (1) Tihansky (1974) which established an original set of regression relationships between increased TDS and life expectancy of water-using appliances; and (2) Lohman et al. 1988, which revised the Tihansky equations based on a revised economic model (one exception is the curve for impacts to galvanized pipes – the equations were unchanged from Tihansky 1974). Figure 4 above illustrates these relationships.

- Ragan et al. (2000) developed their own model relating TDS to salinity effects. The findings from their analyses suggest that salinity impacts may be less than previously believed, in part because of improved methodology, but also because of improved technology that uses more plastic and composites in water-using devices. This technology is less susceptible to the impacts of increased salinity.

- Information regarding the relationship between bottled water use and home water treatment devices is based on data developed in MWD (1999).

- The most recent studies focus on translating residential (and by extension commercial) salinity impacts into economic costs ranging from cost/per household to millions of dollars per year for a given area. For the most part these types of findings are not presented here simply because the findings of these studies are spatially or temporally-specific in their application.

- Regardless of the economic analyses done in recent studies, the findings are being developed using the same salinity impact relationships published by Lohman et al. (1988) and MWD (1999). Efforts to revise the data behind this model or previous models (which used questionnaires, surveys, etc.) apparently have not been repeated in decades.

- Information regarding impacts to non-agricultural industrial equipment or facilities appears to generally be limited with the best summary apparently completed by Lohman et al. (1988). As with residential studies, the most recent studies that include industry in the analysis (e.g., CASS [2003]; Michelsen et al. [2009]; UC Davis [2009]), it is difficult to compare one study with another given differences in methods, economic issues, etc.

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Attachment A

Drinking Water Quality Criteria for Evaluation of Water Quality Objectives for the Lower San Joaquin River, draft prepared by Dennis Westcot for the Lower San Joaquin River Committee of the CV-SALTS Program, June 20, 2012.

Attachment A

DRINKING WATER QUALITY CRITERIA FOR EVALUATION OF WATER QUALITY OBJECTIVES FOR THE LOWER SAN JOAQUIN RIVER

Review Prepared for the Lower San Joaquin River Committee of the CV-SALTS Program

20 June 2012

Recommended Drinking Water Quality Criteria for Evaluation of Water Quality Objectives

The recommendations presented here are based upon the review of each constituent presented in sections that follow this recommendations section. The review considered total dissolved solids (TDS) and the principal cations and anions in water salinity. The cations considered were sodium, potassium, calcium and magnesium. The principal anions were chloride, sulfate, carbonate and bicarbonate. A summary of the recommendations is shown in Table 1 with a brief write-up on the recommendations below.

TDS/EC

Recommend using the Secondary Drinking Water Standard for inorganic chemicals found in CCR §64449 and specifically found in Table 64449-B (Table 2 of the write-up below). This represents the latest information on salinity in drinking water. It should also be clear that the recommendations in Table 64449-B are based on consumer acceptance and are not health-based standards as would be found in Primary Drinking Water Standards located in CCR §64431.

This recommendation is also consistent with the US EPA National Secondary Drinking Water Regulations located in 40 CFR §141.2 of the Safe Drinking Water Act.

This recommendation is also consistent with the most recent international review of TDS in drinking water supplies by World Health Organization (WHO). In their most recent guideline review, WHO made no recommendation for a TDS level because "*not a health concern at levels found in drinking water supplies*". This was based upon a 2003 analysis by a large group of international experts.

Bicarbonate (HCO_3)

No recommended drinking water criteria. This is consistent with the recent review showing no need for such a standard. Bicarbonate is not mentioned in any of the latest federal, state or international guidelines.

Boron (B)

Recommend using the WHO drinking water guideline for boron of 2.4 mg/L. This was developed after an extensive review of all the health data, most of which was developed by US EPA. There is no federal or state primary or secondary drinking water standard for boron and none is being considered for development. The California Department of Public Health has established a state action level of 1.0 mg/L but this has never been translated into a drinking water standard. Other beneficial uses are likely to have more restrictive needs than the present state action level.

Calcium (Ca)

No recommended drinking water criteria. This is consistent with a 1968 review showing no need for such a standard. Calcium is not mentioned in any of the latest federal, state or international guidelines nor are there any reviews planned.

Table 1. Summary of Water Quality Guidelines and Standards for Drinking Water by State, National and International Agencies for Salinity-Based Constituents.

	US EPA Maximum Contaminant Levels and Maximum Contaminant Level Goals located in 40 CFR §141 of the Safe Drinking Water Act	US EPA National Secondary Drinking Water Regulations located in 40 CFR §141.2 of the Safe Drinking Water Act	California Department of Public Health (CDPH) Maximum Contaminant Level (MCL) for Drinking Water located in CCR §64431.	California Department of Public Health (CDPH) Secondary Drinking Water Standards located in CCR §64449	World Health Organization (WHO) International Drinking Water Guidelines	Guidelines for Canadian Drinking Water Quality Guidelines Health-based Maximum Acceptable Concentrations (MAC)	Guidelines for Canadian Drinking Water Quality Guidelines Based on Aesthetic Considerations (AO)
Total Dissolved Solids (TDS)		500 mg/L		500 mg/L (1)	(2)		< 500 mg/L
Electrical Conductivity (EC)				900 µS/cm (3)			
Bicarbonate (HCO_3)							
Boron (B)				1.0 mg/L (4)	2.4 mg/L	5 mg/L	
Calcium (Ca)					(2)		(5)
Carbonate (CO_3)							
Chloride (Cl)				250 mg/L (6)	(2)		< 250 mg/L
Magnesium (Mg)					(2)		(5)
Potassium (K)					(2)		
Sodium (Na)					(2)		< 200 mg/L
Sulfate (SO_4)				250 mg/L (7)	(2)		< 500 mg/L

(1) The 500 mg/L is recommended for continuous use with an upper limit of 1,000 mg/L. Short-term or intermittent use is allowed up to a TDS of 1,500 mg/L.

(2) Some chemical and physical parameters for which a World Health Organization Technical Expert Document is available have been identified as not requiring a numerical guideline, because currently available data indicate that it poses no health risk or aesthetic problem at the levels generally found in drinking water.

(3) The 900 µS/cm is recommended for continuous use with an upper limit of 1,600 µS/cm. Short-term or intermittent use is allowed up to an EC of 2,200 µS/cm.

(4) State Action Level that requires notification of the water users. Boron is not a regulated contaminant but is considered a contaminant of concern.

(5) Some chemical and physical parameters for which a Canadian Guideline Technical Document is available have been identified as not requiring a numerical guideline, because currently available data indicate that it poses no health risk or aesthetic problem at the levels generally found in drinking water.

(6) The 250 mg/L is recommended for continuous use with an upper limit of 500 mg/L. Short-term or intermittent use is allowed up to a Cl of 600 mg/L.

(7) The 250 mg/L is recommended for continuous use with an upper limit of 500 mg/L. Short-term or intermittent use is allowed up to a SO_4 of 600 mg/L.

Carbonate (CO_3)

No recommended drinking water criteria. This is consistent with lack of any mention of carbonate in any of the federal, state or international guidelines that have been considered over the last 5 decades. No new reviews are planned.

Chloride (Cl)

Recommend using the Secondary Drinking Water Standard for inorganic chemicals found in CCR §64449 and specifically found in Table 64449-B (Table 2 of the write-up below). Table 64449-B represents the latest information on chloride in drinking water. It should also be clear that the recommendations in Table 64449-B are based on consumer acceptance and are not health-based standards as would be found in Primary Drinking Water Standards located in CCR §64431.

This recommendation is also consistent with US EPA in their review of water quality criteria as they felt the levels shown in CCR, Table 64449-B were a reasonable maximum to protect consumers of drinking water. This is also consistent with the US EPA National Secondary Drinking Water Regulations located in 40 CFR §141.2 of the Safe Drinking Water Act.

This recommendation is also consistent with the most recent international review by WHO of chloride in drinking water. There is no international guideline or standard for chloride in drinking water due to a lack of evidence of public health effects. None are planned at the present time.

Magnesium (Mg)

No recommended drinking water criteria. This is consistent with lack of any mention of magnesium in any of the federal, state or international guidelines that have been considered over the last 5 decades. No new reviews are planned. However the LSJR Committee should put a goal of 100 mg/L for our studies as magnesium has been shown to be a strong laxative in elevated concentrations above 100 mg/L.

Potassium (K)

No recommended drinking water criteria. This is consistent with information that shows that potassium is considered relatively non-toxic to man and not a public health hazard. WHO stated that "*Currently, there is no evidence that potassium levels in municipally treated drinking water, even water treated with potassium permanganate, are likely to pose any risk for health of consumers.*"

Sodium (Na)

Recommend using an unofficial goal of 100 mg/L with a maximum concentration of 200 mg/L. Neither of these is based on public health but the WHO did recognize that sodium may cause a taste or public acceptance issue at levels above 200 mg/L. Many times domestic water supplies are used for home gardening and above the 200 mg/L level soil infiltration problems may result during gardening.

Sulfate (SO_4)

Recommend using the Secondary Drinking Water Standard for inorganic chemicals found in CCR §64449 and specifically found in Table 64449-B (Table 2 of the write-up below). This represents the latest information on sulfate in drinking water. It should also be clear that the recommendations in Table 64449-B are based on consumer acceptance and are not health-based standards as would be found in Primary Drinking Water Standards located in CCR §64431.

This recommendation is also consistent with the most recent federal and international reviews of sulfate in drinking water supplies by US EPA and WHO. There are no federal drinking water standards and no international guidelines or standards for sulfate in drinking water due to a lack of evidence of public health effects. There are no further reviews in the planning at the present time.

Salinity (Total Dissolved Solids) in Municipal and Domestic Water Supplies

Background

All water contains a certain amount of total dissolved solids (TDS). TDS consists mostly of inorganic salts but also contains minute amounts of organic matter and dissolved materials (Sawyer, 1960 as cited in US EPA, 1986). The principal cations in water salinity are sodium, potassium, calcium and magnesium. The principal anions are chloride, sulfate, carbonate and bicarbonate.

Many communities have used domestic water supplies ranging from 2,000 to 4,000 mg/L of dissolved salts when better supplies were not available (McKee and Wolf, 1963). These supplies however are generally not palatable and may act as a laxative for newer users. It is generally thought that waters containing more than 4,000 mg/L of total dissolved salts are unfit for human use. McKee and Wolf (1963) report that water containing 5,000 mg/L or more of dissolved solids are bitter to the taste and can act as bladder and intestinal irritants.

The U. S. Public Health Service (US PHS) developed the first drinking water standard for TDS in 1925 with a TDS level of 1,000 mg/L. This was revised downward to 500 mg/L in 1942 and continued at this level through the 1946 and 1962 revisions to the standards (McKee and Wolf, 1963). The first international drinking water standard for TDS was developed by the World Health Organization (WHO) in 1958 and called for a TDS level of 500 mg/L but did allow short term use to reach 1,500 mg/L (WHO, 1958).

In 1963 it was generally agreed that the salt concentration of good palatable water should not exceed 500 mg/L. However, water having higher concentrations could be consumed without harmful physiological effect. There is no evidence that mineralized waters are a source of minerals for human nutrition and well being or have any therapeutic value (McKee and Wolf, 1963). McKee and Wolf (1963) stated however that water over 1,000 mg/L should be evaluated based on the local situation, availability of alternative supplies and the reaction of the local population.

A consumer survey in 29 California water systems was conducted to measure the taste threshold of dissolved salts in the drinking water. The study showed various ranges of acceptance. Waters with a TDS ranging between 319 and 397 mg/L was rated as “excellent”, with 658 to 755 mg/L rated as “good” and those in the range of 1,283 to 1,333 mg/L were rated as “unacceptable” (Bruvold et al., 1969 and van Lelyveld and Zoeteman, 1981). The TDS level of water diverted by Metropolitan Water District of Southern California from the Colorado River often has salinity in excess of 700 mg/L. The present salinity standard for the Colorado River at Imperial Dam is 879 mg/L which is then diverted for various uses including municipal and domestic water supplies (Colorado River Basin Salinity Control Forum, 2002).

A 1968 report by the National Technical Advisory Committee to the Secretary of the Interior (sometimes referred to as the Green Book) recommended that the permissible value for TDS be set at 500 mg/L in view of the results from the taste tests yet knowing that limits above the 500 mg/L level are probably acceptable to consumers of domestic water supplies and that economic factors may control the achievement of the recommended 500 mg/L level (FWPCA, 1968). The 1968 FWPCA recommendation was based on the lack of evidence that ingestion of TDS in drinking water showed any adverse health effects and likely was due to consumer acceptance (McKee and Wolf, 1963).

Present Day TDS Drinking Water Standard - federal

US EPA develops ambient water quality criteria for protection of drinking water supplies and establishing additional drinking water treatment needs. The term "water quality criteria" is used in two sections of the Clean Water Act (CWA), Sections 303 (c) (2) and 304 (a) (1). The term has a different definition in each section. Under Section 303 the term is associated with specific water body uses to define the maximum level of a pollutant that would protect designated uses in ambient waters. Under Section 304 the term represents a scientific assessment of ecological and human health effects that the EPA recommends to states and tribes for establishing water quality standards that ultimately provide a basis for controlling discharges or releases of pollutants. They are not regulations in themselves and do not impose legally binding requirements on EPA or the states (CUWA, 2007b).

Human health-based water quality criteria are numeric values set to protect human health from pollutants in ambient water. A human health criterion is the highest concentration of a pollutant in water that is not expected to pose a significant risk to human health. Under Section 304 (a) of the CWA, water quality criteria are developed by assessing the relationship between pollutants and their effect on human health and the environment.

The 1962 US PHS drinking water standard for TDS was reviewed during the development of more intensive water quality criteria documents by the U. S. Environmental Protection Agency. The first (often referred to as the Blue Book) again reaffirmed the 500 mg/L FWPCA recommendation of 1968 (US EPA, 1973). This recommendation was not changed during the review of water quality criteria conducted by US EPA in 1976 (Red Book) and again in 1986 (Gold Book) (US EPA 1976 and USEPA, 1986).

US EPA also develops both Maximum Contaminant Levels and Maximum Contaminant Level Goals for drinking water under the 40 CFR §141. Maximum contaminant level (MCL) means the maximum permissible level of a contaminant in water which is delivered to any user of a public water system. Maximum contaminant level goal (MCLG) means the maximum level of a contaminant in drinking water at which no known or anticipated adverse effect on the health of persons would occur, and which allows an adequate margin of safety. Maximum contaminant level goals are non-enforceable health goals (CUWA, 2007b). There are no known or listed MCLs or MCLGs in §141 of the CWA for TDS or salinity-related constituents (CFR, 2012).

US EPA also establishes National Secondary Drinking Water Regulations pursuant to section 40 CFR §141.2 of the Safe Drinking Water Act. These regulations contain a listing of contaminants in public drinking water supplies that primarily affect the aesthetic qualities relating to the public acceptance of drinking water. The regulations are not federally enforceable but are intended as guidance for the States. The secondary maximum contaminant levels (SMCLs) for TDS is 500 mg/L and is found in 40 CFR §143.3 (CFR, 2012).

Present Day TDS Drinking Water Standard – California

There are two California State agencies that are involved in establishing Drinking Water Standards. The first is the California Office of Environmental Health Hazard Assessment (OEHHA). OEHHA, specifically the Water Toxicology Unit, is responsible for establishing Public Health Goals (PHGs) in California. A PHG is the level of a contaminant in drinking water that does not pose a significant risk to public health. This is not a regulatory standard, rather guidance for California Department of Public Health (CDPH) to consider when setting a drinking water Maximum Contaminant Level (MCL) for a constituent. A PHG is different from Maximum Contaminant Level Goals (MCLGs) which are set by the U.S. Environmental Protection Agency (US EPA). MCLGs are the level of a contaminant in drinking water below which there is no known or expected risk to health, including a margin of safety. The California Urban Water Agencies (CUWA) Central Valley Drinking Water Program Work Group (CUWA, 2007a) found no PHGs for TDS or other salinity-related compounds and found none were in the immediate planning by OEHHA.

The second agency is the California Department of Public Health (CDPH). The drinking water protection program for the CDPH is administered through its Division of Drinking Water and Environmental Management. CDPH drinking water-related regulations are in Titles 22 and 17 of the California Code of Regulations commonly known as the California Safe Drinking Water Act & Related Statutes. Under §116275, maximum contaminant level means the maximum permissible level of a contaminant in the water. The primary drinking water standard is the maximum level of a contaminant that in the judgment of the CDPH may have an adverse effect on the health of persons.

In contrast, a secondary drinking water standard" means a standard that specifies a maximum contaminant level that, in the judgment of the department, are necessary to protect the public welfare. Secondary drinking water standards are not enforceable but set guidance on how public water systems should be operated. A secondary drinking water standard may apply to any contaminant in drinking water that may adversely affect the odor or appearance of the water and may cause a substantial number of persons served by the public water system to discontinue its use, or that may otherwise adversely affect the public welfare. Regulations establishing secondary drinking water standards may vary according to geographic and other circumstances and may apply to any contaminant in drinking water that adversely affects the taste, odor, or appearance of the water when the standards are necessary to ensure a supply of pure, wholesome, and potable water.

Primary drinking water standards for inorganic chemicals that are administered by CDPH are found in §64431. There is no primary drinking water standard for TDS or other salinity-related compounds found in §64431. The Secondary Drinking Water Standards for inorganic chemicals are found in §64449 (Tables 64449-A and 64449-B). Those that are salinity or salinity-related are found in Table 64449-B and include ranges for Total Dissolved Solids (TDS), Specific Conductance (µS/cm), chloride (Cl) and sulfate (SO_4) (see later discussion on chloride and sulfate). For TDS, the recommended maximum contaminant level is 500 mg/L (CUWA, 2007a and CUWA, 2007e) which is consistent with the secondary maximum contaminant levels (SMCLs) for TDS of 500 mg/L found in the federal statute 40 CFR §143.3 (CFR, 2012). Table 64449-B also contains a specific conductance level of 900 µS/cm which is equivalent to the 500 mg/L TDS level (CUWA 2007e) (see Table 2). This standard is applied by the CDPH to community water systems administered by the CDPH and is referenced for domestic and municipal water supply use in the Central Valley Regional Board Basin Plan water quality objectives chapter (p. III-3.00). Also in a policy entitled "Sources of Drinking Water", the State Water Resources Control Board (State Water Board) in Resolution No. 88-63 stated that surface and ground water with a TDS less than 3,000 mg/L (5,000 µmhos/cm EC) is suitable or potentially suitable for municipal or domestic water supply.

Table 64449-B also shows an upper limit for TDS of 1,000 mg/L (1,600 µS/cm) and a maximum contaminant level range for short term or intermittent use of a TDS of 1,500 mg/L (2,200 µS/cm). The upper limit and short-term levels reflect the lack of evidence of any health affects below these values and the findings that consumer acceptance is diminishing above these levels.

Table 2. (Taken from Table 64449-B)

Secondary Maximum Contaminant Levels
"Consumer Acceptance Contaminant Level Ranges"

	Maximum Contaminant Level Ranges		
Constituent, Units	*Recommended*	*Upper*	*Short Term*
Total Dissolved Solids, mg/L	500	1,000	1,500
or			
Specific Conductance, µS/cm	900	1,600	2,200
Chloride, mg/L	250	500	600
Sulfate, mg/L	250	500	600

Present Day TDS Drinking Water Standard – Other States and Countries

This is a summary of work done by CUWA, 2007c in identifying water quality criteria and objectives established by other states for salinity and salinity-related constituents. CUWA used an assessment of several criteria in choosing states to survey, including known incidences of water quality concerns related to the constituent of interest, presence of unfiltered drinking water supplies, historically progressive regulatory arena, and presence of large number of impacted source waters for the Clean Water Act Total Maximum Daily Load program. Of the twelve states contacted, eight had salinity or salinity-related criteria. Those were: Florida, Michigan, Mississippi, New Jersey, New York, North Carolina, Oklahoma, and Utah. A summary of the CUWA, (2007c) findings are:

- Florida has a surface water salinity criterion with a monthly average of 500 mg/L, not to exceed 1,000 mg/L. Groundwaters used for potable supplies are classified by their TDS levels, either Class G-1 less than 3,000 mg/L or Glass G-II less than 10,000 mg/L;

- Michigan has an ambient standard of 500 mg/L (monthly average) that can't be exceeded in surface waters (this is TDS from controllable point source discharges) and TDS can't exceed 750 mg/L as a maximum in surface waters (from controllable point source discharges);

- Mississippi and North Carolina regulations state that there shall be no substances added that will cause the TDS to exceed 500 mg/L in freshwater streams;

- New Jersey has a standard which prohibits an increase in background levels of TDS which may adversely affect the survival, growth or propagation of the aquatic biota or 500 mg/L, whichever is more stringent;

- New York has two standards based on the classification of the waterway. For A-Special (pristine) the amount shall not exceed 200 mg/L and for other classes of potable waters it shall be kept as low as practicable to maintain the best usage of waters but in no case shall it exceed 500 mg/L;

- Oklahoma has a narrative criteria for TDS stating that the waters will be maintained so as to be essentially free of substances of a persistent nature, from other than natural sources; and

- Utah set their TDS criteria at 1,200 mg/L although they have many site-specific salinity criteria because of the natural salinity levels in several parts of Utah. Their site-specific salinity criteria range from 1,800 mg/L to 9,700 mg/L.

- CUWA (2007c) also surveyed five countries for water quality goals or policies related to salinity. Three of the countries, New Zealand, Australia and Canada had national water quality guidelines that related to salinity in drinking water. In Australia and New Zealand national water quality guidelines are set under the National Water Quality Management Strategy for ambient and drinking water. The drinking water guideline for TDS is set at 1,000 mg/L. Canada appeared to have the most thorough water protection program, which monitors and manages water quality from the source to the tap. The National Guideline for drinking water is a health based guideline of 500 mg/L for TDS.

Present Day TDS Drinking Water Standard – International

The World Health Organization (WHO) has been very active in developing guidance for countries to assist them in establishing drinking water standards. The first WHO International Drinking Water Standards were proposed in 1958 and showed a 500 mg/L TDS limit except that the limitation could be relaxed to 1,500 mg/L under conditions where no other better quality supplies were available (McKee and Wolf, 1963 and WHO, 1958). A more in-depth review of the database showed that there were no reliable data on possible health effects associated with the ingestion of TDS in drinking water. The resulting recommendation by WHO was that water containing a TDS concentration below 1,000 mg/L is usually acceptable to consumers although acceptability may vary according to circumstances (WHO, 1996a). WHO also cautioned that extremely low TDS concentrations (<65 mg/L) may also be unacceptable to consumers because of its flat taste and also the corrosiveness to water supply systems (WHO, 1996a). A more recent review confirms that there is no reliable data on possible health effects associated with the ingestion of TDS in drinking water (WHO, 2003c).

In their most recent guidelines, WHO made no recommendation for a TDS level because TDS was "*not a health concern at levels found in drinking water supplies*". This was based on a 2003 analysis by international experts (WHO 2003c and WHO, 2011b).

Present Day TDS Water Quality Objectives – Regional Board Basin Plans

CUWA (2007d) evaluated the Basin Plans of the nine California Regional Water Quality Control Boards for salinity objectives for protection of the drinking water beneficial use. The results are found in Table 3. Most, if not all the water quality objectives in the basin plans are based on the primary and secondary drinking water standards for inorganic chemicals that are administered by CDPH and are found in §64431. There is no primary drinking water standard for TDS in §64431 but there is secondary drinking water standards for Total Dissolved Solids (TDS), Specific Conductance (µS/cm) in §64449 (Tables 64449-B). For TDS, the recommended maximum contaminant level is consistent with the secondary maximum contaminant levels (SMCLs) for TDS of 500 mg/L found in the federal statute 40 CFR §143.3 (CFR, 2012). This standard is applied by the CDPH to community water systems administered by the CDPH and is referenced for domestic and municipal water supply use in the Central Valley Regional Board Basin Plan water quality objectives chapter (p. III-3.00). Also in a policy entitled "Sources of Drinking Water", the State Water Resources Control Board (State Water Board) in Resolution No. 88-63 stated that surface and ground water with a TDS less than 3,000 mg/L (5,000 µmhos/cm EC) is suitable or potentially suitable for municipal or domestic water supply.

Bicarbonate (HCO_3) in Municipal and Domestic Water Supplies

According to McKee and Wolf (1963) the bicarbonate ion is not considered to be detrimental. Bicarbonate in water occurs from many natural processes including absorption of CO_2 from air. Concentrations of bicarbonate are often associated with hardness. Concentrations up to 700 mg/L of bicarbonate in drinking water have been reported to be harmless. Hibbard (1934) has recommended bicarbonate concentrations for domestic water use be less than 150 mg/L.

The US PHS Drinking Water Standards of 1962 (US PHS, 1962) and the WHO European Standards of 1961 (WHO, 1961) and the WHO International Standards of 1958 (WHO, 1958) did not contain any limits for bicarbonate in drinking water. Many cities in the Central Valley do have elevated bicarbonate in their drinking water supplies. The City of Davis has a weighted average for bicarbonate in their drinking water supply of 294 mg/L with drinking water wells ranging from 180 to 560 mg/L (City of Davis, 2011). The City of Woodland has a weighted average for bicarbonate in their drinking water supply of 303 mg/L with drinking water wells ranging from 240 to 410 mg/L (City of Woodland, 2011). Bicarbonate is not mentioned in any of the latest federal, state or international guidelines (US EPA, 1973, US EPA, 1976, US EPA, 1986, WHO, 1996a and WHO, 2011b).

- There is no federal maximum contaminant level goal (MCLG) for bicarbonate in drinking water in CFR 40 §141.51.
- There is no federal maximum contaminant level (MCL) for bicarbonate in drinking water are found in CFR 40 §141.62.
- There is no federal secondary maximum contaminant level (SMCL) for bicarbonate in drinking water in CFR 40 §143.3.
- There is no California primary drinking water standard (Primary MCL) for bicarbonate in drinking water found in CCR §64431.

Table 3

Summary of Existing Water Quality Objectives for the Regional Water Boards (CUWA, 2007d)

	Region 1 – North Coast	**Region 2 – San Francisco Bay**	**Region 3 – Central Coast**	**Region 4 – Los Angeles**	**Region 5 – Central Valley**	**Region 6 - Lahontan**	**Region 7 – Colorado River**	**Region 8 – Santa Ana**	**Region 9 – San Diego**
Dissolved Minerals (TDS, EC, bromide, and chloride)	MUN: Site-specific objective (selected water bodies only) for TDS and EC	MUN: TDS=500 mg/L, EC=900 mmhos/cm, chloride=250 mg/L (2nd MCLs) Controllable water quality factors shall not increase the total dissolved solids or salinity of waters of the state so as to adversely affect beneficial uses, particularly fish migration and estuarine habitat	Controllable water quality factors shall not increase the total dissolved solids or salinity of waters of the state so as to adversely affect beneficial uses, particularly fish migration and estuarine habitat. There are also Specific objectives for TDS and chloride in surface waters And ground waters by sub-basin and sub-area.	MUN: TDS=500 mg/L, chloride= 250 mg/L (2nd MCLs) There are site specific objective for TDS and chloride for selected inland waters, both surface water and groundwater	Site-specific objective for EC and chloride. TDS in Folsom Lake 90th percentile <100 mg/L. TDS in Folsom Lake tributaries and American River from Folsom Dam to the Sacramento River 90th percentile <125 mg/L. EC: Sacramento R. at Knights Landing 50th percentile <230 mmhos/cm and 90th percentile <235, Sacramento R. at I Street 50th percentile <240 and 90th percentile <290, Feather R. 90th percentile <150, San Joaquin R. between Friant Dam and Mendota Pool 90th percentile <150. Chloride: 250 mg/L for selected MUN	MUN: TDS=500 mg/L, EC=900 mmhos/cm, chloride=250 mg/L (2nd MCLs) Also, site-specific water quality objectives for TDS and EC	Discharges are not allowed to increase the receiving water concentrations unless there is no adverse impact to affected beneficial uses. TDS water quality objectives for specific reaches.	MUN: TDS =1,000 mg/L, chloride=500 mg/L There are also site-specific objective for TDS and chloride for selected inland waters, both surface water and groundwater.	For municipal supplies a range of TDS=500 – 1,000 mg/L is recommended and a range for chloride of 250 – 500 mg/L, but many variances have been approved for various water sources due to the naturally high levels of minerals in the groundwaters and surface waters.

- There is no California secondary drinking water standard (Secondary MCL) for bicarbonate in drinking water found in Table 64449-A and 64449-B of CCR §64449.

Boron (B) in Municipal and Domestic Water Supplies

Although boron is essential in the nutrition of higher plants, there is no evidence that it performs any vital function in humans or animal nutrition (Browning, 1961). Murry (1995) stated that there were insufficient data to establish a nutritional need for boron. He cites Nielsen (1994) as suggesting that boron is a probable essential trace element for humans. In food or in water it is rapidly and completely absorbed by the human system, but it is also promptly excreted in urine (Browning, 1961). One study found boron in drinking water supplies ranging from 0.020 to 0.740 mg/L (US PHS, 1964). Boron in drinking water is not generally regarded as a hazard to human beings (Negus, 1938). Early limitations on boron were in the range of 20 -30 mg/L in drinking water, well above levels found in natural water of sufficient quality for drinking water supplies (McKee and Wolf, 1963 and US PHS, 1964). As a result, early drinking water standards by the US PHS did not have any limitation for boron. WHO also did not propose any international drinking water standard or guideline in their initial efforts in 1958 (McKee and Wolf, 1963 and WHO, 1958). The US PHS did establish a 1.0 mg/L limitation which was based as much on drinking water as on the consideration that domestic use of water was also used for home gardening (FWPCA, 1968).

Klasing and Pilch (1988) stated that some human and animal studies indicated adverse male reproductive effects from a “very high level” of dietary boron (e.g. 0.3 mg/kg of body weight for rats exposed over 6 months). However they concluded that acute and/or chronic dose-response, which was shown to cause such effects, was conflicting. They felt that additional studies were needed to determine chronic dose-response effects.

In the 1993 WHO guidelines for Drinking Water Quality (WHO, 1993a), WHO recommended a health-based guideline value for boron in drinking water of 0.3 mg/L. This value was derived from a 2-year study in dogs published in 1972 (testicular atrophy was the critical end-point for toxicity). Murry (1995) as cited in Davis (1999) did a human health risk assessment of boron in drinking water using a relative source concept. He summarized key animal toxicity studies and concluded that the rat was the most sensitive species. It had a no observed adverse effect level (NOAEL) of 9.6 mg boron/kg/day for developmental toxicity. A Reference Dose was calculated at 0.3 mg boron/kg/day based on dividing the NOAEL by an uncertainty factor of eight for intra-species variation and by four for inter-species variation. The Reference Dose of 0.3 mg boron/kg/day resulted in a total acceptable daily intake of 18 mg boron/day based on an average weight of 60 kilograms for a woman of child bearing age. Based on an average diet of 1.5 mg boron/day, and a total acceptable daily intake of 18 mg boron/day resulted in an acceptable drinking water uptake of 16.5 mg boron/day. Based on a daily drinking water consumption of two liters/day, a person could drink water containing up to 8.25 mg/L boron. Murry (1995) concluded from his risk assessment that consuming water with up to 4 mg/L boron per day would not be expected to pose any developmental, reproductive, or other health risk to the public.

After the recommendation in the WHO 1993 drinking water guidelines for boron, WHO began to hear a rising concern for excess levels of boron in drinking water and the human diet in general. As a result, WHO organized a special review of boron in drinking water and concluded that in the future the water quality standard should be established at a level of 0.5 mg/L in drinking water (WHO, 1998). The majority of the initial draft of the WHO boron review was written by Carolyn Smallwood from the Environmental Criteria and Assessment Office of the U.S. EPA in Cincinnati, Ohio.

This sudden and dramatic change in the recommendation by WHO prompted a flurry of activity to review existing data and studies on boron. The US EPA IRIS human health risk assessment database has a calculated reference dose NOAEL of 8.8 mg boron/kg/day for testicular atrophy and spermatogenic arrest in a 2-year dog study which resulted in the first WHO guideline of 0.3 mg/L boron in drinking water (Morry, 1998 as cited in Davis, 1999). The US EPA NOAEL is lower based on the 2-year dog study than the NOEAL that Murry (1995) used based on the rat study. US EPA IRIS data indicate that the dog is more sensitive than the rat to boron compounds. Based on this study on dogs, the reference dose as a drinking water level was calculated to be 0.63 mg/L (Marshack, 1998). A further review of all of the information on the male reproductive tract toxicity and testicular lesions in dogs and rats by the WHO has result in their latest drinking water guideline recommendation of 2.4 mg/L (WHO, 2009a and 2009b and WHO, 2011b).

- The federal maximum contaminant level goal (MCLG) for inorganic contaminants in drinking water are found in CFR 40 §141.51. There is no MCLG for boron found in CFR 40 §141.51.

- The federal maximum contaminant level (MCL) for inorganic contaminants in drinking water are found in CFR 40 §141.62. There is no MCL for boron found in CFR 40 §141.62.

- The federal secondary maximum contaminant level (SMCL) for inorganic contaminants in drinking water are found in CFR 40 §143.3. There is no SMCL for boron found in CFR 40 §143.3.

- The California primary drinking water standard (Primary MCL) for inorganic chemicals in drinking water are found in CCR §64431. There is no Primary MCL for boron found in CCR §64431.

- The California secondary drinking water standard (Secondary MCL) for inorganic chemicals in drinking water are found in Table 64449-A and 64449-B in CCR §64449. There is no secondary drinking water MCL for boron found in Table 64449-A entitled “Secondary Maximum Contaminant levels - Consumer Acceptance Contaminant Levels” or in Table 64449-B entitled “Secondary Maximum Contaminant levels - Consumer Acceptance Contaminant Levels Ranges”.

- The CDPH however has established a state action level of 1.0 mg/L (Marshack, 1998).

Many cities especially on the west side of the Central Valley, such as the cities of Davis and Woodland, have boron levels in drinking water that exceed the state action level. The present weighted average for boron in the City of Davis drinking water supply is 0.84 mg/L with drinking water wells ranging from 0.52 to 1.2 mg/L with no adverse effects (City of Davis, 2011) while the average for the City of Woodland is 2.0 mg/L with a range of 1.6 to 2.6 mg/L (City of Woodland, 2011).

Calcium (Ca) in Municipal and Domestic Water Supplies

According to McKee and Wolf (1963) the human body requires approximately 0.7 to 2.0 grams of calcium per day as a food element, an amount considerably in excess of the calcium concentration normally consumed even with hard water. Concentrations up to 1,800 mg/L of calcium in drinking water have been reported to be harmless. Hibbard (1934) has recommended calcium concentrations for domestic water use be less than 30 mg/L.

The US PHS Drinking Water Standards of 1962 (US PHS, 1962) and the WHO European Standards of 1961 (WHO, 1961) did not contain any limits for calcium; but the WHO International Standards of 1958 (WHO, 1958) show that 75 mg/L is a permissible limit and 200 mg/L is considered an upper limit in drinking water (McKee and Wolf, 1963). A survey done of drinking water supplies in the United States shows calcium levels ranged from 0.8 mg/L to 207 mg/L with the majority below 50 mg/L (US PHS, 1964). As early as 1968, calcium had been removed from any surface water criteria for public drinking water supplies (FWPCA, 1968) and is not mentioned in any of the latest federal, state or international guidelines (US EPA, 1973, US EPA, 1976, US EPA, 1986, WHO, 1996a and WHO, 2011b).

- There is no federal maximum contaminant level goal (MCLG) for calcium in drinking water in CFR 40 §141.51.
- There is no federal maximum contaminant level (MCL) for calcium in drinking water are found in CFR 40 §141.62.
- There is no federal secondary maximum contaminant level (SMCL) for calcium in drinking water in CFR 40 §143.3.
- There is no California primary drinking water standard (Primary MCL) for calcium in drinking water found in CCR §64431.
- There is no California secondary drinking water standard (Secondary MCL) for calcium in drinking water found in Table 64449-A and 64449-B in CCR §64449.

Many cities in the Central Valley do have elevated calcium in their drinking water supplies. The Cities of Davis, Dixon and Woodland have a weighted average for calcium in their drinking water supply of 33, 48 and 62 mg/L, respectively with drinking water supplies ranging from 16 to 91 mg/L (City of Davis, 2011, City of Woodland, 2011 and City of Dixon, 2011).

Carbonate (CO_3) in Municipal and Domestic Water Supplies

According to McKee and Wolf (1963) the carbonate ion is relatively insoluble and has a tendency to precipitate out of a water supply. Carbonate is often associated with scaling problems. Therefore it is not considered to be detrimental to public health. Concentrations of carbonate are often associated with hardness. Hibbard (1934) recommended carbonate concentrations for domestic water use be less than 20 mg/L because of scaling problems when cooking and heating water.

The US PHS Drinking Water Standards of 1962 (US PHS, 1962) and the WHO European Standards of 1961 (WHO, 1961) and the WHO International Standards of 1958 (WHO, 1958) did not contain any limits for carbonate in drinking water (McKee and Wolf, 1963). Many cities in the Central Valley do have elevated carbonate in their drinking water supplies. The City of Davis has a weighted average for carbonate in the City of Davis drinking water supply of 5.9 mg/L with drinking water wells ranging from 3 to 15 mg/L (City of Davis, 2011). The City of Woodland has a weighted average for carbonate in their drinking water supply of 0.7 mg/L with drinking water wells ranging up to 6.3 mg/L (City of Woodland, 2011).

Carbonate is not mentioned in any of the latest federal, state or international guidelines (US EPA, 1973, US EPA, 1976, US EPA, 1986, WHO, 1996a and WHO, 2011b).

- There is no federal maximum contaminant level goal (MCLG) for carbonate in drinking water in CFR 40 §141.51.
- There is no federal maximum contaminant level (MCL) for carbonate in drinking water are found in CFR 40 §141.62.
- There is no federal secondary maximum contaminant level (SMCL) for carbonate in drinking water in CFR 40 §143.3.
- There is no California primary drinking water standard (Primary MCL) for carbonate in drinking water found in CCR §64431.
- There is no California secondary drinking water standard (Secondary MCL) for carbonate in drinking water found in Table 64449-A and 64449-B in CCR §64449.

Chloride (Cl) in Municipal and Domestic Water Supplies

Chloride is found in practically all natural waters. Chlorides are derived mostly from mineral breakdown or from leaching from former marine sediments. Because chloride is highly soluble, it makes up the major portion of ocean water and is often in high concentrations as water moves downstream from the mountains to the ocean. Chloride in drinking water is generally not harmful to human beings until high concentrations are reached, although chloride may be injurious to some people suffering from diseases of the heart or kidneys. Restrictions on chloride concentration in drinking water are based primarily on palatability requirements rather than on health (McKee and Wolf, 1963).

McKee and Wolf (1963) noted that chloride in water may impart a salty taste at concentrations as low as 100 mg/L, although in some waters 700 mg/L may not be noticeable. The Kettering Laboratory (1953, 1956 and 1957) found the most taste-sensitive people can detect chloride from calcium salts at 96 mg/L and from sodium salts at 121 mg/L. For average individuals, the taste threshold is more likely about 400 mg/L. The tolerance to chloride by humans varies. Chloride is lost primarily through perspiration which must either be replaced by diet or the drinking water. Thus climate and exertion play a big factor in tolerance. WHO (1996a) writes that in humans, 88% of the chloride is extracellular and contributes to the osmotic activity of body fluids. The electrolyte balance in the body is maintained by adjusting total dietary intake and by excretion via the kidneys and gastrointestinal tract. Chloride is almost completely absorbed in normal individuals. With normal fluid loss of 1.5-2 L/day results in a loss of approximately 4 g/L of chloride. Most (90-95%) is excreted in the urine. Canadian analysis shows that high levels of sodium chloride can cause hypertension but this appears to be related to the sodium rather than the chloride ion (CDNHW, 1978). As a result of this conclusion, WHO has proposed no health-based guideline for chloride in drinking water. However, they note that chloride concentrations in excess of about 250 mg/L can give rise to detectable taste in water (WHO, 1996a and WHO, 2011b).

The US PHS Drinking Water Standards of 1925, 1942, 1946 and 1962 recommended that chloride not exceed 250 mg/L. The WHO International Standards of 1958 (WHO, 1958) also showed a 250 mg/L limit but also showed that this could be exceeded and recommended 600 mg/L as an upper limit in drinking water. The WHO European Standards of 1961 (WHO, 1961) showed a chloride limit of 350 mg/L (McKee and Wolf, 1963). The 1968 Report on Water Quality Criteria (FWPCA, 1968) recommended a drinking-water criterion of 250 mg/L. US EPA in their reviews of water quality criteria also concluded that 250 mg/L was a reasonable maximum level to protect consumers of drinking water (US EPA, 1973, US EPA, 1976, US EPA, 1986). The criterion however was not based on protection of public health but on studies related to taste and the ability of adults to detect various levels of chloride (Ricter and MacLean, 1939 and Lockhart et al., 1955).

A survey done of drinking water supplies in the United States shows chloride levels ranging from 2 mg/L to 605 mg/L with the majority below 75 mg/L (US PHS, 1964). A survey also was done on 163 public water supplies in the United States showed an average chloride level of 20 mg/L (Schroeder, 1960). Many cities in the Central Valley do have elevated chloride in their drinking water supplies. The City of Davis has a weighted average for chloride in their drinking water supply of 43 mg/L with drinking water wells ranging from 12 to 150 mg/L (City of Davis, 2011). The City of Woodland has a weighted average for chloride in their drinking water supply of 79 mg/L with drinking water wells ranging from 47 to 110 mg/L (City of Woodland, 2011). The City of Dixon has a weighted average for chloride in their drinking water supply of 14 mg/L with drinking water supplies ranging from 11 to 19 mg/L (City of Dixon, 2011).

CUWA (2007d) evaluated the Basin Plans of the nine California Regional Water Quality Control Boards for chloride objectives for protection of the drinking water beneficial use. The results are found in Table 3. Regions 2, 4, 5 and 6 all use the present CDPH secondary contaminant level of 250 mg/L while Regions 8 and 9 use the 500 mg/L upper limit shown in the present CDPH secondary contaminant level guidelines.

- There is no federal maximum contaminant level goal (MCLG) for chloride in drinking water in CFR 40 §141.51.
- There is no federal maximum contaminant level (MCL) for chloride in drinking water are found in CFR 40 §141.62.
- There is a federal secondary maximum contaminant level (SMCL) for chloride in drinking water in CFR 40 §143.3. The level is 250 mg/L.
- There is no California primary drinking water standard (Primary MCL) for chloride in drinking water found in CCR §64431.
- There is a California secondary drinking water standard (Secondary MCL) for chloride in drinking water found in Table 64449-B in CCR §64449. Table 64449-B shows a recommended limit for chloride of 250 mg/L , an upper limit 500 mg/L and a maximum contaminant level for short term or intermittent use of a 600 mg/L (CCR, 2011). The upper limit and short-term levels reflect the lack of evidence of any health affects below these values and the findings that consumer acceptance is diminishing above these levels.

There are also no international guidelines or standards for chloride in drinking water due to a lack of evidence of public health effects at the present quality of most drinking water supplies (WHO, 2003a). There are no chloride evaluations in the planning at the present time (WHO, 1996a and WHO, 2011b).

Magnesium (Mg) in Municipal and Domestic Water Supplies

Magnesium is an essential element for human beings. It is considered relatively non-toxic to man and not a public health hazard because before toxic concentrations are reached in water, the taste becomes quite unpleasant (McKee and Wolf, 1963). At elevated concentrations, magnesium is a strong laxative (Marier et al., 1979).

A survey done of drinking water supplies in the United States shows magnesium levels ranging from 0.5 mg/L to 45 mg/L with the majority below 25 mg/L (US PHS, 1964). A survey also was done on 163 public water supplies in the United States showed an average magnesium level of 10 mg/L (Schroeder, 1960). Many cities in the Central Valley do have elevated magnesium in their drinking water supplies. The City of Davis has a weighted average for magnesium in their drinking water supply of 53 mg/L with drinking water wells ranging from 7 to 300 mg/L (City of Davis, 2011). The City of Woodland has a weighted average for magnesium in their drinking water supply of 46 mg/L with drinking water wells ranging from 25 to 67 mg/L (City of Woodland, 2011). The City of Dixon has a weighted average for magnesium in their drinking water supply of 51 mg/L with drinking water supplies ranging from 23 to 68 mg/L (City of Dixon, 2011).

The 1925 US PHS Drinking Water Standards recommended a limit of 100 mg/L but this was raised to 125 mg/L in the 1942 and 1946 recommendations (McKee and Wolf, 1963). The 1958 WHO International Standards had a limit of 50 mg/L and a short term concentration of 150 mg/L but there was no maximum concentration mentioned (WHO, 1958). In the 1962 US PHS Drinking Water Standards, there was no recommended limit. Since that time, there have been no new standards or guidelines proposed by WHO, US EPA or the CDPH and none of these organizations presently list a drinking water standard or guideline for magnesium (US EPA, 1973, US EPA, 1976, US EPA, 1986, WHO, 1996a and WHO, 2011b).

Potassium (K) in Municipal and Domestic Water Supplies

Potassium occurs widely in the environment, including in all natural waters. Potassium is an essential element for human beings and is seldom, if ever, found in drinking water at levels that could be a concern for human health. It is considered relatively non-toxic to man and not a public health hazard (WHO 2009c and WHO 2011b). Because of this, WHO (2011b) stated that "*Currently, there is no evidence that potassium levels in municipally treated drinking water, even water treated with potassium permanganate, are likely to pose any risk for health of consumers.*" As a result, WHO does not feel it is necessary to establish a health-based guideline value for potassium in drinking water. In addition, the CDPH does not list or define a guideline for potassium in drinking water (CCR, 2011) nor does US EPA establish guidance for potassium (US EPA, 1973, US EPA, 1976, US EPA, 1986).

Many cities in the Central Valley do have potassium in their drinking water supplies but not at strongly elevated levels. The City of Davis has a weighted average for potassium in their drinking water supply of <2 mg/L with drinking water wells ranging from <2 to 3 mg/L (City of Davis, 2011). The City of Woodland has a weighted average for potassium in their drinking water supply of 2.5 mg/L with drinking water wells ranging from 2.1 to 3.1 mg/L (City of Woodland, 2011).

Sodium (Na) in Municipal and Domestic Water Supplies

Sodium is highly soluble in water and is leached from the terrestrial environment to ground and surface waters. Most water supplies contain less than 20 mg/L of sodium, but in some western states levels can exceed 250 mg/L. Often higher levels of sodium are associated with the near presence of seawater or the presence of marine-derived terrestrial formations. In a survey of 2,100 drinking water supplies in the United States, sodium concentrations were found to range from 0.4 – 1,900 mg/L with 42% of the samples showing greater than 20 mg/L and 5% showing concentrations greater than 250 mg/L. In a later survey of 630 water-supply systems, sodium concentrations ranged from 1 to 402 mg/L with similar distribution of values (NAS, 1977 as cited in WHO, 1996a). The highest levels are likely to be encountered in groundwater. The cities of Davis, Woodland, Dixon and Willows had sodium concentrations averaging 84, 64, 34 and 50 mg/L, respectively. The range of supply wells or sources in these cities were 30 to 120 mg/L (City of Davis, 2011, City of Woodland, 2011, City of Dixon, 2011 and City of Willows, 2011).

Studies show that the main source of sodium for humans is food. For water, the consumption of drinking water containing 20 mg/L of sodium would lead to a daily intake of about 40 mg of sodium. This is contrasted with the daily needs for sodium of between 120 and 400 mg/day for children and 500 mg/day for adults (NAS, 1977 as cited in WHO, 1996a). As with chloride, sodium is rapidly absorbed and is the principal cation found in the extracellular body fluids; only small amounts are found within cells (Guthrie, 1989 as cited in WHO, 1996a). The level of sodium in extracellular fluids is carefully maintained by the kidney (NAS, 1977 as cited in WHO, 1996a). Sodium is excreted, like chloride, principally in the urine in amounts reflecting the dietary intake (Guthrie, 1989 as cited in WHO, 1996).

Although it is generally agreed that sodium is essential to human life, there is no agreement on the minimum daily requirement. It is agreed however that sodium is not acutely toxic because of the efficiency with which mature kidneys excrete sodium. Because of the sodium levels normally found in drinking water and the existing database on long-term exposure, mutagenicity and carcinogenicity, WHO feels that no firm conclusion can be drawn concerning the possible association between sodium in drinking water and the occurrence of hypertension. Therefore, no health-based guideline value for sodium was proposed by WHO (WHO, 1996a and WHO, 2011b). WHO however did recognized that sodium may affect the taste of drinking water at levels above 200 mg/L. Much of the WHO conclusion was based on a detailed assessment of sodium in drinking water done by the National Academy of Sciences (NAS, 1977) and a WHO team of experts (WHO, 2003d). In these studies it was concluded that with sodium concentrations below 100 mg/L in the water supply, intake of sodium from this source would be 10% or less of the average daily sodium consumption. Therefore WHO recommended that sodium balancing be done through a review of the entire diet of the individual.

- There is no federal maximum contaminant level goal (MCLG) for sodium in drinking water in CFR 40 §141.51.

- There is no federal maximum contaminant level (MCL) for sodium in drinking water are found in CFR 40 §141.62.

- There is no federal secondary maximum contaminant level (SMCL) for sodium in drinking water in CFR 40 §143.3.

- There is no California primary drinking water standard (Primary MCL) for sodium in drinking water found in CCR §64431.

- There is no California secondary drinking water standard (Secondary MCL) for sodium in drinking water found in Table 64449-B in CCR §64449 (CCR, 2011).

Sulfate (SO_4) in Municipal and Domestic Water Supplies

Sulfate occurs naturally in water, particularly in the western United States as a result of leaching from gypsum and other common minerals, often associated with marine-type formations such as the western portion of the San Joaquin River Basin in California and the multi-state Colorado River Basin. Sulfate is one of the least toxic ions (WHO, 1993b and WHO 2003b). Sulfate in water has a taste threshold about 250 mg/L. The major physiological effect from sulfate is diarrhea and in extreme cases, dehydration (Gutherie, 1989). Water containing 600 mg/L of magnesium sulfate acts as a purgative in humans (WHO, 1996a), however this level of sulfate will not be toxic (WHO, 2003b).

A survey of 98 rivers in the United States showed sulfate concentrations ranging from 4 – 473 mg/L (Nordell, 1961). A survey of drinking water supplies nationwide showed sulfate levels ranging from 1.4 – 205 with the vast majority being below 60 mg/L (US PHS, 1964). Many cities in the Central Valley do have elevated sulfate in their drinking water supplies. The City of Davis has a weighted average for sulfate in their drinking water supply of 66 mg/L with drinking water wells ranging from 21 to 270 mg/L (City of Davis, 2011). The City of Woodland has a weighted average for sulfate in their drinking water supply of 36 mg/L with drinking water wells ranging from 28 to 48 mg/L (City of Woodland, 2011). The City of Dixon has a weighted average for sulfate in their drinking water supply of 42 mg/L with drinking water supplies ranging from 14 to 62 mg/L (City of Dixon, 2011). The City of Willows has a weighted average for sulfate in their drinking water supply of 33 mg/L with drinking water supplies ranging from 21 to 39 mg/L (City of Willows, 2011). Each of these is far below the 250 mg/L identified as the taste threshold for sulfate in water.

The US PHS Drinking Water Standards of 1925, 1942, 1946 and 1962 recommended that sulfate not exceed 250 mg/L. The WHO International Standards of 1958 also showed a 200 mg/L limit but also showed that this could be exceeded but WHO considered 400 mg/L an upper limit in drinking water (WHO, 1958). The WHO European Standards of 1961 showed a sulfate limit of 250 mg/L (McKee and Wolf, 1963 and WHO, 1961). The 1968 Report on Water Quality Criteria (FWPCA, 1968) recommended a sulfate drinking-water criterion of 250 mg/L. US EPA in their reviews of water quality criteria did not suggest changes to the 1968 recommendation (US EPA, 1973, US EPA, 1976, US EPA, 1986). McKee and Wolf (1963) recommended a water quality criterion of 500 mg/L as protective of domestic water supplies. The criterion however was not based on protection of public health but on studies related to taste and the ability of adults to detect various levels of sulfate (McKee and Wolf, 1963).

Based on information on the physiological effects and the levels seen in drinking water, WHO did not recommend continuation of the 1958 WHO International Standard or the continuation of the 1961 WHO European Standard for sulfate (WHO, 1996a and WHO 2011). Currently there is no international drinking water guideline or standard.

CUWA (2007d) evaluated the Basin Plans of the nine California Regional Water Quality Control Boards for sulfate objectives for protection of the drinking water beneficial use. Table 3 shows that none of the

Regions have established a water quality objective for sulfate other than to refer in their narrative objectives to the present CDPH secondary contaminant level (CCR, 2011).

- There is no federal maximum contaminant level goal (MCLG) for sulfate in drinking water in CFR 40 §141.51.

- There is no federal maximum contaminant level (MCL) for sulfate in drinking water are found in CFR 40 §141.62.

- There is no federal secondary maximum contaminant level (SMCL) for sulfate in drinking water in CFR 40 §143.3.

- There is no California primary drinking water standard (Primary MCL) for sulfate in drinking water found in CCR §64431.

- There is a California secondary drinking water standard (Secondary MCL) for sulfate in drinking water found in Table 64449-B in CCR §64449. Table 64449-B shows a recommended limit for sulfate of 250 mg/L, an upper limit 500 mg/L and a maximum contaminant level for short term or intermittent use of a 600 mg/L (CCR, 2011). The upper limit and short-term levels reflect the lack of evidence of any health affects below these values and findings that consumer acceptance is diminishing above these levels.

There is also no international guideline or standard for sulfate in drinking water due to a lack of evidence of public health effects at the present quality of most drinking water supplies. There are no sulfate evaluations planned at the present time (WHO, 1996a, WHO 2003b and WHO, 2011b).

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