GROUNDWATER INFORMATION SHEET

Salinity

The purpose of this groundwater information sheet is to provide general information regarding a specific constituent of concern (COC). The information provided herein relates to wells (groundwater sources) used for public drinking water, not water served at the tap.

"Salinity" is a measure of the amount of dissolved particles and ions in water. There are several different ways to measure salinity; the two most frequently used analyses are described below:

- Total Dissolved Solids (TDS): TDS is a measure of all dissolved substances in water, including organic and suspended particles that can pass through a very small filter. TDS is measured in a laboratory and reported as milligrams per liter (mg/L).

- Electrical Conductivity (EC): The ability of an electric current to pass through water is proportional to the amount of dissolved salts in the water – specifically, the amount of charged (ionic) particles. EC is a measure of the concentration of dissolved ions in water, and is reported as micromhos per centimeter (µmhos/cm) or microSiemens per centimeter (µS/cm). A µmho is equivalent to a µS. EC can be measured in a laboratory or with an inexpensive field meter. It is also called specific conductance or specific conductivity.

"Salinity" can include many different ions; however, relatively few make up most of the dissolved salts/minerals in water. The most common are the following: chloride (Cl^-), sodium (Na^+), nitrate (NO_3^-), calcium (Ca^{+2}), magnesium (Mg^{+2}), bicarbonate (HCO_3^-), and sulfate (SO_4^-). The concentration of boron (B), bromide (Br), iron (Fe), and other trace ions can be locally important.

Approximate Total Dissolved Solids (TDS) Values in Natural Waters

Natural Water	TDS (mg/L)
Precipitation	10 mg/L
Pristine Freshwater Lakes and Rivers	10 to 200 mg/L
Amazon River	40 mg/L
State Water Project Deliveries	275 mg/L
Lakes Impacted by Road Salt Application	400 mg/L
Agricultural Impact to Sensitive Crops	500 mg/L
Colorado River Water	700 mg/L
Average Seawater	35,000 mg/L
Brines	>50,000 mg/L
Groundwater	100 to >50,000 mg/L

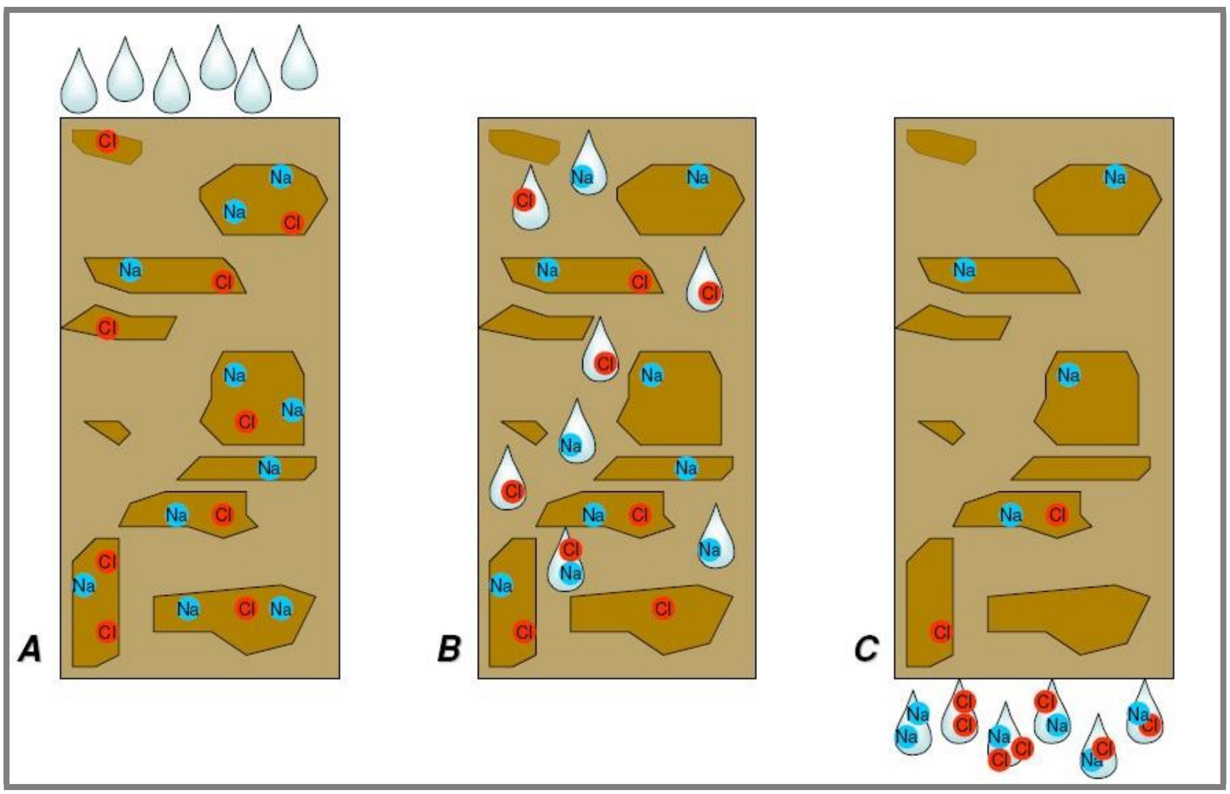
The clarity of water is unrelated to salinity (TDS). For example, visibility in the ocean can be hundreds of feet, even though ocean water has a very high salinity (TDS of 35,000 mg/L). On the other hand, water with low visibility like the Mississippi River can have low TDS (~200 mg/L) because the particles that obscure visibility are not dissolved, and can be easily filtered from the water. The amount of dissolved material in natural waters is a complex function of climate, land-use patterns, human activity in the watershed, and geologic formations (rocks and soils) of the hydrologic basin.

Adverse Effects

High concentrations of salts can damage crops, affect plant growth, degrade drinking water, and damage home or industrial equipment. High concentrations of nitrate are a health threat. Most salts do not naturally degrade, and can remain in groundwater indefinitely. The economic cost of increased groundwater and surface water salinity to California – manifested in fallowed farmland, unsuitable drinking water, and environmental degradation – is estimated in the millions of dollars annually.

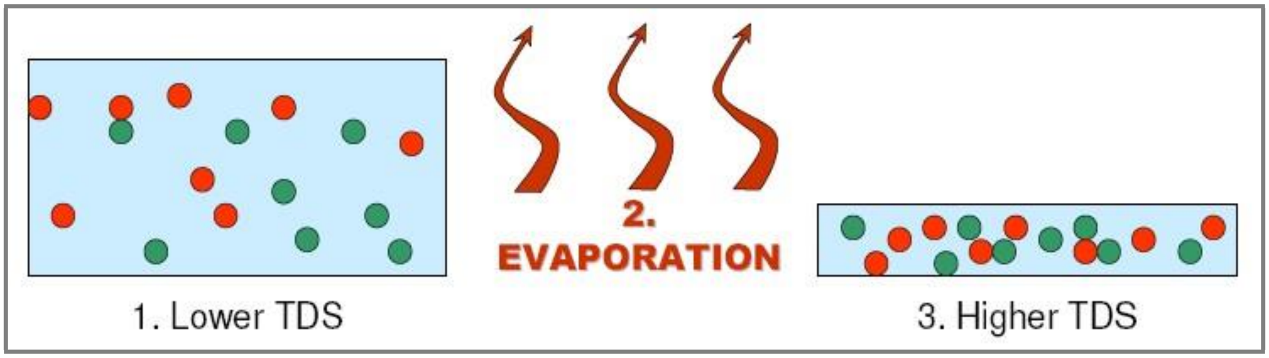
Sources of Salt

Salts enter groundwater naturally through dissolution of soil, rock, and organic material. A schematic illustrating how dissolution occurs is shown below. Salinity will increase with time as more minerals in contact with groundwater will dissolve.



Dissolution of Natural Materials: Water is introduced to the soil from irrigation or rain (A). As the water percolates downwards it dissolves ionic and non-ionic particles from minerals in the soil column (B). The water that leaves the soil to the underlying groundwater is enriched in salts (C).

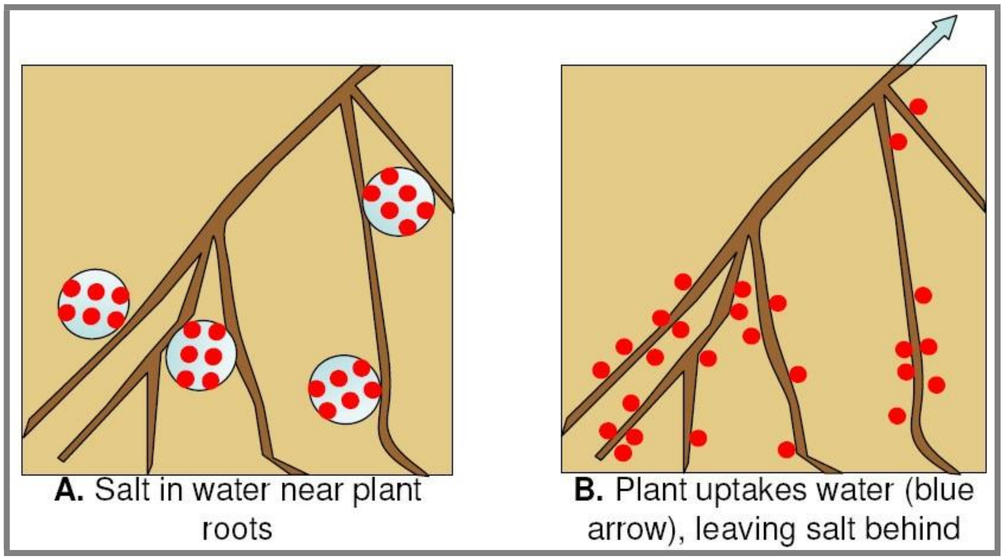
The concentration of salts in surface and groundwater can increase in several ways. Increased dissolution can increase salinity levels. Evaporative enrichment is the process of increasing salinity levels in surface or groundwater by removing water via evaporation. For example, irrigation water is often applied to crops during the summer when evaporation rates are highest. As water molecules evaporate into the atmosphere, salts remain behind in the irrigation water. This irrigation water can percolate into the underlying groundwater. If the groundwater is later pumped and used for additional irrigation, the evaporation cycle is repeated and salinity levels will continue to increase. Dryland salinity affects soils when groundwater is brought to the surface by capillary action; evaporation removes water and leaves salt at the soil surface.



Evaporative Enrichment: As water evaporates, salts will remain behind. As a result, the concentration of salts in water with a relatively low starting salinity (TDS) can increase simply due to evaporation. Irrigation can result in significant increases in salinity through evaporative enrichment.

Water uptake by plants can also increase soil salinity. Water percolating through the ground has salts dissolved in it. Plant roots work by taking in water while excluding salts and other non- nutrients. The excluded salts will gradually build up around the roots, and must be periodically “flushed” from the root zone or plant death may occur. In natural systems, the types of plants found in a specific environment are adapted for naturally-occurring soil salinities. In many agricultural areas, salts are flushed from the soil by applying irrigation water. The salts that are flushed from the soil either enter groundwater or are discharged to surficial drains.

Human activities also affect salinity levels in ground and surface water. Application of synthetic fertilizers, manures, and wastewater treatment facilities can all contribute salt to surface and groundwater. Nitrogen is a necessary nutrient for plant growth and nitrogen fertilizers are typically in the form of the salt, nitrate. If excess nitrate fertilizer is applied to a field, the nitrate not used by plants can dissolve and move to groundwater. Manure from confined animal facilities is enriched in nutrients and other salts, and can also increase salinity levels in receiving waters. Domestic wastewater is typically enriched in salts due to household activities such as washing and water softening. Most water treatment facilities cannot remove salt. As a result, discharges from these facilities can increase surface and groundwater salinity.



Plants Increase Soil Salinity: Soil pore water used by plants contains dissolved solids and other salts (A). Water uptake by roots will exclude salts and dissolved solids. Over time, as water is moved upwards through the roots to the rest of the plant, salts will build up in the soil surrounding the roots (B). Salts must be periodically flushed from the soil; otherwise, rising soil salinities may cause the plant to die.

Summary of Salinity Sources:

- Agriculture: Evaporation of irrigation water will remove water and leave salts behind. More salt can be dissolved from soil as irrigation water percolates downward. Plants can naturally increase soil salinity as they uptake water and exclude salts. Application of synthetic fertilizers can increase nitrate concentrations in surface and groundwater. Manure from confined animal facilities is enriched in nutrients and other salts, and can also increase salinity levels in receiving waters.

- Municipal: Detergents, water softeners, and industrial processes all use salts. Wastewater discharged to Publicly Owned Treatment Works (POTWs) and septic systems is often more salty than the original source water. Discharges from POTWs and septic systems can increase the salinity of receiving waters. Overwatering of lawns and residential use can also contribute to salinity.

- Industrial: Many industrial processes can increase salinity in process wastewater. Cooling towers, power plants, food processors, and canning facilities can contribute to salinity.

- Natural: Groundwater contains naturally-occurring salts from dissolving rocks and organic material. Some rocks dissolve very easily; groundwater in these areas can naturally be of very high salinity.

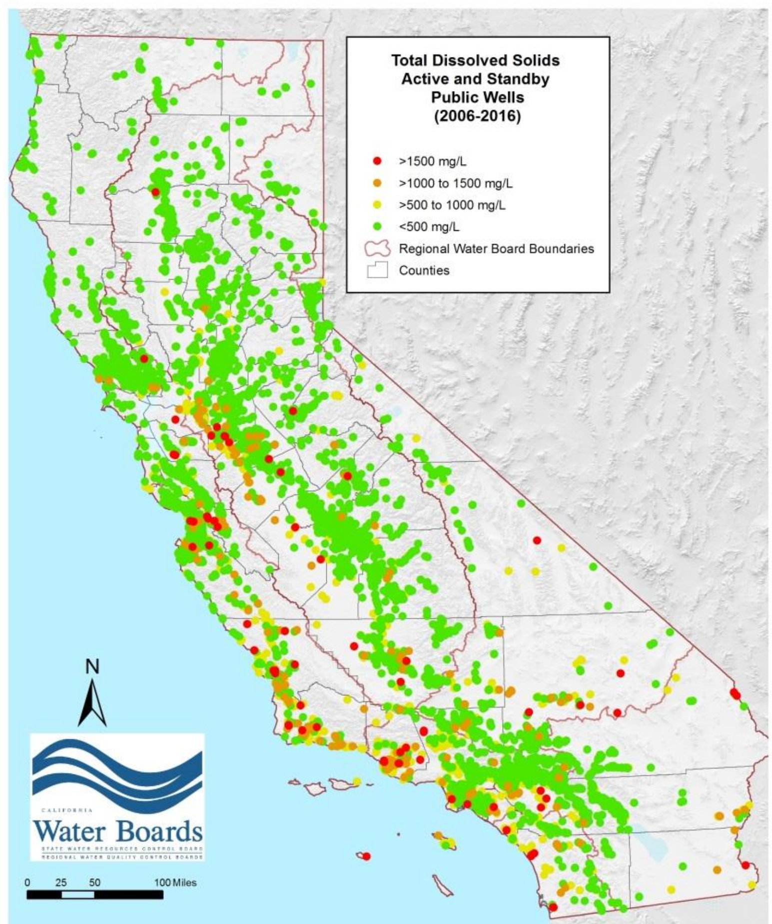
Drinking Water Standards for Salinity

The California State Water Resources Control Board Division of Drinking Water (DDW) has established EC and TDS secondary maximum contaminant level (SMCL) drinking water standards for public water supplies. SMCLs are ranges set by DDW for taste and odor thresholds; for TDS, the recommended SMCL is 500 mg/L and the upper SMCL is 1,000 mg/L. For EC, the recommended SMCL is 900 µS/cm, and the upper SMCL is 1,600 µS/cm. EC and TDS also have short-term SMCLs that are generally allowed only under rare circumstances at 2,200 µS/cm and 1,500 mg/L, respectively.

A map of TDS in California's active and standby public wells measured between 2006 and 2016 is shown below. Specific areas with groundwater TDS concentrations above the SMCLs are located along the southern coast, the Sacramento-San Joaquin Delta, the southern and western San Joaquin Valley, and the San Francisco Bay.

TDS in Groundwater, 2006-2016

Map shows TDS concentrations for active and standby public supply wells. Red dots indicate wells where TDS concentrations are above short term public drinking water standards (133 wells). Orange dots indicate wells where TDS concentrations are above upper limit public drinking water standards (279 wells). Yellow dots indicate wells where TDS concentrations are above recommended public drinking water standards (1,704 wells), and green dots indicate wells with TDS equal or below recommended public drinking water standards (10,042 wells). *Data source: GeoTracker GAMA: 2006 -2016.*



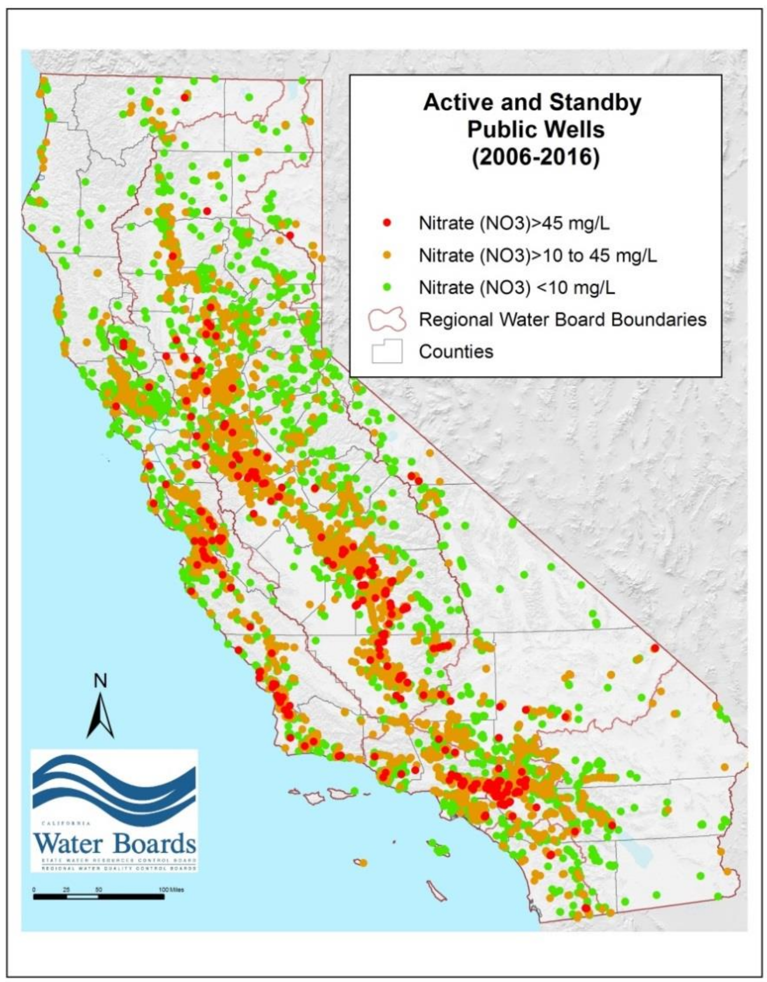
Nitrate: A Unique Salt

Nitrate (NO_3^-) is formed naturally when nitrogen-containing organic compounds are broken down in the presence of oxygen. Nitrate is also produced in an industrial process of manufacturing synthetic fertilizers. High levels of nitrate in groundwater are associated with intense agricultural activity, septic systems, confined animal facilities, and wastewater treatment facilities. Nitrate is also one of the few salts that can be removed from water through a naturally occurring process (denitrification). Denitrification is defined as the reduction of nitrate to nitrogen-containing gases such as nitric oxide, nitrous oxide, and nitrogen gas. Denitrification relies on microbial activity to break apart nitrogen-containing elements.

Nitrate in drinking water is a health concern. Methemoglobinemia, or "blue baby syndrome," can affect infants when elevated nitrate levels in drinking water cause a decrease in the oxygen carrying capacity of blood. The current state drinking water standard of 45 mg/L as NO_3 (10 mg/L as N) is specifically designed to protect infants. High levels of nitrate in drinking water may be unhealthy for pregnant women. Livestock can also be sensitive to high levels of nitrate in their drinking water.

Nitrate in Groundwater, 2006-2016

Nitrate concentrations using data from the standby and active public wells. Red dots indicate nitrate concentrations above the MCL (800 wells). Data source: GeoTracker GAMA: 2006-2016.



Water Softeners

Water with high concentrations of calcium and magnesium is referred to as 'hard water.' Hard water, which can clog pipes and reduce the lathering action of soaps, may be treated using a water softener that exchanges magnesium and calcium ions for sodium or potassium ions. In order for the water softener to function properly, the exchange resin must be periodically recharged using highly saline brine. The brine used in the regeneration process is discharged to municipal sewage systems or a septic leachfield. Wide-spread use of water softeners has been known to significantly increase salinity levels in wastewater sent to water treatment facilities. As of August 2014, more than 25 communities in the state have banned or greatly restricted the use of salt-based water softeners, and more are mulling the ban.

Seawater Intrusion

In some locations, groundwater overdraft (excessive pumping) has caused the natural groundwater gradient to reverse and has allowed seawater to intrude coastal aquifers that historically contained only fresh water. Seawater intrusion can ruin drinking water and irrigation wells, and render some areas unsuitable for continued agriculture. The Salinas groundwater basin, Santa Clara Valley (San Francisco Bay), and the Los Angeles basin have experienced significant seawater intrusion into drinking water aquifers. To prevent additional seawater intrusion, communities have installed subsurface barriers and injection wells to restore or at least lower salinity of groundwater.

Salinity Challenges

Addressing salinity in California's waters is a challenge for the state. Some generation of salt is unavoidable: public water works, industrial activities, food processors, and dairies are important parts of the economy and society – and can all increase salt loads to the State's waters. The following summarize efforts made to address salinity in California:

- The State's National Pollutant Discharge Elimination System (NDPES) and Waste Discharge Requirements (WDR) regulatory programs manage salt impacts to surface water and groundwater.
- Institution of preventative measures by local agencies, such as requiring more efficient water softeners and managing lawn fertilizer application.
- Reducing salt loads from imported irrigation water.
- Development of technical advances in irrigated water and fertilizer application methods.
- Disposal of salts through brine lines, deep injection wells, lined landfills, and evaporation ponds.
- Limiting the use of salt for road de-icing in sensitive areas.

KEY REFERENCES

1. California State Water Resources Control Board, A Compilation of Water Quality Goals, January 2016, prepared by Jon Marshack, http://www.waterboards.ca.gov/water_issues/programs/water_quality_goals/docs/wq_goals_text.pdf

2. California State Water Resources Control Board, National Pollutant Discharge Elimination System (NPDES), http://www.waterboards.ca.gov/water_issues/programs/npdes/drinkingwatersystems.shtml

3. California State Water Resources Control Board, Chemicals and Contaminants in Drinking Water, http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Chemicalcontaminants.shtml

4. United States Geological Survey, Sources of Dissolved Solids in Brackish Groundwater, http://water.usgs.gov/ogw/gwrp/brackishgw/sources.html

5. SUAREZ, D.L., Impact of Agricultural Practices on Groundwater Salinity, Agric., Ecosystems and Environ., 26: 215-227, 1989, Elsevier Science Publishers B.V., Amsterdam-Printed in the Netherlands, https://www.ars.usda.gov/SP2UserFiles/Place/20360500/pdf_pubs/P1043.pdf