Conceptual Model For
SALINITY IN THE CENTRAL VALLEY AND SACRAMENTO-SAN JOAQUIN DELTA

Prepared for
Central Valley Drinking Water Policy Workgroup

Prepared by

CALFED Bay-Delta Program
Water Quality Program
650 Capitol Mall, 5th Floor
Sacramento, CA 95814

July 2007

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS & ABBREVIATIONS

µg/L	Micrograms per Liter
µS/cm	Microsiemens per centimeter
CALFED	CALFED Bay-Delta Program
CCWD	Contra Costa Water District
CDEC	CDEC
cfs	Cubic Feet per Second
CUWA	California Urban Water Agencies
CVP	Central Valley Project
CVRWQCB	Regional Water Quality Control Board, Central Valley Region
DCC	Delta Cross Channel
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DSM2	Delta Simulation Model 2
DWR	Department of Water Resources
EC	Electrical Conductivity
MCL	Maximum Contaminant Level
mg/L	Milligrams per Liter
ROD	CALFED Bay-Delta Program, Programmatic Record of Decision
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	Thousand Acre-Feet
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Load
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey

ACKNOWLEDGEMENTS

This report was produced almost entirely by the CALFED Water Quality Program staff. Lisa Holm, Water Quality Program Manager, provided direction and oversight. Sam Harader did most of the research and was the principle author. Patricia Fernandez assisted with data collection, analysis, and graphics.

A number of people from several different agencies and organizations contributed ideas, materials, and other input during the preparation of this report. Others helped with editing and graphics. The CALFED Water Quality Program would particularly like to thank Jon Burau, Sujoy Roy, Matt McCarthy, Karen Larsen, Xiao Li, Leah Orloff, Robert Ullrey, and Donna Podger for their assistance.

CALFED Bay-Delta Program
Lisa Holm
Donna Podger
Sam Harader
Patricia Fernandez
Robert Ullrey

California Department of Water Resources
Xiao Li

Central Valley Regional Water Quality Control Board
Matt McCarthy
Karen Larsen

United States Geological Survey
Jon Burau

Contra Costa Water District
Leah Orloff

Tetra Tech
Sujoy Roy

INTRODUCTION

> *"The value of water is determined by its potential uses. In turn, the uses that can be made of water are determined by its quality."*
>
> – CALFED Water Quality Program Plan, July 2000.

Salinity, the amount of dissolved salts in water, is a basic measure of the quality of water. People and the vast majority of the world's land animals and plants need an adequate supply of fresh water to survive. Water with too high a salt concentration tastes bad, can be harmful to health, reduces plant growth, can be corrosive, and limits our ability to recycle water or recharge groundwater. Salinity is expensive to treat and is often the characteristic of water that compels us to discharge it rather than reuse it. Some of the component constituents of salinity, bromide for example, may be even more problematic than salinity itself. Bromide can be converted into carcinogenic disinfection byproducts in the drinking water treatment process.

While dissolved salts naturally increase in a watershed from the source in snow or rain, water quality is significantly degraded as it passes through the Central Valley and Delta on its way to the points where it is diverted for municipal and agricultural uses. High quality water from Sierra Nevada streams generally has a total dissolved solids (TDS) concentration (one measure of salinity) of less than 100 mg/L[1]. Drinking water taken from the Delta typically has a TDS of from 150 mg/L to 300 mg/L but may be more than 500[2]. The reasons for these differences in water supply salinity and what can be anticipated for Delta salinity in the future is the subject of this report.

The primary source of salinity in Delta water is the ocean itself. The Delta is the upstream part of the San Francisco Bay – Sacramento-San Joaquin Delta and Estuary, the largest estuary on the west coast of the United States. It is natural for estuaries to have a gradation in salinity from completely fresh water to the salinity of the ocean. In fact this salinity gradation is a defining characteristic of estuaries. This mixing of seawater and fresh water is the result of tidal water movement and other complex hydrodynamic processes. By volume, only a small fraction of the water that makes it to the export pumps in the central and southwestern Delta is seawater but that tiny fraction has a

[1] Average total dissolved solids reported in East Bay Municipal Utility Districts annual water quality report for 2004 was 97 mg/L. This is mostly Mokelumne River water diverted at Pardee Reservoir. _http://www.ebmud.com/water_&_environment/water_quality/annual_report/2004_wq_report.pdf. Average total dissolved solids concentration reported I the San Francisco Public Utilities Commission annual water quality report for 2004 was 101 mg/L. The primary source is the Tuolumne River at Hetch Hetchy Reservoir http://sfwater.org/detail.cfm/MSC_ID/51/MTO_ID/63/MC_ID/10/C_ID/2525/holdSession/1.

[2] Contra Costa Water District annual report for 2004 http://www.ccwater.com/files/AWQR04.pdf and DWR presentation on SWP water quality http://wwwomwq.water.ca.gov/PublicationsPage/Documents/SWP WQ talk_files/frame.htm.

profound effect on the concentration of salts. Seasonally, seawater mixing into the Delta can increase salinity by more than 40% at the diversion points.

The remaining significant sources of salinity are drainage from irrigated agriculture and managed wetlands in the San Joaquin Valley, the Sacramento Valley, and the Delta. This includes subsurface drainage, return flows, and runoff. The high salinities from these sources are the result of several processes including concentration of salts in the applied water through evapotranspiration, leaching of natural salts from soils, and agricultural chemical addition. Evapotranspiration is a combination of simple evaporation from water surfaces and soils and transpiration by plants. This is complicated in the San Joaquin River by the use of Delta water for irrigation that carries some seawater salinity. Some of this seawater salinity finds its way into agricultural drainage, into the San Joaquin River and back to the Delta. Municipal wastewater discharges, industrial discharges, urban runoff, and natural leaching of minerals also contribute salts to the system but these sources are minor compared to the contributions from seawater intrusion, irrigated agriculture, and managed wetlands.

This report examines the state of knowledge about the causes of salinity increase in the system and opportunities to improve the Delta as a source of municipal and agricultural water supply. It begins with background information about salinity, its measurement, and its impacts. Following that, we present observed salinity in the Bay-Delta system. The conceptual models section, the core of this report, then seeks to explain the forces and processes (drivers) that cause the salinity patterns we observe. The computational models section introduces some of the tools available to assist with salinity management and planning. The last chapter explores the implications of the conceptual model for monitoring and management of salinity.

PURPOSE AND SCOPE

This conceptual model was prepared as part of the Central Valley Drinking Water Policy development project, a major CALFED Bay-Delta Program Record of Decision (ROD) action. This is an effort to clarify and enhance the regulatory policies of the Central Valley Regional Water Quality Control Board (CVRWQCB) with respect to protection of the municipal water supply beneficial use. This conceptual model will help to identify information gaps and potential measures for monitoring progress towards water quality improvement.

The conceptual model will address salinity sources and impacts throughout the CALFED solution area (Figure 1) with respect to municipal water supply.

Figure 1: CALFED Program solution area.

The focus will be on the Delta and the San Joaquin Valley but will extend to the Sacramento River watershed and those areas of the State that receive Delta water as needed.

It will not address the importance of salinity to ecosystem function in the Bay-Delta system in anything more than a cursory way. Salinity and its implication for the Bay-Delta ecosystem is well covered in Kimmerer 2004 and other publications. Likewise, this report will not go into any depth on agricultural water quality issues. For an overview of the effects of salinity and associated constituents on agriculture and other beneficial uses, see the Central Valley Regional Water Quality Control Board San Joaquin River salinity TMDL report (*Regional Water Quality Control Board 2002)*.

There is a long record of Delta salinity measurements. Much of the recent data is from permanent continuous electrical conductivity (EC) monitoring stations. Figure 2 shows the current Department of Water Resources (DWR) Delta monitoring stations.

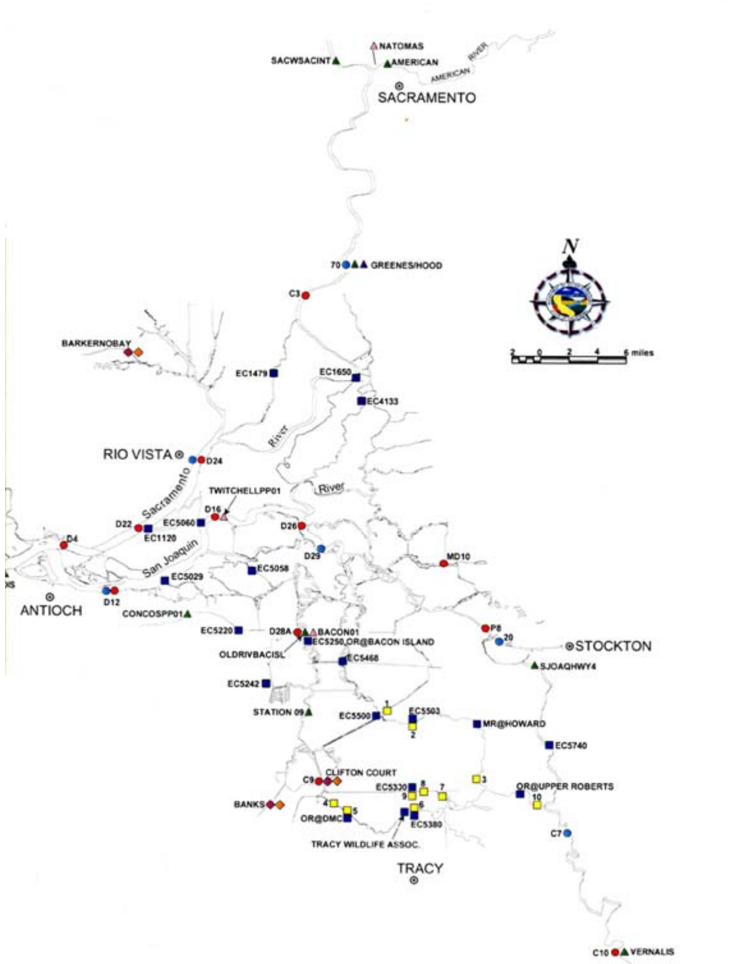


Figure 2: Department of Water Resources monitoring stations in the Delta.

There is also an extensive amount of grab sample data available. Salinity is the most extensively monitored water quality constituent in the system. Naturally, operation of the system has changed over the years placing the emphasis on more recent data (1975-present) but early data can also be instructive. For example, the historic extent of seawater intrusion in the Delta, discussed later, illustrates the profound effect of the Federal and State water projects on Delta salinity.

PROBLEM DESCRIPTION

Salinity is generally defined as the amount of salt dissolved in a given unit volume of water. It is variously measured in units of electrical conductivity (EC), total dissolved solids (TDS), practical salinity units (psu), or other units depending on the scientific discipline of the person doing the measuring and the purpose of the study or monitoring program.

Salinity is often considered equivalent to total dissolved solids. More specifically, TDS is the fraction of solids in water that will pass through a 1.2 µm filter and that will remain on a dish when a sample of water is dried at a specified temperature. The remaining solids may include volatile and non-volatile organic and inorganic compounds. The vast majority of dissolved solids in most ambient waters are ionic inorganic substances (salts) such as calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, bromide, and nitrate.

The composition of dissolved substances varies depending on source. Freshwaters are typically high in calcium, magnesium, bicarbonate, and sulfate while seawater is higher in sodium and chloride. Bromide concentrations are typically low in freshwater and high in seawater. The average bromide concentration in U.S. drinking water sources is 62 µg/L (Amy, 1998) while the concentration in seawater is about one thousand times higher, 67 mg/L (Hem, 1989). The average bromide concentration at the State Water Project's Delta (Banks) Pumping Plant is about 230 µg/L. In contrast, the average bromide concentration in the Sacramento River at Hood is about 14 µg/L and is often less than the 10 µg/L detection limit. In the Delta, high bromide concentrations are usually associated, directly or indirectly, with seawater. Other ions are associated with specific source areas in the watershed. Runoff and drainage from irrigated lands on the west side of the San Joaquin Valley have characteristically high concentrations of sulfate. The composition of salts in water can be an important determinant of the impact on a particular beneficial use and can be an indicator of the source. At the Delta diversion points, water that has relatively high concentrations of chloride and bromide is indicative of seawater intrusion.

The ability of water containing dissolved salts to conduct electricity gives rise to a simple method for measuring the concentration of salt. Electrical conductivity (EC) is a measure of the ability of water to conduct an electric current and thus is a measure of the amount of dissolved salts. EC is often measured in units of microsiemens per centimeter (µS/cm), also called micromhos per centimeter, which is the inverse of the resistance of a sample of water between two electrodes that are one centimeter apart. It is a far simpler to measure this property of water than doing the required laboratory method to measure TDS directly. EC is therefore a quick, cost effective, and widely used surrogate measure of salinity.

Impacts of Salinity on Use of Delta Water for Domestic Supply

Bad taste is one of the most common complaints that utilities receive about tap water and salinity is often the problem. There is a secondary maximum contaminant level (MCL) for TDS of 500 mg/L set primarily to address taste but also to prevent staining and mineral deposits. Secondary MCLs regulate contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. Chloride (250 mg/L) and sulfate (250 mg/L) are also secondary MCLs established to prevent salty taste in tap water.

The State of California has established the following secondary standards for salinity and chloride.

Table 1: Secondary maximum contaminant levels and ranges.

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

Even though the 500 mg/L TDS and 250 mg/L chloride standards are only "recommended" levels, water suppliers rarely serve water that exceeds these concentrations and then only when there is no feasible alternative.

Another impact of salinity on municipal water use is on the "utility" of the water. Utility is the ability to recycle the water or blend it with lower quality supplies. Domestic and commercial use of water increases its salinity. Wastewater may be further treated beyond the typical secondary level to produce usable recycled water. This recycled wastewater typically used for landscape watering and other non-potable uses, makes up a significant fraction of the water supply in many parts of the state. Water can be collected and reused or recycled until the salinity increases to the point where it is too high for even landscape irrigation (usually the most salt tolerant use). Lower salinity to start with allows more cycles of water use and reuse. Higher quality water is therefore equivalent to more water in many parts of the State.

The most critical impact of salinity on drinking water, however, is the role it plays in the formation of disinfection byproducts (DBPs). Bromide is a precursor to formation of a variety of harmful byproducts when water is treated and disinfected for domestic water supply. Trihalomethanes and haloacetic acids form when water containing organic carbon is treated with chlorine. Disinfection byproduct formation is increased when the source water contains both dissolved organic compounds and bromide. Bromate forms when water containing bromide is disinfected with ozone. A study commissioned by the California Urban Water Agencies (CUWA) in 1998 concluded that, if a bromate MCL of 5 µg/L were adopted, it would be necessary to keep raw water bromide concentrations below 50 µg/L for plants that use unmodified ozone disinfection. Since bromide concentrations at Delta municipal water supply diversions are nearly always higher than 50 µg/L, the reduced bromate MCL would have been extremely problematic. Even though the connection between bromide in source water and disinfection byproducts in finished water is fairly well known, there are no applicable bromide water quality standards. The high concentrations of bromide, from seawater intrusion into the upper estuary, are unusual for a major drinking water source.

Contrary to early indications about new regulatory limits and the associated compliance problems, the MCL for bromate has remained at 10 µg/L and nearly all treatment plants using Delta water as their primary supply modify their raw water supply and treatment systems to minimize bromate formation. Acceptable bromide concentrations at Delta drinking water intakes are clearly greater than 50 µg/L however, the exact concentration that can be tolerated is not known and the evolution of drinking water regulations under the Safe Drinking Water Act continues. The recent promulgation of new disinfection byproduct and surface water treatment rules presents new challenges for municipal water suppliers using Delta water.

Impacts of Salinity on Other Uses: Agriculture, Industry, Wildlife

The standards that are most controlling of CVP and SWP operations have been established to protect the agricultural, industrial, and fish and wildlife beneficial uses. Collectively these standards require the responsible agencies to balance reservoir releases, export pumping, and the routing of water through the Delta to achieve their water delivery goals and stay in compliance. The agencies maintain a complex network of monitoring stations and computer models to give them the information necessary to manage the system.

To protect salt sensitive crops during the irrigation season, the conductivity objective in the San Joaquin River and the interior South Delta is set at 0.7 mS/cm (700 µS/cm) during the irrigation season (April – August) and at 1.0 mS/cm for the remainder of the year. These standards are based on research on a variety of crops. For the most sensitive crops grown in this area, it was determined that water exceeding these standards could reduce yields.

Excess salinity in soil water can decrease plant available water and cause plant stress. In the San Joaquin Valley, particularly on the west side, soils and shallow groundwater have become increasingly saline and groundwater levels have risen since irrigation began in these areas. These factors have required installation of tile drains in the most heavily impacted fields in order to keep them in production. The shallow groundwater drained through these systems is high in salts, nitrate, and selenium making discharge of this water problematic. Management of agricultural drainage water in the San Joaquin Valley will be discussed further in the watershed sources section.

The chloride objectives that apply at Delta export locations are intended to protect municipal and industrial uses. The most restrictive of these, the 150 mg/L chloride objective for Contra Costa Canal and the Antioch intake, was developed to prevent the adverse effects of residual salt in corrugated paper boxes. Linerboard made using water with too high a salt content can cause corrosion in canned goods. This standard was originally established to protect the water supply for a corrugated paper box plant in Contra Costa County that has since closed but the standard was retained to protect drinking water quality pending further evaluation.

A number of fish and wildlife species are dependent on the estuarine zone of the Bay-Delta system. Some of these species are highly dependent on water of a particular salinity at certain life stages to survive. The extent and location of estuarine habitat of the correct salinity is highly dependent on flow. The Delta outflow standards are intended to maintain this estuarine habitat and minimize seawater intrusion into the Delta. The outflow standards are therefore also an important factor governing water quality at the Delta water diversion points.

History of Delta Salinity

Salinity in the Delta is a function of freshwater inflow, wastestreams, tides, reservoir operations, Delta exports, diversions, and the configuration of Delta channels. Early records of Delta salinity (Jackson and Paterson, 1977) and evidence from diatoms in marsh sediments (Starratt, 2001) suggest that seawater intrusion into the Delta was relatively rare prior to the development of large scale irrigated agriculture in the Central Valley. The natural patterns of water movement in the Delta began to change with the sediment influx from hydraulic mining and the beginning of Delta levee construction in the late 1800s. Steadily increasing agricultural water diversions reduced Delta inflow in the early 1900s exacerbating seawater intrusion. The era of modern Delta water management, and with it significant changes in salinity, began with the completion of Shasta Dam in 1945 and continued with the first State Water Project deliveries in 1967. As Figure 3 shows, from 1921 to 1943, Delta salinity was much more variable than it is today. In the late fall of dry years during this period, brackish water extended far inland. Figure 4 shows the extent of seawater intrusion from 1944-1990. The storage of winter and spring runoff behind the many Federal and State Water Project dams and the subsequent release has changed the seasonal pattern of Delta inflow and has reduced the year to year variability.

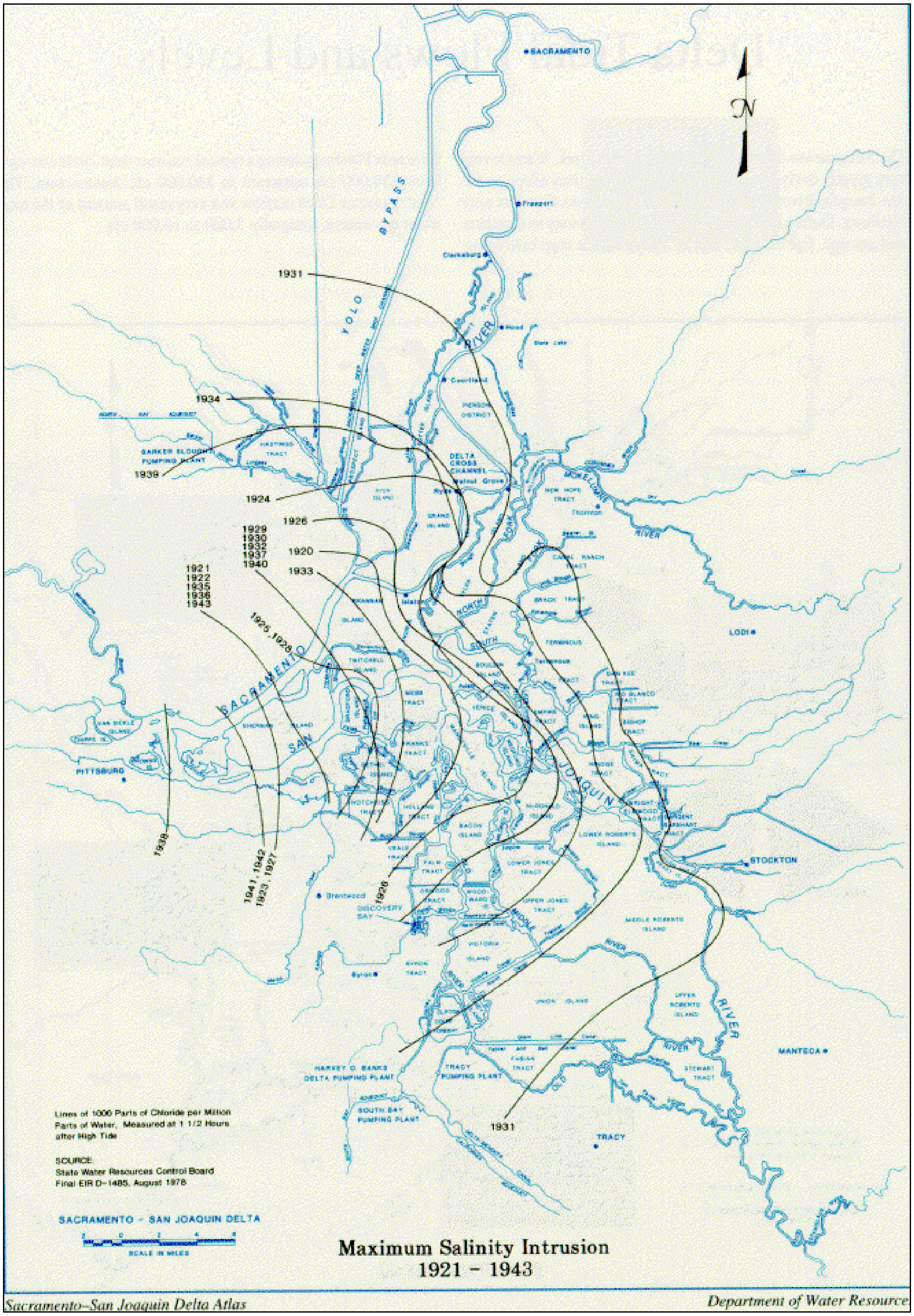


Figure 3: (DWR 1995)

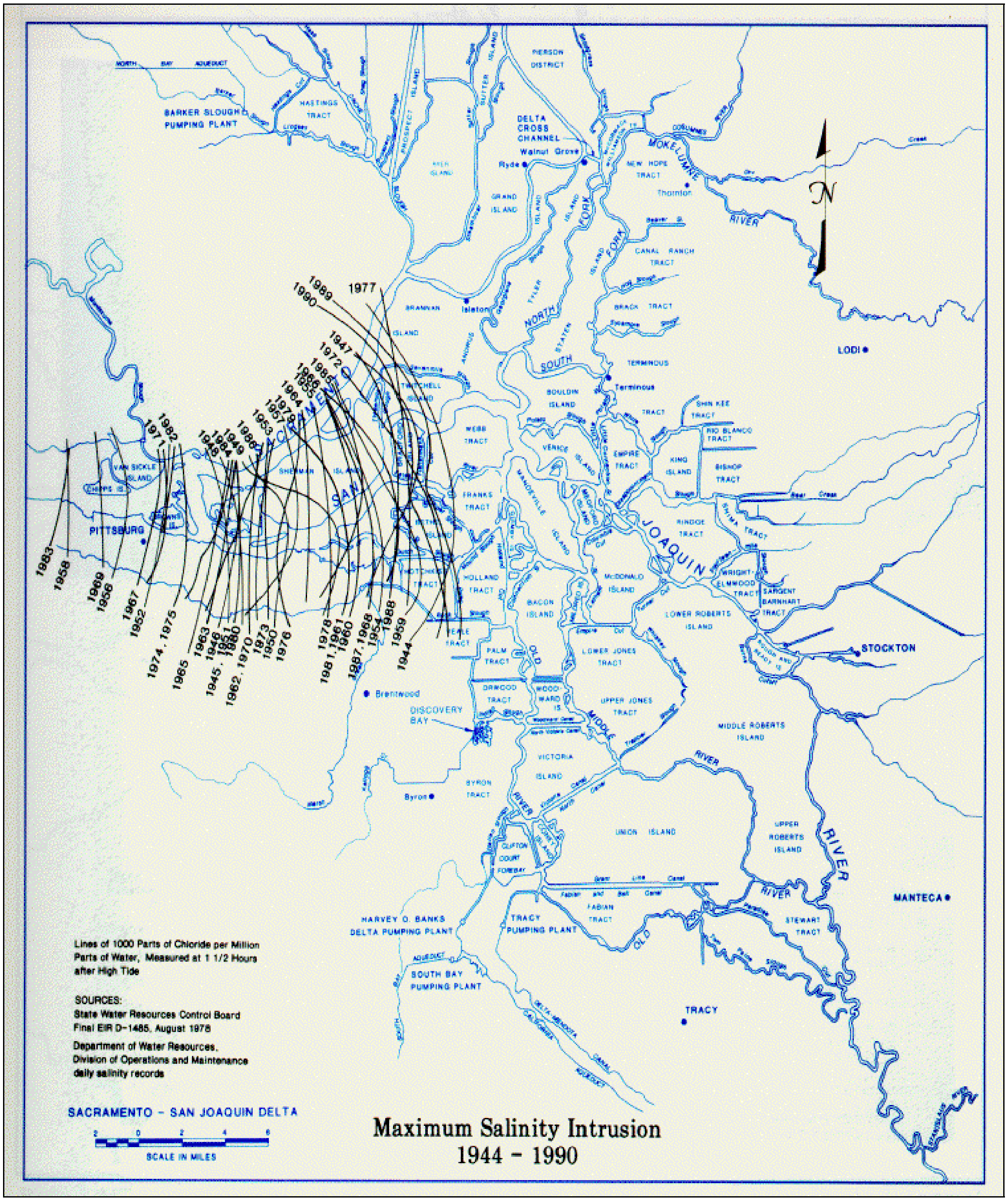


Figure 4: (DWR, 1995)

The changing patterns of Delta salinity have continued to a lesser degree with changes in water project operations in recent years and will continue with any significant shifts in the way we manage water. The continuing rise in sea level and changing runoff patterns associated with climate change are also expected to change Delta salinity.

OBSERVED SALINITY IN THE CENTRAL VALLEY AND DELTA

There is more conductivity and TDS information available in the Bay-Delta sytem than for any other constituent. This allows us to characterize salinity with a great deal more confidence, but can also be a challenge just due to the sheer volume of data that needs to be captured. This chapter presents available salinity and flow monitoring data that indicate where salinity is a problem, how salinity is changing over time, how salinity changes seasonally, and the sources of salinity. The monitoring data used in this chapter was taken from a variety of sources including agricultural, urban, and surface water discrete samples as well as conductivity measurements from continuously recording meters operated by several agencies. In some cases, computational models were used to generate continuous salinity distributions based on observed monitoring data. In essence, the models were used to fill in the gaps and graphically display the data. Information from the models is identified as such and should be viewed with appropriate caution.

Even with our level of control over Delta inflow through reservoir releases and water diversions, salinity is periodically a problem both in the Delta and in the San Joaquin River. One of the basic conflicts in the Delta is the complex relationship between water quality, water for the environment, and water supply for cities and farms. Meeting water quality objectives frequently means that the SWP and CVP must release much more water from upstream reservoirs than the amount of water to be diverted at the South Delta pumps in order to meet environmental and water supply demands. Even while meeting the applicable objectives, salinity at south and central Delta diversions has changed with recent changes in system operations.

Monitoring

The simplicity and reliability of the monitoring equipment makes EC one of the most commonly monitored characteristics in the Delta and its tributaries. A recent examination of the data available online through the California Data Exchange Center (CDEC) found 69 stations that are continuously monitoring EC. Of these 69 stations, 25 also have continuous flow monitoring. Most of these stations have several years of hourly data available and many have data at 15-minute intervals as well. If each station has an average of 6 years of data and there is hourly data for each station, then there are more than 3,600,000 EC results in the system. Although this data is labeled “preliminary” and is not considered “data of record,” when checked against laboratory analyses, it is reasonably accurate.

The system of conductivity sensors connected by the CDEC system gives the user a real-time view of salinity in the Delta and the San Joaquin River. The same is not true however for most of the Sacramento River watershed. The station at Hood has the only

CDEC conductivity sensor in the Sacramento River system. However, salinities in the Sacramento River watershed are generally very low so periodic discrete EC data captured in the CVDWPWG database is generally adequate to characterize Sacramento Valley streams. The amount of EC and TDS data is generally more than adequate, however; in a survey of existing data (CVDWPWG 2004), the authors concluded that additional TDS monitoring in some of the San Joaquin River lesser tributaries would be useful.

Salinity in the Bay-Delta and Tributaries

This section presents the spatial and temporal distribution of salinity with two basic types of graphic tools. The first are traditional time series plots of daily average salinity parameters for key monitoring locations. These plots show the seasonal, between years, and, in some cases, long-term trends in salinity at a specific location. The second way salinity data is presented is with false color EC contour maps. These maps show a snap shot of average salinity over the entire system on a given day.

Figure 5 shows EC taken from monthly grab samples taken at the H.O. Banks Pumping Plant for the period 1986-2006. The data shows a weak downward trend over this period.

Figure 6 shows fall chloride concentrations at Rock Slough from 1944 to 2004 (CCWD, 2005). As the figure shows, salinity (chloride) near the intake of the Contra Costa canal has increased since the early 1970s. This is thought to be largely the result of changed operations at the State and Federal water projects in the south Delta where, to protect threatened and endangered fish species, pumping has been shifted from spring to summer and fall.

Figures 7, 8, and 9 show more recent salinity (EC) at the southern Delta intakes. Several generalizations about Delta salinity are apparent from these figures: 1) At times Delta Mendota Canal and Contra Costa Canal salinities have exceeded the recommended secondary MCL for drinking water; 2) Banks Pumping Plant and Delta Mendota canal salinities are similar and both are much better than Contra Costa Canal; and 3) All three intakes show the typical seasonal variation in salinity. Salinity is generally lowest in late winter or spring and highest in the fall. Although there may appear to be a downward trend in salinity over the period shown, this is probably due primarily to an upward trend in precipitation and runoff over this period.

Figure 10 shows a single calendar year of EC data averaged from continuously recorded data at the Banks Pumping Plant. Although the seasonal EC variation is different each year, this pattern is typical with a seasonal minimum in early spring and a maximum in late fall. The timing and magnitude of the seasonal maximum and minimum each year depends on the amount of Delta inflow during the preceding weeks and months which in turn depends on the timing and amount of precipitation and the amount of carryover reservoir storage from the previous year.

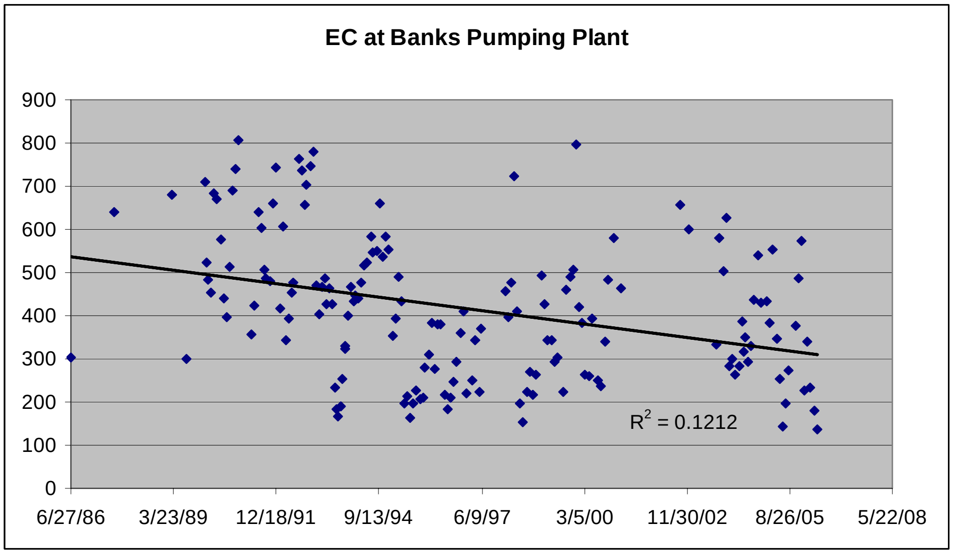


Figure 5: Electrical Conductivity at the H.O. Banks Delta Pumping Plant

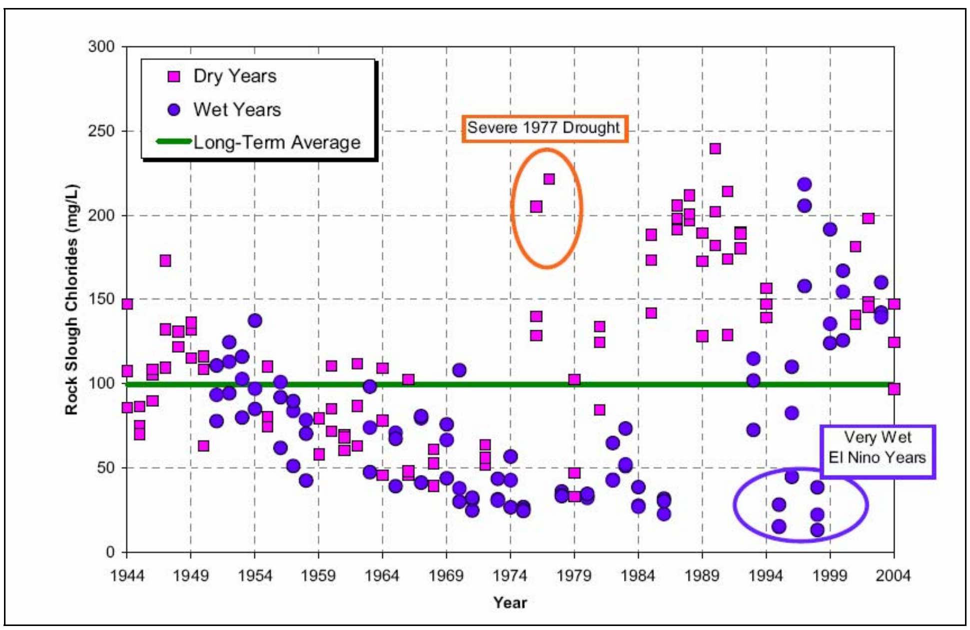


Figure 6: Fall chloride concentration in Rock Slough, 1944-2004

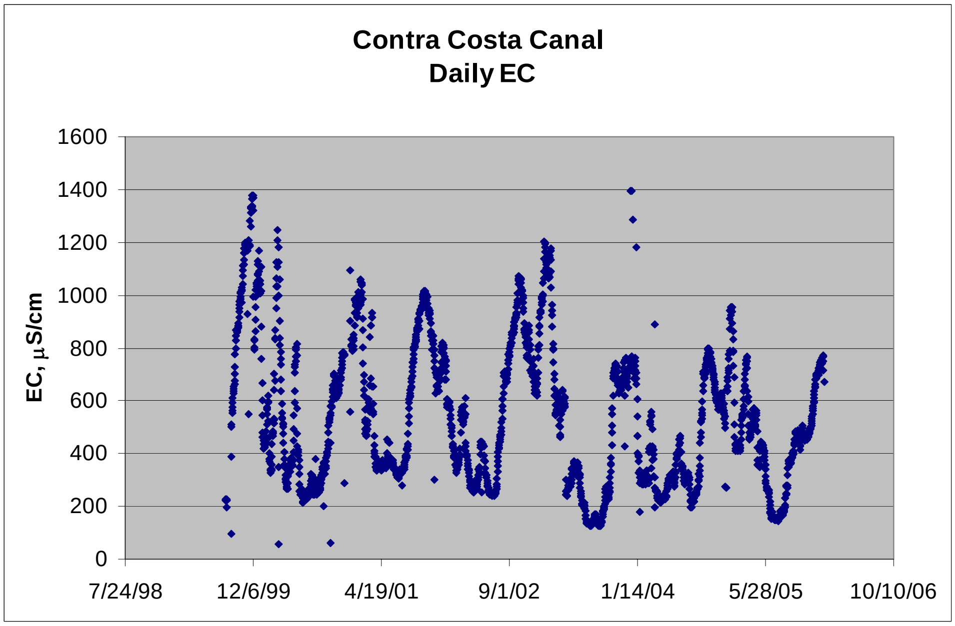


Figure 7: Daily average Electrical Conductivity (EC) in the Contra Costa Canal 1999-2006

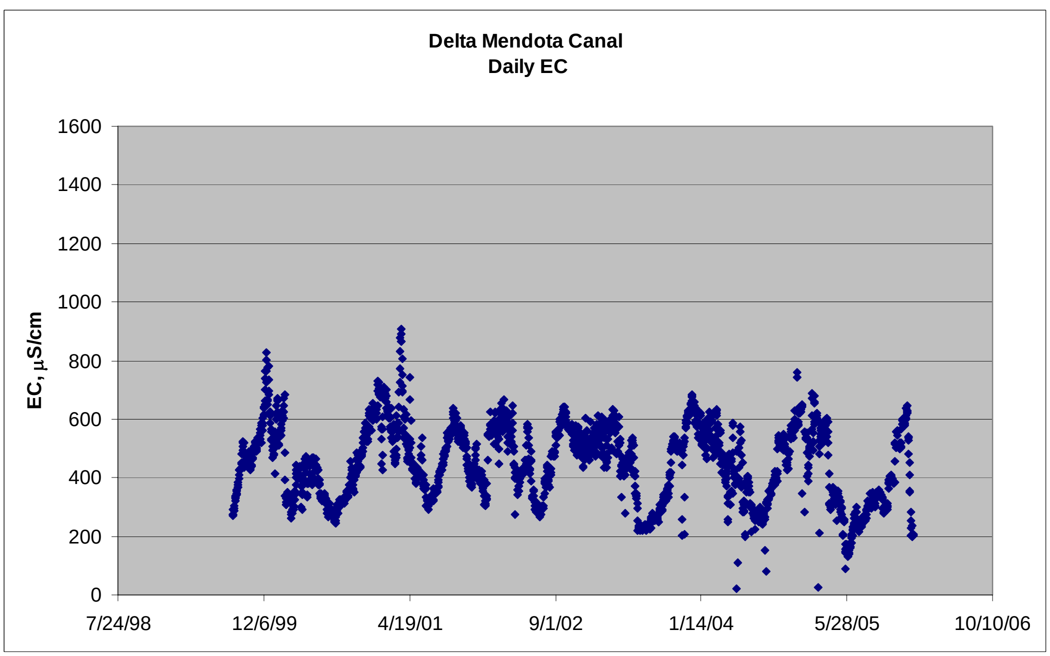


Figure 8: Daily average Electrical Conductivity (EC) in the Delta Mendota Canal near Tracy 1999-2006.

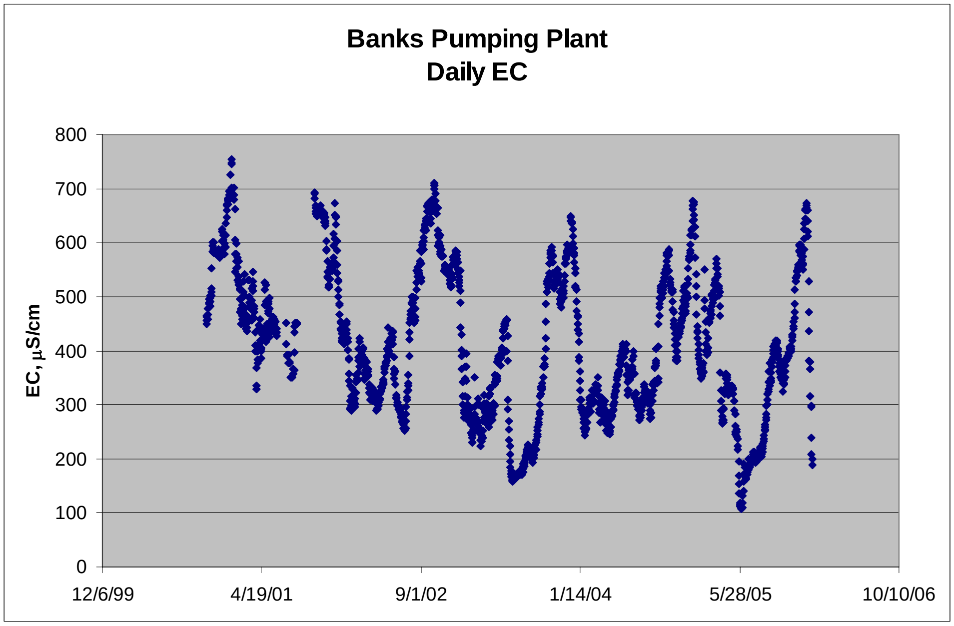


Figure 9: Daily average Electrical Conductivity (EC) at the State Water Project Banks pumping plant 2000-2005.

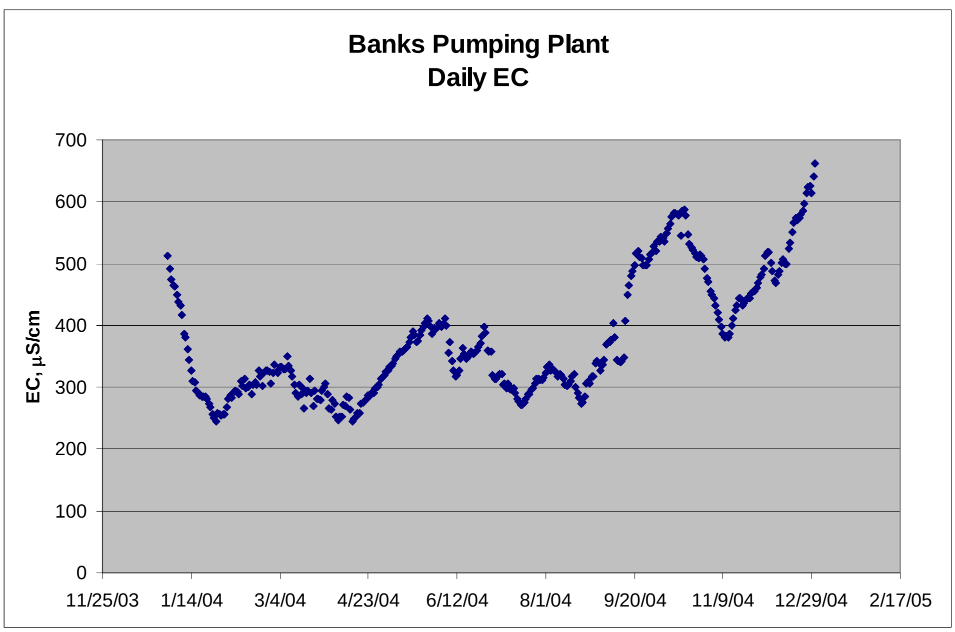


Figure 10: Daily average EC at H.O. Banks Delta Pumping Plant in 2004 (DWR data from CDEC).

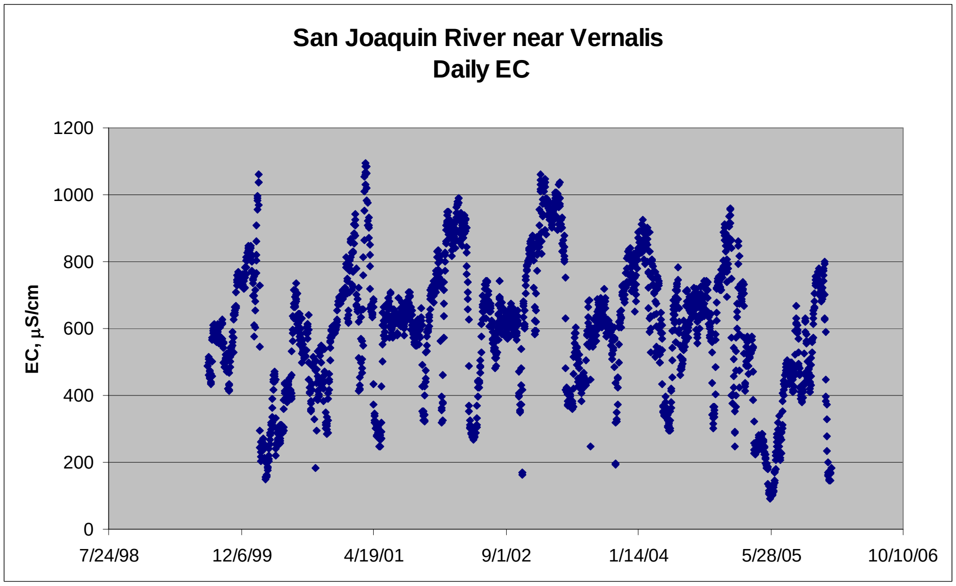


Figure 11: Daily average Electrical Conductivity (EC) for the San Joaquin River near Vernalis 1999-2005.

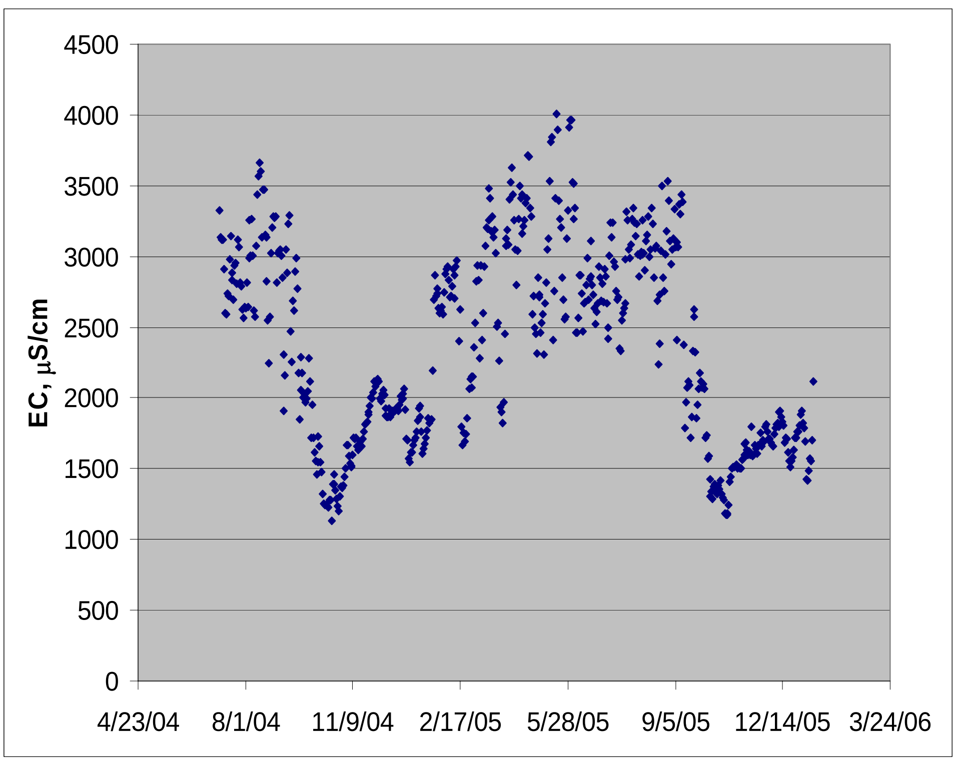


Figure 12: Daily average Electrical Conductivity (EC) for Mud Slough near Gustine, 2004-2006. (Notice that the scale is approximately 4 times the scale at the downstream Vernalis site shown in Figure 11.)

Next to seawater intrusion, the San Joaquin River is the largest source of salinity at the south Delta pumps (- this is discussed in the conceptual model section). Figure 11 shows recent salinity concentrations for the San Joaquin River near Vernalis, CA. The source of this San Joaquin River salinity is not evenly spread over the watershed but is concentrated on the west side. The largest concentrations and loads have historically come from the west side tributaries upstream of the Merced River confluence. Figure 12 shows the EC typical in Mud Slough.

Bromide and Chloride

Bromide at the Banks Pumping Plant has averaged 230 µg/L in recent years (1990-2006). The time series for bromide at the Banks Pumping Plant is shown in the Figure 13. The consistently high bromide concentration at the export pumps ranks the Delta among the drinking water sources with the highest Br concentrations in the United States (Amy et al, 1994). As Figure 14 shows, San Joaquin River bromide concentrations are also high because of the recirculation of Delta salts and bromide through the San Joaquin Valley. In contrast to the elevated concentrations of bromide seen at the Banks Pumping Plant and the San Joaquin River at Vernalis, the median concentration in the Sacramento River at Hood is at the method reporting limit of 10 µg/L with the 95th percentile at 20 µg/L.

Bromide concentration at the south Delta diversion points is closely correlated with chloride (Figure 15). This suggests that both constituents have a common origin (seawater). There is also a predictable relationship between EC and bromide (Figure 16) at the diversion points although it appears to be bimodal suggesting more than one major source of salts contributes to the observed conductivity. These plots show that bromide concentration in water diverted from the south Delta can be estimated from EC or chloride data with chloride being the most reliable indicator.

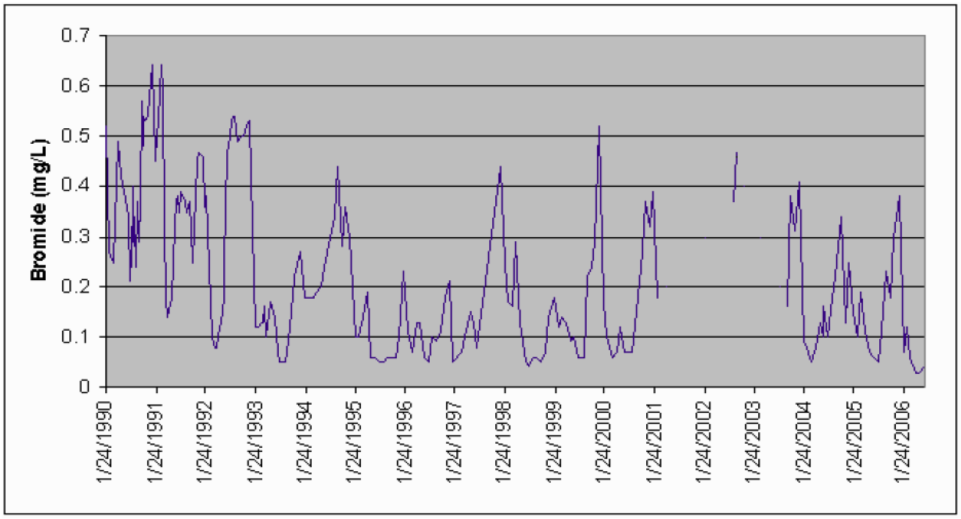


Figure 13: Bromide concentration at Banks Pumping Plant 1990-2006.

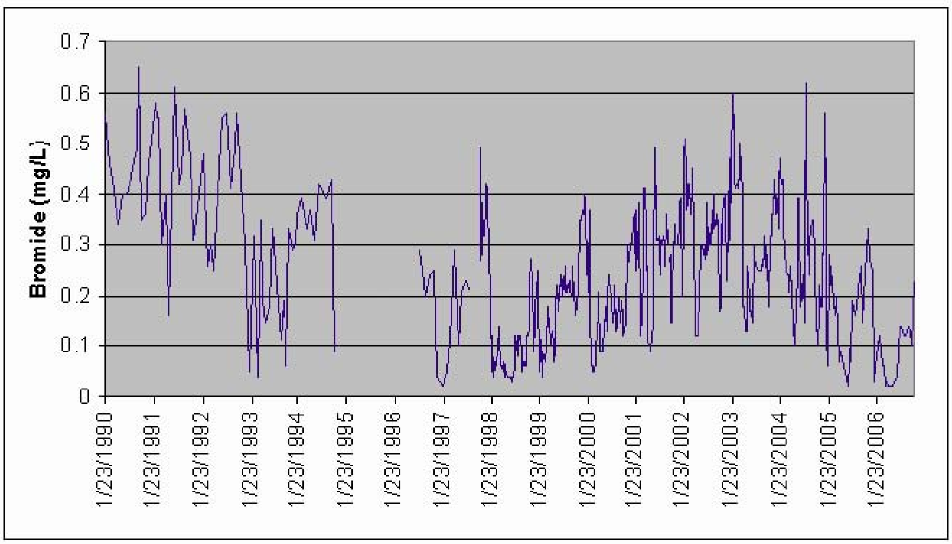


Figure 14: Bromide concentration for the San Joaquin River near Vernalis 1990-2006

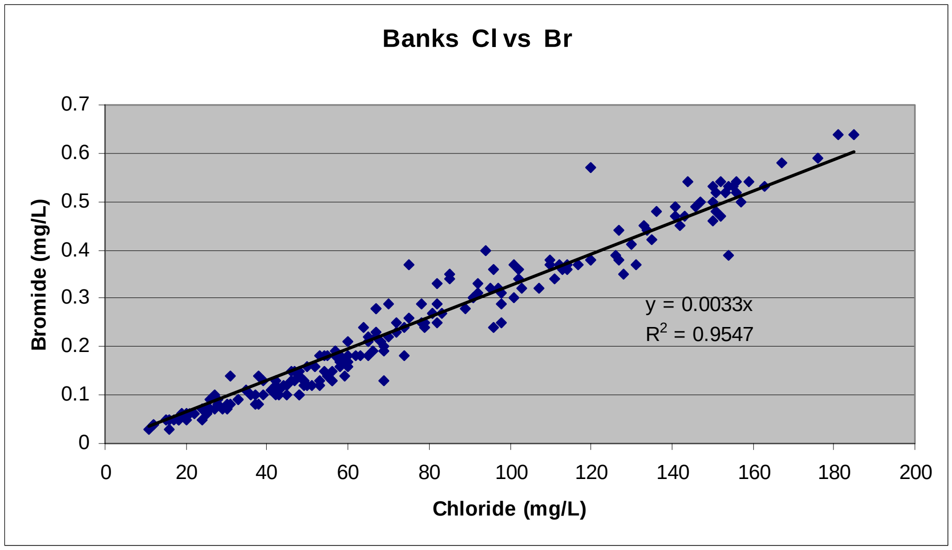


Figure 15: Chloride and bromide at the H.O. Banks Pumping Plant, 1990-2006.

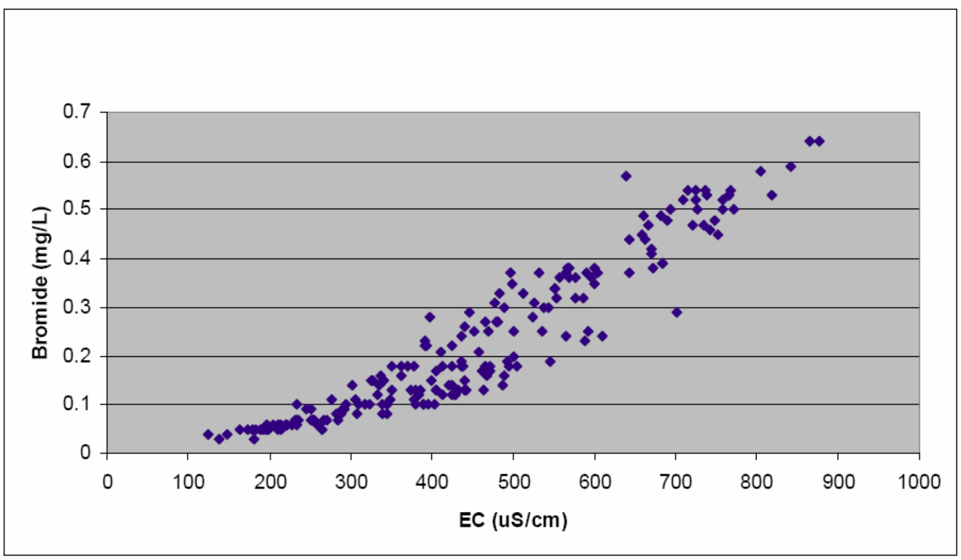


Figure 16: Bromide and EC at the H.O. Banks Pumping Plant, 1990-2006.

Color Contour Maps of Delta EC

Figures 17-20 show daily average Delta EC contours in false color. Generated by Resource Management Associates (RMA), these images show the output of a two-dimensional Delta hydrodynamics model based on historical EC and flow data. These four figures are snap shots in time of average flow and salinity for a single day under differing Delta conditions to illustrate the wide variation in salinity regimes that can occur. These images are a powerful tool for visualizing the distribution of Delta salinity. When coupled with other observations and studies, these distributions point to the sources and processes that drive Delta salinity. They help to illustrate the relative importance of different sources and the underlying water movement (hydrodynamics) of the Delta.

Figure 17 shows a typical early summer salinity distribution for the Delta. Seawater intrusion is evident in Suisun Bay and extending into the western Delta. Salinity from the San Joaquin River is seen impinging on the southeastern part of the Delta and the very fresh water of the Sacramento can be seen coming in from the north. The combined influence of Sacramento River inflow and export pumping at the Banks and Tracy pumping plants is thought to be the cause of the “freshwater corridor” extending across the central Delta from north to south.

Figure 18 shows high EC conditions (737 µS/cm) at the Banks and Tracy pumps. This was near the period of maximum EC for the year at the end of a series of dry to critically dry years (1987-1992). This is near the worst case for export salinity experienced in recent years.

EC at Banks was poor on the date represented in Figure 19 (~600 µS/cm) even though this was a wet year. This is thought to be due to closure of the Delta Cross Channel (DCC) gates to protect juvenile Chinook salmon migrating downstream. With the expected delay due to travel time across the Delta, an EC spike at the pumps coincided with the DCC closure. Subsequent studies of the effects of the DCC on salinity at the Banks and Tracy pumping plants have reinforced the association of DCC closure with high intake EC, especially when Delta outflow is relatively low.

Figure 20 shows the Delta during conditions of high Delta inflow. San Joaquin River inflow was greater than 15,000 cfs. EC at Banks was very low (~115 µS/cm). Computer “fingerprint” modeling of Delta flows suggests that nearly all of the water at the South Delta pumps was from the San Joaquin River on this date.

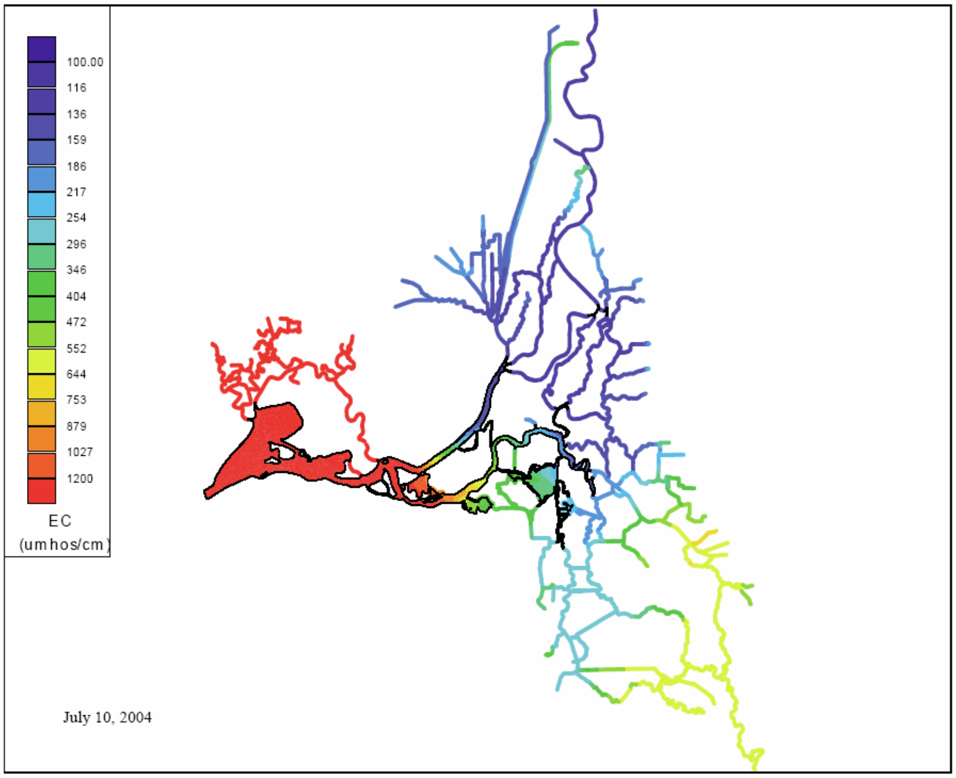


Figure 17: Tidally averaged Electrical Conductivity (EC) contours for July 10, 2004 (courtesy of RMA).

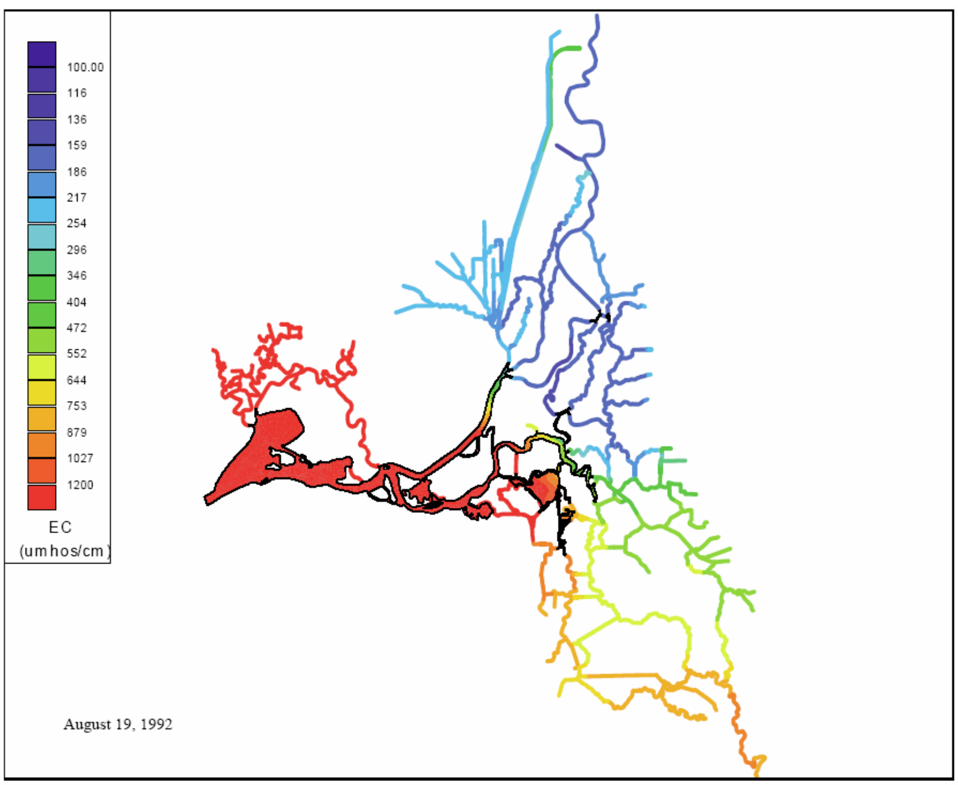


Figure 18: Tidally averaged EC contours on August 19, 1992.

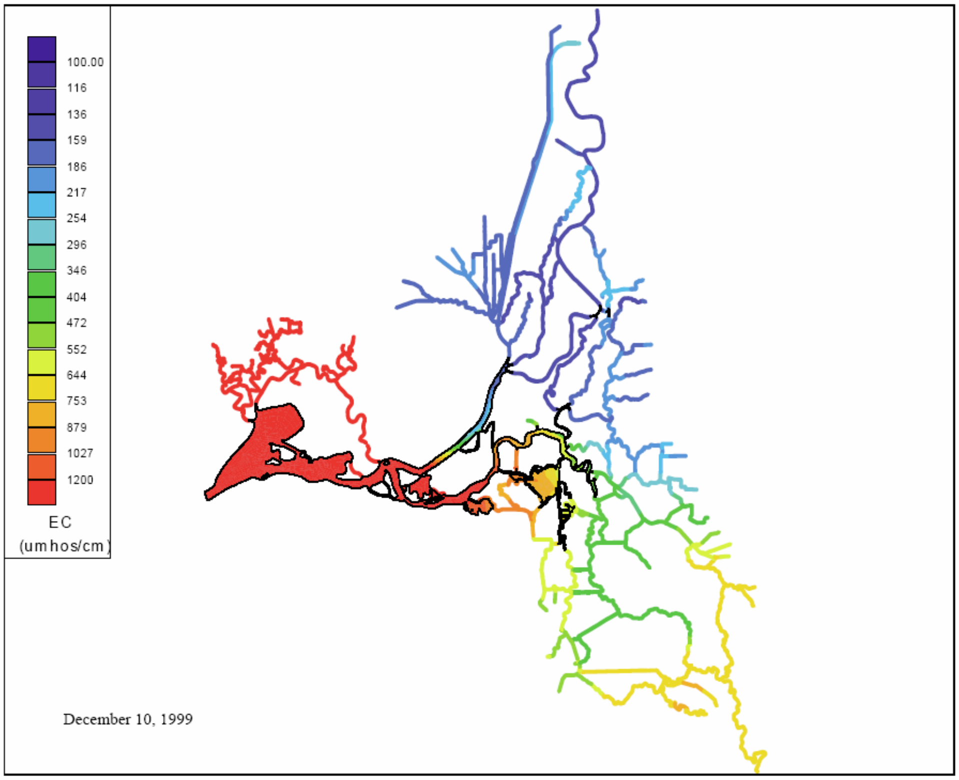


Figure 19: Tidally averaged EC contours on December 10, 1999.

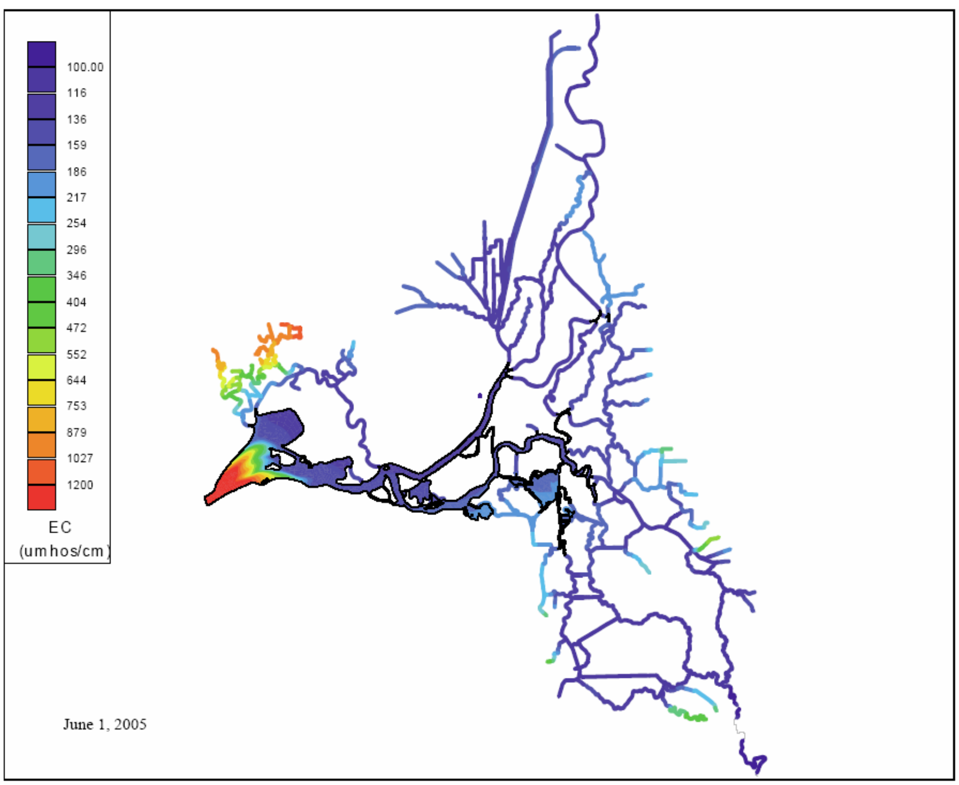


Figure 20: Tidally averaged EC contours on June 1, 2005.

CONCEPTUAL MODEL

This conceptual model differs to some extent from the usual quest for environmental knowledge in the wealth of monitoring data available and the depth of understanding that exists. Knowledge of the dynamics of salinity in the Delta has grown to the point where a sophisticated system of continuous monitoring equipment and computer models are used to operate the water projects' pumps and reservoirs to meet salinity objectives with a high degree of accuracy. We can plot the salinity at nearly any point in the system and we can model where the water and the salt that reaches the pumps comes from. In some critical locations we can even model the movement and mixing of salt in three dimensions with high spatial and temporal resolution. This "conceptual model" is an attempt to capture the current thinking about the factors that drive salinity at the municipal water supply diversion points and to put this knowledge into a simplified and understandable framework.

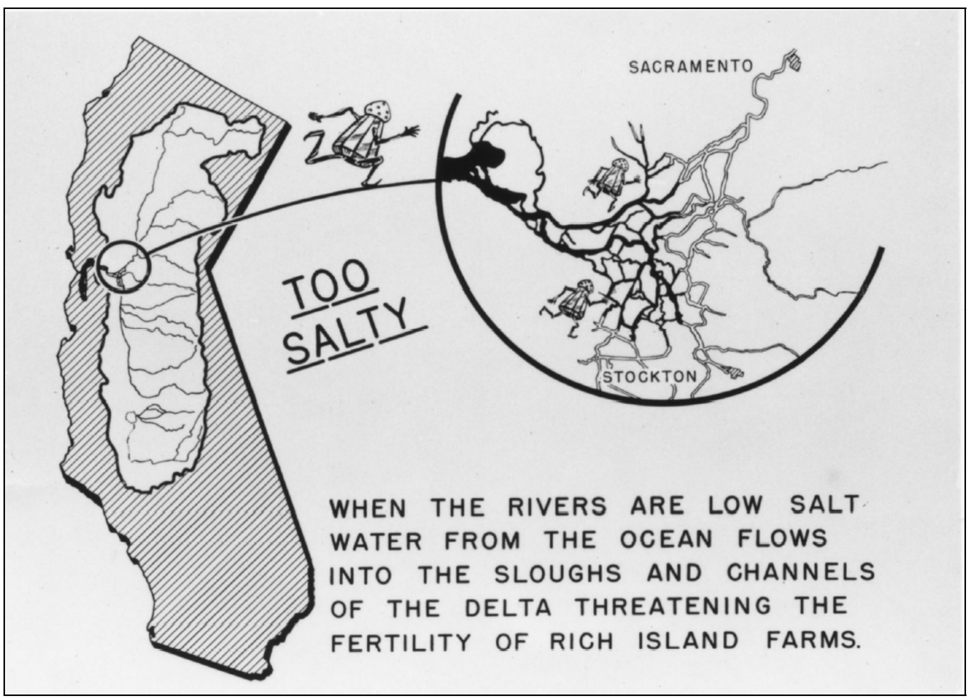


Figure 21: 1945 USBR depiction of Delta salinity intrusion.

At its simplest, the salinity in the Delta can be viewed as the movement of salt from San Francisco Bay into the Delta. Figure 21 is from a 1945 document on the history of the Central Valley project. This early public information piece conveys a basic understanding of salinity in the Delta and one of its effects.

Salinity Drivers and Outcomes

We now know that salinity at the municipal supply diversion points at any given time is the result of a number of factors. Figure 22 shows these "drivers" and the outcomes, salinity at the five major diversion points for drinking water supply. Factors are identified as uncontrollable (hydrology) or partially controllable (water operations, hydrodynamics, and watershed sources). Hydrology (precipitation and runoff) varies seasonally and year to year and is beyond our control. Water operations, reservoir releases, channel barrier operations, and diversion pumping rates, are our primary means of controlling flow in the system, and thereby salinity, but operations are driven by regulatory factors other than water quality so are only partially controllable for water quality purposes. Together hydrology and water operations determine Delta inflow, the most important determinant of salinity distribution in the estuary. The changes in maximum salinity intrusion after construction of Shasta dam in 1949 (Figures 3 and 4) are an indication of the powerful effect of water operations on salinity. Hydrodynamics, the movement of water, in the Delta is another important driver of salinity. We have been able to influence movement of water through the Delta to some extent through construction of channels (the Delta Cross Channel), barriers (south Delta temporary barriers, Suisun Marsh Salinity Control Gate) and, although not designed for this purpose in most cases, the Delta levees.

Watershed sources are only partially controllable; a certain amount of the salinity of the Delta's tributaries is the result of natural solution of minerals in rocks and soils. Non-point sources such as agricultural drainage and runoff have recently been subject to additional regulatory requirements but do not yet have limits on salinity. Municipal wastewater discharges have typically been subject to narrative limitations that prevent the discharge of excessive amounts of salt but have not been given numeric limitations on salinity or salt loads. Some industrial discharges have been regulated for salinity.

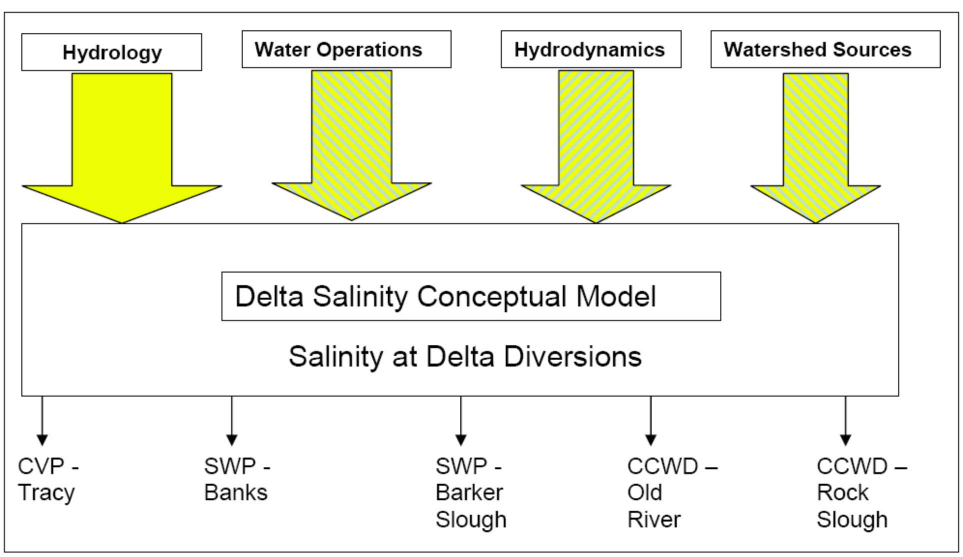
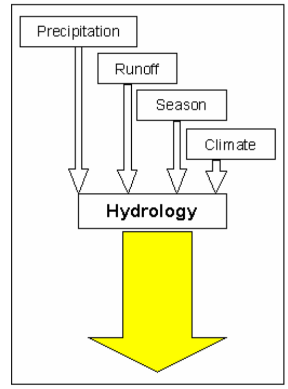


Figure 22: Drivers and Outcomes model of Delta salinity.

Hydrology



The amount of water flowing into the Delta is the single most important determinant of salinity at the export pumps and the amount of inflow is largely determined by hydrology. During very wet years average salinity at the SWP pumps is low. The average EC at the Banks Pumping Plant for the 1983 water year, one of the wettest on record, was 276 µS/cm. In the critically dry 1991 water year, EC at the same location averaged 589 µS/cm. Figure 23 shows the relationship between water year indices for the Sacramento and San Joaquin Rivers and annual conductivity at the Banks Pumping Plant. The water year index is calculated using a weighted formula based on current and the previous year's runoff. Higher water year index means more Delta inflow and therefore lower salinity.

The seasonal variation can be even greater. EC can vary from less than 200 to more than 750 µS/cm in a single water year. The highest salinities occur during the fall and early winter when Delta inflow is lowest. The amount of precipitation that falls in a given year, where it falls, when it falls, how much runs off, and other aspects of hydrology drive these changes and are generally beyond our control.

One of the key features of California hydrology is the difference in precipitation and runoff between the northern and southern parts of the state. There is much more runoff coming from the northern part of the Delta watershed (Sacramento River) than the southern part of the watershed (San Joaquin River). The annual inflow and outflow statistics for the Delta from the 1980 to 1991 period (DWR 1995) are shown in Table 2.

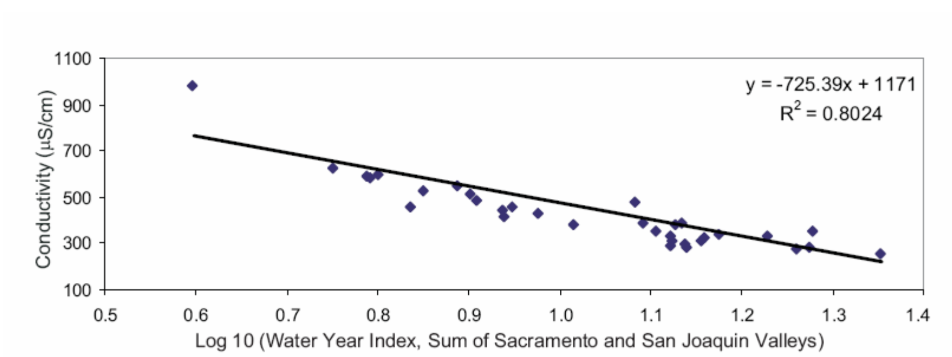


Figure 23: Relationship between water year index and annual average conductivity at the Banks Pumping Plant (DWR, 2004).

Table 2: Inflow sources, and outflow/diversions of California Delta water in thousands of acre-feet (TAF).

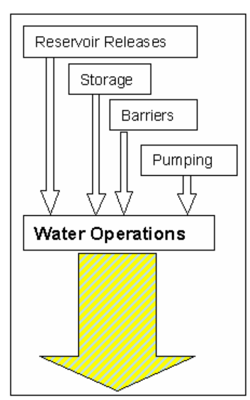
Inflow	Volume (TAF)
Sacramento River	17,220
East Side Sierra Streams	1,360
San Joaquin River	4,300
Delta Precipitation	990
Yolo Bypass	3,970
Total Inflows	**27,840**

Outflow/Diversion	Volume (TAF)
Delta Outflow to Bay	21,020
Consumptive Use and Channel Depletion	1,690
Tracy Pumping Plant	2,530
Banks Pumping Plant	2,490
Contra Costa Pumping Plant	110
Total Outflows	**27,840**

On average, during this period, approximately two thirds of the Delta inflow came from the Sacramento River and the Sierra streams draining into the east side of the Delta (the Cosumnes Mokelumne, and Calaveras rivers). However, the majority of water demand in the State is south of the Delta. The main purpose for the State and federal water projects is to modify the natural hydrology of the state by storing water when and where it is most available so that it can be used when and where it is needed. Water from winter and spring runoff in Northern California is stored in reservoirs and conveyed to Southern and Central California throughout the year.

Water Operations

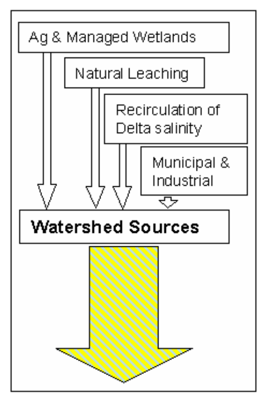
Even though we physically have control over all of the structures and processes, operations are represented as only partially controllable relative to water quality because they are subject to other constraints. For example, dam license provisions may require maintenance of flood reserve capacity at a time of year that reduces the amount of water available to meet water quality goals later. Reservoir releases may be driven by in-stream flow and temperature requirements. Delta barrier and pumping operations are regulated to protect fish and in-Delta agricultural water diversions.



At times, water project operations can be the dominant driver of Delta salinity. During periods of low natural inflow, the combination of reservoir releases and Delta diversion pumping governs salinity. Fall Delta outflow can be less than 4000 cfs while combined SWP and CVP diversions are near 10,000 cfs. It is during these periods, when the majority of Delta inflow is diverted, that salinities at the pumps are usually highest. When Delta outflow increases with the late fall and winter rains, salinities begin to decrease.

Installation and operation of Delta barriers can also have a significant effect on salinity at the SWP and CVP pumps. Installation of the temporary barriers in the south Delta can cut off the flow of high salinity San Joaquin River water through Old River, Middle River, and Grant Line Canal reducing the average salinity at the State and Federal pumps. Operation of the Delta Cross Channel (DCC) gates can also have a significant effect on water quality particularly in the fall months when Delta outflow is low. (This is in fact why the DCC was constructed.) The DCC gates are generally opened for the summer sometime in late June, allowing higher quality Sacramento River water into the central Delta by way of the Mokelumne River channels, and closed in December. However, the DCC gates are operated in accordance with water rights permit conditions issued by the SWRCB and are frequently closed to protect migrating fish or because of high flows at various times in the fall, winter, and spring. They are also sometimes opened expressly to improve water quality in the Delta.

Watershed Sources



Included here are salts added through material inputs to agricultural, municipal, industrial, and natural processes. These sources of salt are as varied and complex as land use and water use in the watersheds. Only the sources that monitoring and studies indicate are most important are discussed here. The salt from seawater entrained at the Delta export pumps, used for irrigation, and ultimately finding its way back to the San Joaquin River and the Delta is one of these sources. Another significant source in the San Joaquin River watershed is naturally occurring salt in soils that are mobilized by irrigation practices.

Soils on much of the west side of the San Joaquin Valley are derived from ancient marine sediments and are naturally high in gypsum and other salts. Irrigated **agriculture** in these areas dissolves these naturally occurring salts and moves them downward into the groundwater. Addition of fertilizers, soil amendments, and land application of animal wastes also contribute to this salt load. This groundwater eventually finds its way to surface water either through accretion to streams, groundwater use, or through specially constructed drains (tile drains). Both agriculture and **managed wetlands** concentrate the salts in supply water and soils through the process of evapotranspiration. This salty water is often discharged through drainage canals, sloughs, and creeks.

Natural leaching of salts from rocks and soils occurs everywhere in the watershed. This gradual increase in dissolved substances in water as it flows downstream through a watershed is normal and depends on factors such as geology and plant communities.

Because water is pumped upstream from the Delta and used in the lower San Joaquin Valley, salts there (which may be of seawater or watershed origin) can be **recirculated** within the system. Salts in water diverted from the Delta at the Banks and Tracy export pumps can travel through the Delta Mendota Canal and the California Aqueduct, through agricultural supply canals in the San Joaquin Valley, through agricultural fields, groundwater, or wetlands, through the drainage system, and back to the Delta by way of the San Joaquin River. The exact pathways for this recirculation are no doubt highly variable and the time it takes for salts to make this circuit is also highly variable.

Municipal and **industrial** use of water is known to both add and concentrate salts in supply water. These discharges of salt are easily quantifiable because they are monitored in accordance with discharge permit requirements. These discharges contribute much less salt to the system than agriculture and managed wetlands but they are increasing along with development in the Central Valley. It is also sometimes difficult to differentiate salt sources in a watershed because of mixed land uses and reuse of water within the system. For example, municipal and industrial wastewater is often land applied to grow crops. This is often the case with food processing wastewater.

Table 3: Source category salt loading (WY 1985-1995).

Table 3-6: Source Category Salt Loading (WY 1985 to 1995)

Source Category	Discharge		Salt Load		Salinity
	thousand acre-feet	Percent*	thousand tons	Percent*	(mg/L)
Sierra Nevada Tributaries and LSJR Upstream of Salt Slough (background)	3100	84%	222	20%	52
Groundwater Accretions	145	4%	320	30%	1,600
Municipal and Industrial	26	1%	23	1%	680
Wetland	193	5%	101	9%	380
Agricultural Surface Return Flows	310	8%	280	26%	660
Agricultural Subsurface Return Flows (Grassland Watershed)	37	1%	160	15%	3,300
Agricultural Subsurface Return Flows (NWS)	11	0.3%	25	2%	1,700
Total (SJR near Vernalis)*	3,670	100%	1,1	100%	

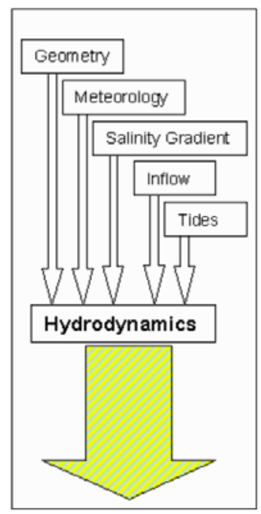
* The total discharge and salt load for the SJR at Vernalis is based on the historical data for 1977 through 1997; the sum of source categories is different from total at Vernalis because independent methods were used to estimate source category discharge and salt loads (not a mass balance calculation)

The Central Valley Regional Water Quality Control Board estimated the salt loading from different source types in the San Joaquin Valley shown in Table 3 (CVRWQCB 2004).

For the Sacramento River, municipal wastewater plant discharges contribute approximately 7% of the salt load at Hood. Municipal sources make up a higher percentage of the salt load than in the San Joaquin River because of the large population of the Sacramento metropolitan area and low background concentrations.

Hydrodynamics

As used here, hydrodynamics includes the major physical attributes and forces that govern the movement of water within the Delta and Bay. One indication of the importance of hydrodynamics is that the geographic extent of the Delta is largely defined by the upstream extent of tidal water level fluctuations. Although tidal hydrodynamics is important throughout the Delta, its impact on salinity is most important in the central to western Delta and less important as one travels upstream. Tides are the primary engine driving water mixing (dispersion) in the Delta. A parcel of water can move up and downstream several miles with the ebb and flow of the tide. This causes complex patterns of mixing and water movement and makes sophisticated computer modeling programs a must for understanding Delta water quality.



Geometry refers to the layout of bays, channels, rivers, sloughs, and flooded islands in the Delta and the depth profiles of these features. There are approximately seven hundred miles of interconnected channels and at least five permanently flooded islands in the Delta’s 738,000 acres. The importance of geometry is illustrated by several key projects that improve water quality by changing the routing of water through the Delta. The Delta Cross Channel was constructed as part of the Central Valley Project in 1951 to divert high quality Sacramento River water into the central Delta and towards the south Delta pumps. Another project, the Suisun Marsh Salinity Control Gates seek to lower salinities within Suisun Marsh by restricting upstream movement of brackish water and increasing freshwater flows into Suisun Marsh.

Controlling the flow of water at strategic locations in the Delta can have a major effect on salinity. Channels that branch off into flooded islands are much more effective at trapping and moving salty water into the Delta than are straight and uniform channels. Computer modeling of various options for restricting water movement in and around Franks Tract have shown that, under certain conditions, salinity at the south Delta pumps could be reduced by as much as 30%. Related studies indicate that constructing a screened diversion near Hood on the Sacramento River and discharging the diverted water into the South Fork of the Mokelumne River could further reduce salinity at the SWP and CVP pumps. Changing the way that the Delta Cross Channel is operated could also reduce salinity at the SWP and CVP pumps. The Department of Water Resources is conducting studies and planning a pilot project to further analyze these findings.

The depth profile (bathymetry) of a channel is important both across the width of the channel and in the upstream-downstream direction. Recent modeling studies have shown that bathymetry is an important factor in determining where density driven movement of seawater occurs. In several areas, shallow flats adjacent to deeper channels increase the tidal mixing and spread (dispersion) of salinity in the system. Bathymetry is also an important factor in the propagation of tides into the Delta.

The movement of water in the estuary can also be driven by the **salinity gradient** between fresh and salt water. The difference in density between the more saline waters of San Francisco Bay and fresher water flowing out of the Delta is an important force determining the extent of salt water intrusion into the Bay-Delta system. Rather than mixing immediately, less dense (fresher water) tends to ride up over the more dense saline water and the saltier water pushes upstream underneath. This effect is most pronounced in the deeper reaches of San Pablo Bay and the Carquinez Straights. Significant density driven water movement (baroclinic flow) occurs primarily downstream of Sherman Island.

As stated earlier, freshwater **inflow** into the Delta is highly correlated with salinity at Delta diversions pumps and is thus an extremely important driver. Water flows downhill into the Delta from its tributaries. The effect of this inflow is partly due to the volume of water entering the Delta and partly due to water surface elevation (stage). This flow of water downstream primarily driven by the gradient of water surface elevation is known as advective flow. At high water inflows during the winter and spring, the water surface of the Delta and its tributaries is higher, reducing tidally driven water movement. At the same time the increased volume pushes brackish water out of the Delta.

As stated above, movement of water due to the **tides** is a definitive characteristic of the Delta. The Delta is the freshwater tidal portion of the San Francisco Bay-Delta estuary. Much of the land surface in the Delta is at or below the elevation of the mean high tide. The twice daily high and low tide signal can be seen in stage (water surface elevation) measurements in most of the rivers, sloughs, and channels of the Delta for at least some part of the year. This tidal fluctuation can clearly be seen in stage recorded at the I Street Bridge on the Sacramento River and at Mossdale Bridge on the San Joaquin River when flows are low during the late summer and fall. However, this does not mean that flow reversals (upstream flow due to the tide) occur this far upstream. For example, there is strong upstream and downstream tidal flow at Rio Vista on the Sacramento River but usually not at Freeport. Conversely, tidal flows in the main channels of the western Delta are often many times higher than the net downstream flow.

Sea level has risen by an estimated eight inches on average over the past one hundred years and is projected to rise by at least another one to three feet over the next 100 years (Twiss et al, 2006). This rise in sea level will have two important effects relative to salinity: 1) It will increase the risk of levee failures that could draw seawater into the Delta; and, 2) It will increase the tidal mixing of seawater into the western Delta (both scenarios will increase salinity at Delta diversions). The position of the salinity gradient in the Delta is determined largely by sea level and is likely to encroach further into the Delta as sea level rises.

After rainfall (captured in "inflow") the aspects of **meteorology** that have the biggest effect on hydrodynamics in the Delta are wind and barometric pressure. Strong westerly winds can push water upstream causing abnormally high tide stages and affecting the timing of the tides. Such winds are common in the western Delta during much of the year. During winter storms, wind effects can be exacerbated by low barometric pressure. The additive effects of reduced atmospheric pressure and strong upstream winds can produce storm surges that raise water levels by two feet or more.

The DRERIP Hydrodynamics Conceptual Model

The conceptual model illustrated in Figure 24 is under development as part of the CALFED Delta Regional Ecosystem Restoration Implementation Plan (DRERIP). This diagram is the simplified version of the basic model diagram but still shows the complexity of the factors that drive salinity in the system. At the time of this report, the DRERIP hydrodynamics conceptual model is planned for web based deployment. Each

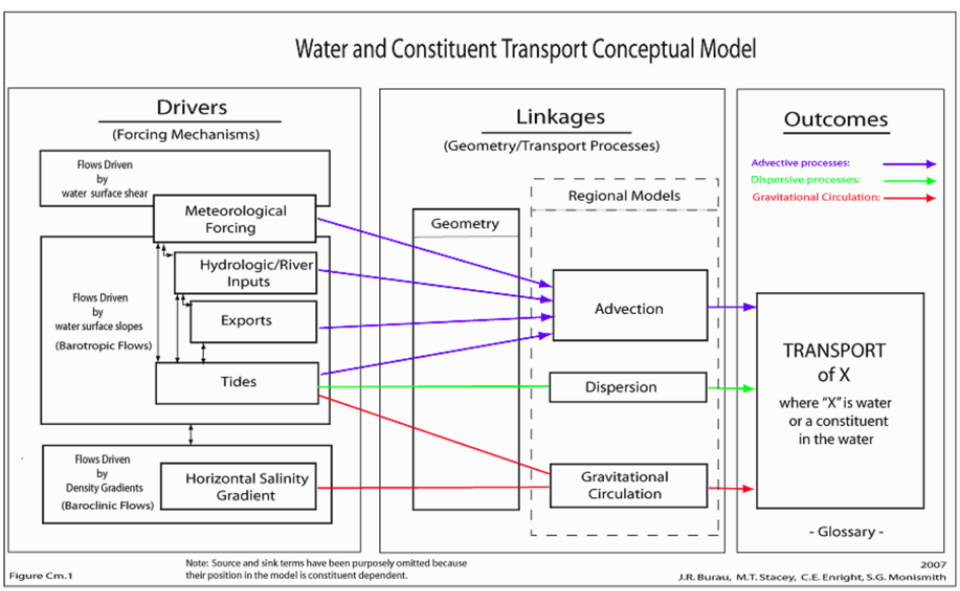


Figure 24: Conceptual model of the major hydrodynamic drivers and linkages in San Francisco Bay and the Delta (Burau et al, 2007).

of the primary drivers and linkages in the model will be expanded to include additional diagrams, text, and graphics to further explain the concept and provide supporting information. This web based conceptual model will be a more scientifically rigorous treatment of Delta hydrodynamics and will be easily modified as new information becomes available.

At its most basic level, water movement in the Delta is the result of fresh water flowing into the Delta, export pumping, tides, and flow driven by salinity gradients all acting through the complex geometry of the Delta. Tidal movement and density driven flow are the engines that move seawater into the Delta. Delta outflow (dependent on Delta inflow and diversions) pushes salinity out of the Delta. These two forces working against one another determine how much and how far salinity from seawater intrudes into the Delta. This is one way to look at what is better described as a dynamic salinity field acted on by the downstream flow of water, tidal mixing, and density driven movement of seawater in the upstream direction (baroclinic flow). This salinity field moves upstream and downstream, and expands and contracts, in response to the amount of freshwater entering the Delta, operation of Delta gates, the presence of barriers, and the amount of water pumped out of the Delta, tidal cycles, and other forces. The times of the year (usually late fall) when the Delta outflows are lowest and the field is furthest upstream are the most critical for drinking water quality.

It is important to note that the importance of the drivers shown in Figure 24 depends on the local area of interest within the Delta. Please refer to the conceptual model on the web for much more complete treatment of all aspects of Delta hydrodynamics including the geographic variation in drivers. The DRERIP conceptual models will be posted on the web at http://www.delta.dfg.ca.gov/erpdeltaplan/.

Tributary Conceptual Models

Figures 25-27 capture the significant factors driving salinity in Delta tributaries. Dissolved solids (salinity) in most freshwater systems comes from a few major sources 1) natural dissolution of minerals in soils and rocks 2) agricultural chemicals 3) human or animal wastes and 4) waste from industrial chemical use. These salts are further concentrated through evapotranspiration, the evaporation of water from soil or water surfaces plus the transpiration of water by plants. Evapotranspiration is a dominant factor resulting in highly saline groundwater and drainage from irrigated lands in arid regions.

Separate conceptual model diagrams were developed for the west side of the San Joaquin Valley and the remainder of the Delta tributaries because of one unique source of salts. An estimated 513,000 tons of salt per year are transported into the west side of the San Joaquin Valley with the Delta water supplied through the Delta Mendota Canal (RWQCB, 2002). This is equivalent to about half of the San Joaquin River salt load. This salinity is a mixture of salt from seawater and salt from the tributaries and exacerbates the typical arid region irrigated agriculture problem of concentration through evapotranspiration. Salinization of soils and groundwater is most pronounced on the west side of the San Joaquin Valley and in the Tulare Basin where land is irrigated with Delta water. In the San Joaquin River watershed, salinity is highest in the sloughs draining the Grassland area on the west side and is diluted by the flows of the east side streams. Approximately 67% of Lower San Joaquin salt load comes from the west side (RWQCB, 2002). Finally, just upstream of the point where the San Joaquin River meets the Delta, Stanislaus River releases from New Melones Reservoir are used to reduce salinity to meet the EC standard at Vernalis.

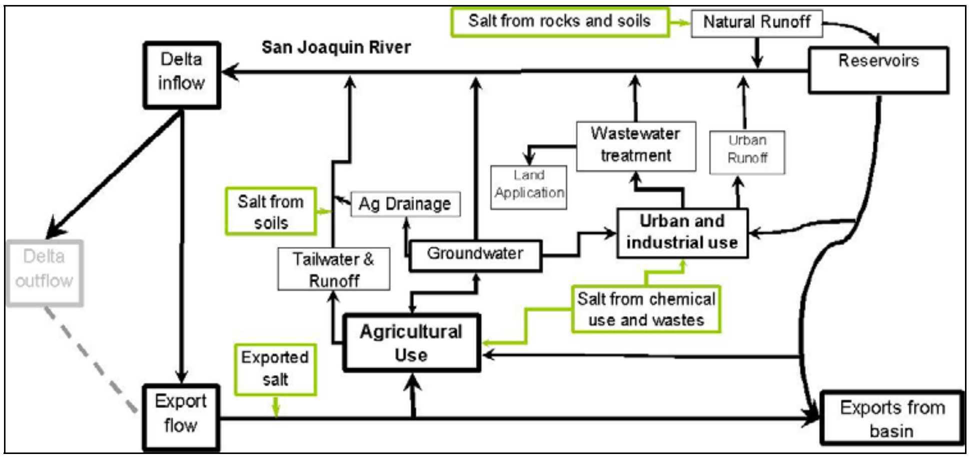


Figure 25: Conceptual model of the sources and transport of salinity in the west side of the San Joaquin basin.

In the San Joaquin Valley, the dominant sources of salinity are seawater from the Delta and natural minerals (mostly gypsum) in soils and rocks. The small amount of gypsum added to increase soil arability is thought to be insignificant compared to the amounts naturally present. Irrigation dissolves and mobilizes this store of salts. Other agricultural chemicals, animal wastes, and domestic wastewater also contribute but sulfate from gypsum dominates the salt load from the west side of the San Joaquin Valley. These sources along with the effects of evapotranspiration result in the very high salinity observed in some of the tributaries (Mud Slough for example, Figure 12). Figure 26 further illustrates the dominant sources and movement of salt in the west San Joaquin Valley. Irrigation practices, plant water utilization, and groundwater processes are central to understanding salt accumulation, mobilization, and movement associated with agriculture.

Figure 26 also illustrates the important role of consumptive use of water through evapotranspiration in western San Joaquin Valley groundwater and drainage salinity. Not shown in this figure is the significant fraction of this salt coming from naturally occurring minerals (mostly gypsum) in these soils.

Further evidence of the sources of salts in the San Joaquin River can be seen in the composition of the major ions. The ratio of chloride to sulfate in seawater is approximately 7:1. In the San Joaquin River the chloride/sulfate ratio is approximately

1:1 (DWR, 2004). The situation is complicated by the fact that a constantly varying fraction of the San Joaquin River salt load is re-circulated through the CVP and SWP diversions.

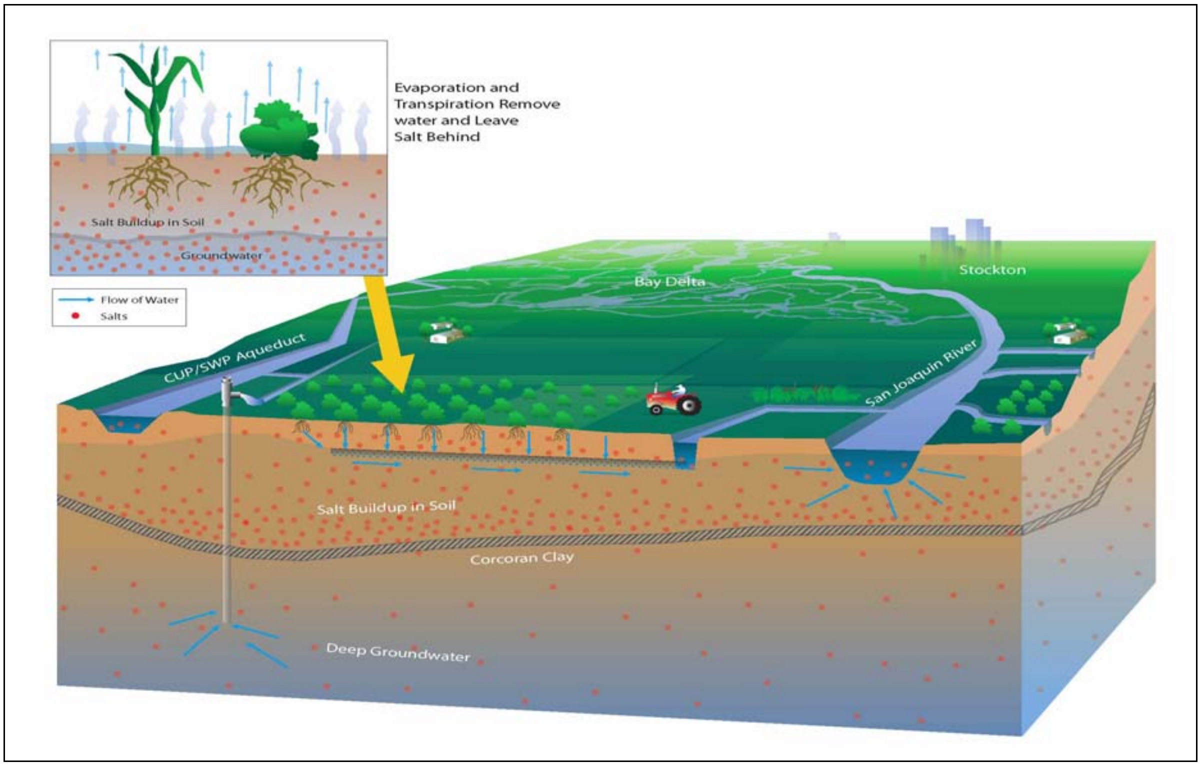


Figure 26: Salt Sources and Transport in the San Joaquin Valley

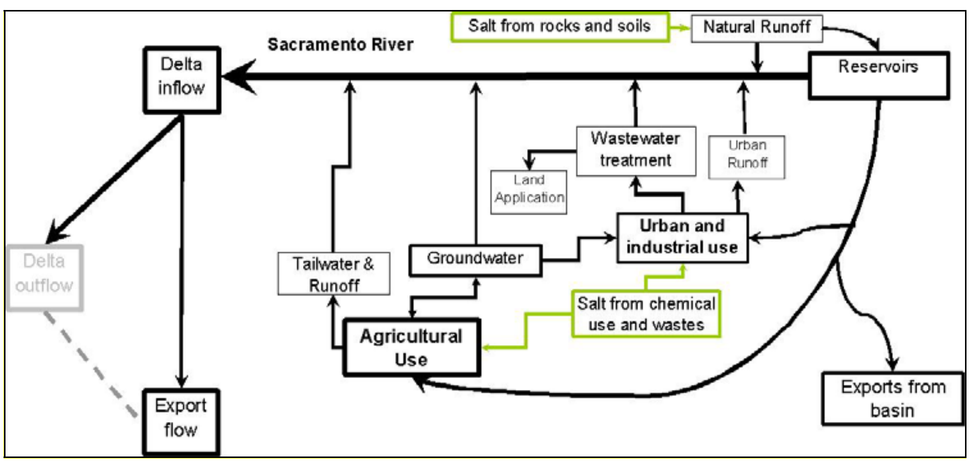


Figure 27: Conceptual model of the sources of salinity in the Sacramento Valley and most other Delta watersheds.

The Sacramento River and other tributaries section of the conceptual model differs from that for the San Joaquin River only in the absence of the Delta diversion loop and the contribution from soil gypsum. The natural watershed, agricultural, domestic wastewater sources, and other factors are similar. However, in the Sacramento River and most other major Delta tributaries, salinities are much lower than in the San Joaquin. This is primarily because of the much higher dilution flows, a result of the greater water supply in the northern half of the State. In an average year, approximately 85% of the Delta inflow comes from the Sacramento River yet the amount of acreage under cultivation in the Sacramento Valley is much less than in the San Joaquin Valley. The anion composition of the Sacramento River also indicates that gypsum is not a significant source of salt in the watershed.

COMPUTATIONAL MODELS

In 1958, the U.S. Army Corps of Engineers constructed a physical model of San Francisco Bay and the Delta to address a number of management issues. This model, located in Sausalito, was used for scientific and engineering studies until 2000 and is still used as an educational tool. Now, computer models are the tools used by engineers and scientists to study and manage water in the Bay-Delta and its watersheds. These models have been designed for specific uses and vary considerably in complexity and performance. Models currently in regular use by the State and Federal water management agencies include DWR’s Delta Simulation Model 2 (DSM2), CALSIM-II, and the Resource Management Associates (RMA) Bay-Delta Model. A number of other models are in-use by researchers and water management agencies varying in complexity from simple spreadsheet models to cutting-edge high resolution three dimensional models. Brief descriptions of the most commonly used models and their uses are provided here with examples of some of the model output tools of particular value for salinity management.

DSM2

DSM2 is a river, estuary, and land modeling system based on a one dimensional link-node type of hydrodynamic and water quality model. It can simulate stages, flows, velocities, many mass transport processes (including salts), multiple non-conservative constituents, temperature, and movement of individual particles.

An example of the application of DSM2 is “fingerprinting.” While we can (and do) monitor the flow and salinity of the major Delta tributaries we cannot predict what the resulting water quality will be at the water diversions without using a set of sophisticated computer models. This is because of the complex flow patterns and mixing that occur in the Delta’s seven hundred miles of interconnected channels. The total Delta outflow is important in determining salinity at the pumps but so is the flow of the San Joaquin River itself, the ratio of San Joaquin River flow to export flow, and the configuration and operation of the Delta barriers (DWR, 2004).

Figure 28 shows a computer generated “fingerprint” of the sources of salinity at Clifton Court Forebay (feeds Banks pumping plant). It shows that the source of salinity can vary from more than 90% San Joaquin River to less than 20% over the course of a few months. Figure 29 is a volumetric fingerprint for the same period showing that even when the Sacramento River water makes up 80% of the flow at Clifton Court, it stills accounts for less than half of the salinity. The salinity graph also shows that the model does not account for all of the salinity that is monitored at Clifton Court. The DWR modelers

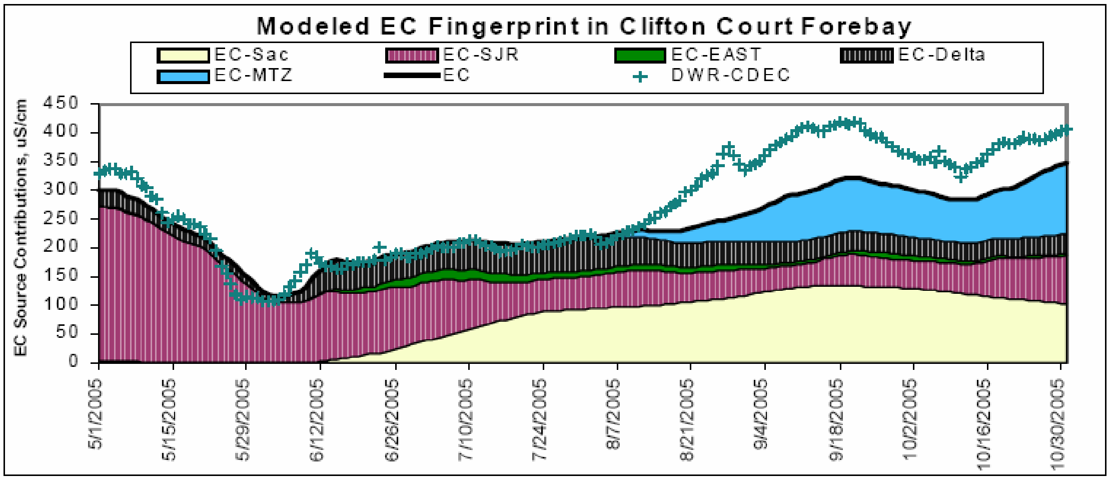


Figure 28: Modeled Conductivity Fingerprint for Clifton Court Forebay (DWR 2005)

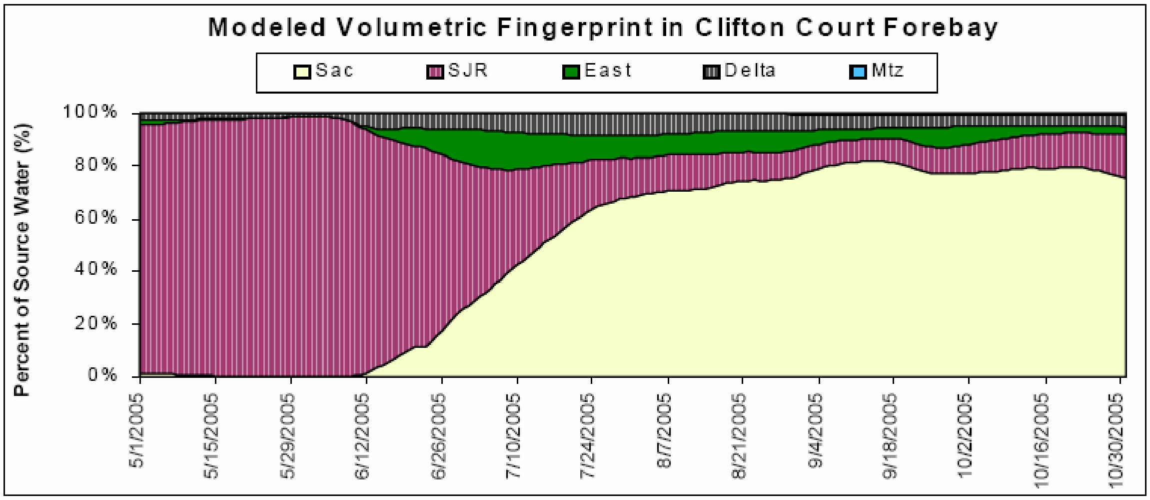


Figure 28: Modeled Volumetric Fingerprint for Clifton Court Forebay (DWR 2005)

think that the model is underestimating the amount of seawater salinity. Seawater salinity is represented by EC at the Martinez boundary of the model (EC –MTZ). Water quality at the export pumps can best be understood and predicted by monitoring flow and water quality conditions at the major Delta inflows and modeling the movement of water in the Delta with an adjustment for Delta island consumptive use and discharge.

Further evidence for the validity of "fingerprinting" using the Delta models can be seen in analysis of the anion species composition of Delta waters. As discussed previously, San Joaquin River salinity has a much higher sulfate fraction than seawater. Thus the relative concentration of sulfate to total salts or sulfate to chloride can be used as a sort of tracer for San Joaquin water (DWR, 2004). Analysis of this kind of anion concentration data confirms the kinds of variation and the range that the modeling indicates.

CALSIM-II

CALSIM is a generalized water resources simulation model for evaluating operational alternatives of large, complex river basins. It is used in planning studies and for development of operating rules for California's major water management systems.

RMA

The Resource Management Associates (RMA) model is an advanced two dimensional model that more accurately simulates the movement of water and solutes in the large channels and flooded islands of the Bay and west Delta. It is being used extensively in planning studies in this part of the system. This kind of model is particularly useful for predicting the effects of major changes to Delta geometry such as the breaching of levees.

3-D Models

Although not routinely used, advanced three dimensional (3-D) models have been developed and applied in limited areas for specific purposes. The intensive data and computational resource demands of these models generally limit their use to high priority problems. For example, three dimensional modeling has been essential to understanding the movement of water and fish at the intersection of the Sacramento River and the Delta Cross Channel.

SALINITY MANAGEMENT

Here are some of the key findings from the salinity conceptual modeling exercise:

- Salinity at the Delta diversions comes primarily from seawater and naturally occurring minerals present in the San Joaquin River watershed.
- Discharges from urban and industrial sources are currently relatively minor sources of salt but should be monitored. New or increased industrial discharges in particular have the potential to contribute significant salt loads.
- Seawater intrusion into the Delta is highly dependent on the amount of Delta inflow.
- Water movement driven by the tides is the primary force moving seawater into the western Delta.
- When salinity and bromide are highest at the delta diversions, seawater is a significant contributing source.
- The ionic composition of San Joaquin River water is different from that of seawater and indicates that gypsum in soils is a significant source.
- The sources of the water and salts exported from the Delta at the SWP and CVP pumps vary seasonally and from year to year.
- Because regulatory standards for salinity in the San Joaquin River at Vernalis are met through release of additional water from storage in New Melones Reservoir, reducing salt loads upstream of Vernalis does not always improve water quality downstream. When salinity at Vernalis is controlled through dilution with New Melones Reservoir releases, upstream salinity reduction only serves to increase water supply by reducing the amount of New Melones water needed to meet the standard. That is, under current operations rules, salinity source reduction will only improve water quality downstream of Vernalis when the river is below the standard. A similar (although more complicated) effect may take place in the Delta when salinity standards are driving operations (reservoir releases and/or export pumping). Salinity source reduction may result in increased water supply (increased exports and/or reduced reservoir releases) rather than lower salinity in exported water.
- When San Joaquin River inflow exceeds approximately 3500 cfs, it is the dominant source of exported water at the SWP and CVP south Delta intakes.
- Bromide comes primarily from seawater in the Bay-Delta system. Median concentrations at the export pumps are about 16 times higher than in the Sacramento River at Hood and other Delta tributaries upstream of any seawater influence. (The CVP, SWP, west side San Joaquin Valley and the lower San Joaquin River are influenced by seawater and have elevated bromide concentrations.)
- Disinfection byproducts formed from bromide tend to have more serious health effects than those that do not contain bromine. These brominated chemicals are more likely to be the subject of future regulation.

Implications for Salinity Management

- Actions that reduce tidal pumping of seawater into the western Delta will reduce drinking water salinity when it is most critical (when it is highest).
- Reducing the seawater contribution to exported salinity will also do the most to reduce bromide concentrations in exported water.

- Reducing the amount of irrigation water applied on the west side of the San Joaquin Valley will reduce the amounts of naturally occurring salts leached into groundwater and into the San Joaquin River.
- Regulatory actions that reduce agricultural drainage discharges into the San Joaquin River will reduce river salinity but may not protect groundwater in the San Joaquin Valley in the long term.
- Standards specifically designed to improve salinity at the Delta diversions may be needed for source improvements to achieve the desired results. Under the current rules governing operations, upstream water quality improvement could be neutralized through reduced reservoir releases, increased pumping, or other changes to operations.
- Delta conveyance alternatives that separate high quality water from seawater will be highly effective.

Standards and Regulatory Programs

Salinity in the Delta and its watersheds is largely managed through regulatory actions of the SWRCB and the Central Valley Regional Water Quality Control Board. Salinity intrusion into the Delta is controlled through standards established by the SWRCB in its Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Appendix 1). These standards are implemented through SWRCB Decision 1641 that governs operation of the CVP and SWP to protect aquatic life, agricultural, and other beneficial uses. The Water Quality Control Plan for the Sacramento River and San Joaquin River Basins contains standards (Appendix 2) and control programs for salinity in specific areas and water bodies especially in the San Joaquin Valley.

Since historical data and modeled water quality in the San Joaquin River showed that the San Joaquin River standards at Vernalis would be violated in dry years, the CVRWQCB developed and adopted a Total Maximum Daily Load (TMDL) for this river segment. This TMDL includes a system of load allocations and alternative compliance methods and has now been incorporated into the Basin Plan. On the heels of the Vernalis TMDL, the CVRWCB is developing standards and an associated TMDL for the San Joaquin River upstream to about the confluence with the Merced River. Implementation of this TMDL could have the effect of further reducing salinity in the San Joaquin River.

A related program to control selenium discharges from the Grassland area has compelled agricultural drainage dischargers using the existing section of the San Luis Drain to move towards zero discharge. The most current calculations and modeling indicate that reducing Grasslands agricultural drainage to zero will also remove enough salt from the system to achieve compliance with the Vernalis salinity standards under most hydrologic conditions.

The United States Bureau of Reclamation is required by federal law (bolstered by a court order) to address salinity in its San Luis unit area. This includes the Westlands Water

District and most of the Grasslands area. Although the USBR is compelled to provide agricultural drainage service for this area the method for complying with this requirement is not specified. The current preferred alternative is to divert drainage into reuse areas and concentrate it further through sequential reuse and an evaporation system. The accumulated concentrated brine or solid salts would be sequestered in ponds or recycled. This is the so called "in-valley" approach rather than the original San Luis Drain or a brine line to the coast to carry salts out of the Central Valley.

Voluntary programs such as the Department of Water Resources and University of California agricultural drainage management programs help to reduce the impacts of salinity by helping farmers to better manage water and salt.

Although these regulations and programs are capable of achieving compliance with the San Joaquin River salinity standards, they will not completely address the salt problems of the San Joaquin Valley. Calculated salt loads into and out of the San Joaquin Valley show that there is a salt imbalance. That is, there is more salt entering the valley than leaving it. Monitoring and studies of salt sources and transport show that the salt is accumulating in groundwater. This will eventually render this water unusable and could again increase the salinity of the San Joaquin River. To address these issues, the SWRCB and the CVRWQCB have initiated a project to develop a long-term salinity management strategy for the Central Valley.

The overall effect of these regulations and mandates is to force a complex system of water and salt management methods that allow agencies to stay in compliance while continuing to provide water and drainage services. Water quality and regulatory trends will likely require additional actions to address salinity problems in the Central Valley and Delta.

Current Management Tools

The current Delta salinity control methods have evolved along with the development of the CVP and SWP and the regulations that control their operations. The major operational control methods, discussed in the "Water Operations" section of the conceptual model, include reservoir releases, barrier or gate operations, and export pumping rates. As was seen during the Jones Tract levee failure of 2004, these can be highly effective tools. When the Jones Tract levee failed on June 3, 2004, the Department of Water Resources acted quickly to counteract the sudden influx of water onto the island and the expected pulling of seawater into the system. The pumping rate at the SWP and CVP south Delta facilities was reduced drastically and reservoir releases were increased. These two operational changes kept the salinity increase to a minimum.

The Delta Cross Channel (DCC) is also an important control for salinity at the export pumps under certain hydrologic conditions. This was never more apparent than in December of 1999 when the DCC gates were closed to protect out-migrating juvenile

Chinook salmon. The gate closure was followed several days later by a rapid increase in salinity at Tracy and Banks forcing them to curtail pumping. A short time later, after the gates were reopened, water quality and operations returned to more seasonally normal conditions. Recent studies of Delta Cross Channel operations confirm its importance to export water quality when Delta inflows are low. Operation of the Delta Cross Channel, reservoir releases, and export pumping rates are the primary means of controlling salinity intrusion into the western Delta.

The other major source of salinity in the Delta - infiltration, runoff, and drainage from agriculture - is more diffuse and difficult to control. In the San Joaquin Valley, reduced salinity of imported Delta water could help to reduce the salinity of surface water and groundwater finding its way to the San Joaquin River. More efficient use of irrigation water could reduce the salt load to the river and to groundwater by reducing dissolution and mobilization of soil salts. Likewise, retirement of land from agricultural production in the most heavily salt impacted areas could also reduce salt loads. Drainage management actions, like reuse and evaporation of drainage water can provide an immediate reduction in surface water salt loads to the San Joaquin River. Real-time drainage management, the holding of drainage water and release when the river has assimilative capacity can also help to reduce peak salinities in the river and prevent violations of the salinity standards. However, these drainage mitigation measures might not be enough to prevent the gradual long term increase in groundwater salinity.

Future Management Options

DWR and USBR are planning to replace the current temporary flow barriers in the south Delta with permanent operable South Delta barriers by the end of 2009. These barriers will be capable of opening and closing tidally as needed to control flows and water levels in the Delta channels between the head of Old River and the CVP and SWP south Delta pumps. These barriers will primarily be used to reduce salinity and improve water levels for agricultural water supply in these channels but may also be capable of more wide reaching flow and salinity management in the Delta. These barriers are currently undergoing environmental review with construction originally scheduled to begin in 2006.

Another tool that has been proposed to reduce salinity in the San Joaquin River is the recirculation of Delta water by way of the Delta Mendota Canal and the Newman Wasteway. This would release higher quality Delta water directly to the San Joaquin River near the confluence with the Merced River and would reduce downstream salinities. Initial experiments and studies have shown that this would be an effective salinity control tool under some flow and water quality conditions.

The Franks Tract pilot project stemmed from early hydrodynamic and water quality modeling studies suggesting that water quality at the SWP and CVP pumps could be improved significantly by restricting the tidal movement of water into Franks Tract from the west. It has evolved into a more specific proposal for a project to restrict flow into Franks Tract by installing a barrier in False River. The CALFED agencies are also investigating how the operating scheme of the Delta Cross Channel could be modified to improve water quality while still protecting fish. The ROD action to investigate the proposed installation and operation of a screened diversion between the Sacramento River near Hood and the east Delta Mokelumne River channels is also under way. These three actions are being investigated together and are collectively called "through-Delta conveyance."

Alternatives to through-Delta conveyance are also being reconsidered in light of recent assessments of the risks to Delta water quality posed by earthquakes and climate change. One of these alternatives is to convey water completely around the Delta from the Sacramento River to the export pumps, some variation of the so-called "Peripheral Canal". This alternative would certainly reduce the salinity of exported water and salinity problems in those areas receiving this water. This alternative; however, will change the flow of fresh water through the Delta and may result in local increases in salinity.

Water rights and water quality regulations, including drinking water protection policies, will play a key role in the long term solution for salinity problems in the Delta, its watersheds, and its service area. All of the above management options will need to be considered individually and in combination to find an equitable and sustainable Central Valley and Delta salt management strategy.

References

Amy, G., R. Bull, K. Kerri, S. Regli, and P. Singer. 1998. Bay-Delta Drinking Water Quality: Bromide Ion (Br^-) and Formation of Brominated Disinfection By-Products (DBPs). Appendix E to July 2000 CALFED Bay-Delta Program Water Quality Program Plan. Sacramento, CA.

Ayers, R. S. and D. W. Westcot. 1985. Water Quality For Agriculture. UN FAO Irrigation and Drainage Paper 29 Rev.1, Rome.

CALFED Bay-Delta Program. 2000. Water Quality Program Plan.

CALFED Bay-Delta Program. 2004. Science in Action –
Demystifying the Delta.

California Urban Water Agencies (CUWA). 1998. Bay-Delta Water Quality Evaluation Draft Final Report.

Contra Costa Water District, City of Stockton, and Solano County Water Agency. 2005. Final Draft Delta Region Drinking Water Quality Management Plan.

Department of Water Resources. 1979-Present. Methodology for flow and salinity estimates in the Sacramento-San Joaquin Delta and Suisun Marsh, Annual Progress Reports. Sacramento, CA.

Department of Water Resources. 1995. Sacramento-San Joaquin Delta Atlas

Department of Water Resources. 1996. Water quality conditions in the Sacramento-San Joaquin Delta 1970-1993. Sacramento, CA.

Department of Water Resources. 2001. Sanitary survey update report. Sacramento, CA

Department of Water Resources. 2004. Factors affecting the composition and salinity of exports from the south Sacramento-San Joaquin Delta. Sacramento, CA.

Department of Water Resources. 2004. Water Quality in the State Water Project, 2000 and 2001. Sacramento, CA.

Department of Water Resources. 2005. Real Time Data and Forecasting Project - Water Quality Weekly Reports. Sacramento, CA.

Fischer, H.B., List, E.J., Koh, R.C.Y., Imberger, J., and Brooks, N.H. (1979). Mixing in Inland and Coastal Waters. New York: Academic Press

Hem, J. D. 1989. Study and Interpretation of the Chemical Characteristics of Natural Water. United States Geological Survey

Jackson, W.T. and Paterson, A. M. 1977. The Sacramento-San Joaquin Delta, The Evolution, and Implementation of Water Policy. University of California. Davis, CA

Kimmerer, W. J. 2004. Open water processes of the San Francisco Estuary: from physical forcing to biological responses. San Francisco Estuary and Watershed Science [online serial]. Vol. 2, Issue 1 (February 2004), Article 1.

Larry Walker Associates. 2004. Technical analysis to support development of drinking water policy for the central valley basin plan: Identification of existing data and planned monitoring.

Maas, E. V. 1990. Chapter 13, Crop Salt Tolerance. In: K. K. Tanji (ed.); Agricultural Salinity Assessment and Management, ASCE Manuals and Reports on Engineering Practices No. 71, ASCE, N.Y., pp. 262-304.

Maas, E.V. 1984. Salt Tolerance of Plants. In: The Handbook of Plant Science in Agriculture. B.R. Christie (ed.), Boca Raton, Florida. As cited in Ayers and Westcot, 1985.

Maas, E.V., and S.R. Grattan. 1999. Crops Yields as Affected by Salinity. Agricultural Drainage. Am. Soc. Agron. Monograph No. 38. Eds. Skaggs and Van Schilfgaarde. p. 55-108.

Pearson, K.E., Adapted from a paper by Warrence, N.J., Pearson, K. E., and J.W. Bauder, 2003. The Basics of Salinity and Sodicity Effects on Soil Physical Properties Information Highlights for the General Public http://waterquality.montana.edu/docs/methane/basics_highlights.pdf

Regional Water Quality Control Board Central Valley Region. 2003. Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Salt and Boron Discharges Into the San Joaquin River.

Regional Water Quality Control Board, Central Valley Region. 2002. Total Maximum Daily Load for Salinity and Boron in the Lower San Joaquin River.

San Joaquin Valley Drainage Program. 1990. A management plan for agricultural subsurface drainage and related problems on the Westside Sand Joaquin Valley.

Schoups, G., Hopmans, J.W., Young, C.A., Jasper, A.V., Wallender, W.W., Tanji, K.K., and S. Panday. 2005. Sustainability of irrigated agriculture in the San Joaquin Valley, California. Proceedings of the National Academy of Sciences

Sobey, R.J. 2001. Review of One-Dimensional Hydrodynamic and Transport Models. Bay-Delta Modeling Forum. Davis, CA

Starratt, S.W. 2001. Diatoms as Indicators of Freshwater Flow Variation in Central California. PACLIM Conference Proceedings.

State Water Resources Control Board. 1991. Water Quality Control Plan for Salinity.

State Water Resources Control Board. 1995. Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary. Sacramento, CA.

State Water Resources Control Board. 2000. Water Right Decision 1641 (Revised).

United States Environmental Protection Agency. January 4, 2006. Federal Register Vol. 71, No. 2. National Primary Drinking Water Regulations: Stage 2 Disinfectants and Disinfection Byproducts Rule; Final Rule.

Appendices

Standards tables from the 1995 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary

Table 1 — WATER QUALITY OBJECTIVES FOR MUNICIPAL AND INDUSTRIAL BENEFICIAL USES

COMPLIANCE LOCATION	INTERAGENCY STATION NUMBER (RKI [1])	PARAMETER	DESCRIPTION (UNIT)	WATER YEAR TYPE [2]	TIME PERIOD	VALUE
Contra Cosfa Canal at Pumping Plant #1	*C-5 (CHCCC06)*	*Chloride (Cl^-)*	*Maximum mean daily 150 mg/l Cl^- for at least the number of days shown during the Calendar Year. Must be provided in intervals of not less than two weeks duration. (Percentage of Calendar Year shown in parenthesis)*			*No. of days each Calendar Year ≤ 150 mg/l Cl^-*
-or-						
San Joaquin River at Antioch Water Works Intake	*D-12 (near) (RSAN007)*			*W*		*240 (66%)*
				AN		*190 (52%)*
				BN		*175 (48%)*
				D		*165 (45%)*
				C		*155 (42%)*
Contra Costa Canal at Pumping Plant #1	*C-5 (CHCCC06)*	*Chloride (Cl^-)*	*Maximum mean daily (mg/l)*	*All*	*Oct-Sep*	*250*
-and-						
West Canal at mouth of Clifton Court Forebay	*C-9 (CHWST0)*					
-and-						
Delta-Mendota Canal at Tracy Pumping Plant	*DMC-1 (CHDMC004)*					
-and-						
Barker Sbugh at North Bay Aqueduct Intake	*----- (SLSAR3)*					
-and-						
Cache Slough at City of Vallejo Intake [3]	*C-19 (SLCCH16)*					

[1] River Kilometer Index station number.
[2] The Sacramento Valley 40-30-30 water year hydrologic classification index (see page 23) applies for determinations of water year type.
[3] The Cache Slough objective to be effective only when water is being diverted from this location.

Table 2 **WATER QUALITY OBJECTIVES FOR AGRICULTURAL BENEFICIAL USES**

COMPLIANCE LOCATION	INTERAGENCY STATION NUMBER (RKI [1])	PARAMETER	DESCRIPTION (UNIT) [2]	WATER YEAR TYPE [3]	TIME PERIOD	& VALUE
WESTERN DELTA						
Sacramento River at Emmaton	*D-22 (RSAC092)*	*Electrical Con-ductivity (EC)*	*Maximum 14-day running average of mean daily EC (mmhos/cm)*		*0.45 EC April 1 to date shown*	*EC from date shown to Aug 15 [4]*
				W	*Aug 15*	*----*
				AN	*Jul 1*	*0.63*
				BN	*Jun 20*	*1.14*
				D	*Jun 15*	*1.67*
				C	*----*	*2.78*
San Joaquin River at Jersey Point	*D-15\ (RSAN018)*	*Electrical Con-ductivity (EC)*	*Maximum 14-day running average of mean daily EC (mmhos/cm)*		*0.45 EC April 1 to date shown*	*EC from date shown to Aug 15 [4]*
				W	*Aug 15*	*----*
				AN	*Aug 15*	*----*
				BN	*Jun 20*	*0.74*
				D	*Jun 15*	*1.35*
				C	*----*	*2.20*
INTERIOR DELTA						
South Fork Mokelumne River at Terminous	*C-13 (RSMKL08)*	*Electrical Con-ductivity (EC)*	*Maximum 14-day running average of mean daily EC (mmhos/cm)*		*0.45 EC April 1 to date shown*	*EC from date shown to Aug 15 [4]*
				W	*Aug 15*	*----*
				AN	*Aug 15*	*----*
				BN	*Aug 15*	*----*
				D	*Aug 15*	*----*
				C	*----*	*0.54*
San Joaquin River at San Andreas Landing	*C-4 (RSAN032)*	*Electrical Con-Ductivity (EC)*	*Maximum 14-day running average of mean daily EC (mmhos/cm)*		*0.45 EC April 1 to date shown*	*EC from date shown to Aug 15 [4]*
				W	*Aug 15*	*----*
				AN	*Aug 15*	*----*
				BN	*Aug 15*	*----*
				D	*Jun 25*	*0.58*
				C	*----*	*0.87*
SOUTHERN DELTA						
San Joaquin River at Airport Way Bridge, Vernalis **-and-** *San Joaquin River at Brandt Bridge site* **-and-** *Old River near Middle River [5]* **-and-** *Old River at Tracy Road Bridge [5]*	*C-10 (RSAN112)* *C-6 (RSAN073)* *C-8 (ROLD69)* *P-12 (ROLD59)*	*Electrical Con-ductivity (EC)*	*Maximum 30-day running average of mean daily EC (mmhos/cm)*	*All*	*Apr-Aug* *Sep-Mar*	*0.7* *1.0*
					-or-	
			If a three-party contract has been implemented among the DWR, USBR, and SDWA, that contract will be reviewed prior to implementation of the above and, after also considering the needs of other beneficial uses, revisions will be made to the objectives and compliance/monitoring locations noted, as appropriate.			
EXPORT AREA						
West Canal at mouth of Clifton Court Forebay **-and-** *Delta-Mendota Canal at Tracy Pumping Plant*	*C-9 (CHWST0)* *DMC-1 (CHDMC004)*	*Electrical Con-ductivity (EC)*	*Maximum monthly average of mean daily EC (mmhos/cm)*	*All*	*Oct-Sep*	*1.0*

[1] River Kilometer Index station number.

[2] Determination of compliance with an objective expressed as a running average begins on the last day of the averaging period. If the objective is not met on the last day of the averaging period, all days in the averaging period are considered out of compliance.

[3] The Sacramento Valley 40-30-30 water year hydrologic classification index (see page 23) applies for determinations of water year type.

[4] When no date is shown, EC limit continues from April 1.

[5] The EC objectives shall be implemented at this location by December 31, 1997.

Table 3 — WATER QUALITY OBJECTIVES FOR FISH AND WILDLIFE BENIFICIAL USES

COMPLIANCE LOCATION	INTERAGENCY STATION NUMBER(RKI 1[])	PARAMETER	DESCRIPTION (UNIT) [2]	WATER YEAR TYPE [3]	TIME PERIOD	VALUE
DISSOLVED OXYGEN						
San Joaquin River between Turner Cut & Stockton	*(RSAN050- RSAN061)*	*Dissolved Oxygen (DO)*	*Minimum DO (mg/l)*	*All*	*Sep-Nov*	*6.0 [4]*
SALMON PROTECTION						
			narrative	*Water quality conditions shall be maintained, together with otehr measures in the watershed, sufficient to achieve a doubling of natural production of chinook salmon from the average production of 1967-1991, consistent with the provisions of State and federal law.*		
SAN JOAQUIN RIVER SALINITY						
San Joaquin River at and between Jersey Point and Prisoners Point [5]	*D-15 (RSAN018)* **-and-** *D-29 (RSAN038)*	*Electrical Conductivity (EC)*	*Maximum 14-day running average of mean daily EC(mmhos/cm)*	*W,AN,BN,D*	*Apr-May*	*0.44 [6]*
EASTERN SUISUN MARSH SALINITY						
Sacramento River at Collinsville **-and-** *Montezuma Slough at National Steel* **-and-** *Montezuma Slough near Beldon Landing*	*C-2 (RSAC081)* *S-64 (SLMZU25)* *S-49 (SLMZU11)*	*Electrical Conductivity (EC)*	*Maximum monthly average of both daily high tide EC values (mmhos/cm), or demonstrate that equivalent or better protection will be provided at the location*	*All*	*Oct* *Nov-Dec* *Jan* *Feb-Mar* *Apr-May*	*19.0* *15.5* *12.5* *8.0* *11.0*
WESTERN SUISUN MARSH SALINITY						
Chadbourne Slough at Sunrise Duck Club **-and-** *Suisun Slough, 300 feet south of Volanti Slough* **-and-** *Cordelia Slough at Ibis Club* **-and-** *Goodyear Slough at Morrow Island Clubhouse* **-and-** *Water supply intakes for waterfowl management areas on Van Sickle and Chipps islands*	*S-21 [7] (SLCBN1)* *S-42 [8] (SLSUS12)* *S-97 [8] (SLCRD06)* *S-35 [8] (SLGYR03)* *No locations specified*	*Electrical Conductivity (EC)*	*Maximum monthly average of both daily high tide EC values (mmhos/cm), or demonstrate that equivalent or better protection will be provided at the location*	*All but deficiency period*	*Oct* *Nov* *Dec* *Jan* *Feb-Mar* *Apr-May*	*19.0* *16.5* *15.5* *12.5* *8.0* *11.0*
				Deficiency period [9]	*Oct* *Nov* *Dec-Mar* *Apr* *May*	*19.0* *16.5* *15.6* *14.0* *12.5*
BRACKISH TIDAL MARSHES OF SUISUN BAY						
			narrative		*[10]*	

Table 3	WATER QUALITY OBJECTIVES FOR FISH AND WILDLIFE BENIFICIAL USES	(continued)

COMPLIANCE LOCATION	INTERAGENCY STATION NUMBER(RKI 1□)	PARAMETER	DESCRIPTION (UNIT) [2]	WATER YEAR TYPE [3]	TIME PERIOD	VALUE
DELTA OUTFLOW						
		Net Delta Outflow Index (NDOI) (11)	*Minimum monthly average (12) NDOI (cfs)*	*All*	*Jan*	*4,500 [13]*
				All	*Feb-Jun*	*[14]*
				W,AN	*Jul*	*8,000*
				BN		*6,500*
				D		*5,000*
				C		*4,000*
				W,AN,BN	*Aug*	*4,000*
				D		*3,500*
				C		*3,000*
				All	*Sep*	*3,000*
				W,AN,BN,D	*Oct*	*4,000*
				C		*3,000*
				W,AN,BN,D	*Nov-Dec*	*4,500*
				C		*3,500*
RIVER FLOWS						
Sacramento River at Rio Vista	*D-24 (RSAC101)*	*Flow rate*	*Minimum monthly average [15] flow rate (cfs)*	*All*	*Sep*	*3,000*
				W,AN,BN,D	*Oct*	*4,000*
				C		*3,000*
				W,AN,BN,D	*Nove-Dec*	*4,500*
				C		*3,500*
San Joaquin River at Airport Way Bridge, Vernalis	*C-10 (RSAN112)*	*Flow rate*	*Minimum monthly average [16] flow rate (cfs) [17]*	*W,AN*	*Feb-Apr 14 and May 16-Jun*	*2,130 or 3,420*
				BN,D		*1,420 or 2,280*
				C		*710 or 1,140*
				W	*Apr 15-May 15 [18]*	*7,330 or 8,620*
				AN		*5,730 or 7,020*
				BN		*4,620 or 5,480*
				D		*4,020 or 4,880*
				C		*3,110 or 3,540*
				All	*Oct*	*1,000 [19]*
EXPORT LIMITS						
		Combined export rate [20]	*Maximum 3-day running average (cfs)*	*All*	*Apr 15-May 15 [21]*	*[22]*
			Maximum percent of Delta inflow diverted [23] [24]	*All*	*Feb-Jun*	*35% Delta inflow [25]*
				All	*Jul-Jan*	*65% Delta inflow*
DELTA CROSS CHANNEL GATES CLOSURE						
Delta Cross Channel at Walnut Grove	—	*Closure of gates*	*Closed gates*	*All*	*Nov-Jan*	*[26]*
					Feb-May 20	—
					May 21-Jun 15	*[27]*

Table 3 Footnotes

[1] River Kilometer Index station number.

[2] Determination of compliance with an objective expressed as a running average begins on the last day of the averaging period. If the objective is not met on the last day of the averaging period, all days in the averaging period are considered out of compliance.

[3] The Sacramento Valley 40-30-30 Water Year Hydrologic Classification Index (see page 23) applies unless otherwise specified.

[4] If it is infeasible for a waste discharger to meet this objective immediately, a time extension or schedule of compliance may be granted, but this objective must be met no later than September 1, 2005.

[5] Compliance will be determined at Jersey Point (station D15) and Prisoners Point (station D29).

[6] This standard does not apply in May when the best available May estimate of the Sacramento River Index for the water year is less than 8.1 MAF at the 90% exceedence level. [Note: The Sacramento River Index refers to the sum of the unimpaired runoff in the water year as published in the DWR Bulletin 120 for the following locations: Sacramento River above Bend Bridge, near Red Bluff; Feather River, total unimpaired inflow to Oroville Reservoir; Yuba River at Smartville; and American River, total unimpaired inflow to Folsom Reservoir.]

[7] The effective date for objectives for this station is October 1, 1995.

[8] The effective date for objectives for this station is October 1, 1997.

[9] A deficiency period is: (1) the second consecutive dry water year following a critical year; (2) a dry water year following a year in which the Sacramento River Index (described in footnote 6) was less than 11.35; or (3) a critical water year following a dry or critical water year.

[10] Water quality conditions sufficient to support a natural gradient in species composition and wildlife habitat characteristic of a brackish marsh throughout all elevations of the tidal marshes bordering Suisun Bay shall be maintained. Water quality conditions shall be maintained so that none of the following occurs: (a) loss of diversity; (b) conversion of brackish marsh to salt marsh; (c) for animals, decreased population abundance of those species vulnerable to increased mortality and loss of habitat from increased water salinity; or (d) for plants, significant reduction in stature or percent cover from increased water or soil salinity or other water quality parameters.

[11] Net Delta Outflow Index (NDOI) is defined in on page 25.

[12] For the May-January objectives, if the value is less than or equal to 5,000 cfs, the 7-day running average shall not be less than 1,000 cfs below the value; if the value is greater than 5,000 cfs, the 7-day running average shall not be less than 80% of the value.

[13] The objective is increased to 6,000 cfs if the best available estimate of the Eight River Index for December is greater than 800 TAF. [Note: The Eight River Index refers to the sum of the unimpaired runoff as published in the DWR Bulletin 120 for the following locations: Sacramento River flow at Bend Bridge, near Red Bluff; Feather River, total inflow to Oroville Reservoir; Yuba River flow at Smartville; American River, total inflow to Folsom Reservoir; Stanislaus River, total inflow to New Melones Reservoir; Tuolumne River, total inflow to Don Pedro Reservoir; Merced River, total inflow to Exchequer Reservoir; and San Joaquin River, total inflow to Millerton Lake.]

[14] The minimum daily Delta outflow shall be 7,100 cfs for this period, calculated as a 3-day running average. This requirement is also met if either the daily average or 14-day running average EC at the confluence of the Sacramento and the San Joaquin rivers is less than or equal to 2.64 mmhos/cm (Collinsville station C2). If the best available estimate of the Eight River Index (described in footnote 13) for January is more than 900 TAF, the daily average or 14-day running average EC at station C2 shall be less than or equal to 2.64 mmhos/cm for at least one day between February 1 and February 14; however, if the best available estimate of the Eight River Index for January is between 650 TAF and 900 TAF, the operations group established under the Framework Agreement shall decide whether this requirement will apply, with any disputes resolved by the CALFED policy group. If the best available estimate of the Eight River Index for February is less than 500 TAF, the standard may be further relaxed in March upon the recommendation of the operations group established under the Framework Agreement, with any disputes resolved by the CALFED policy group. The standard does not apply in May and June if the best available May estimate of the Sacramento River Index (described in footnote 6) for the water year is less than 8.1 MAF at the 90% exceedence level. Under this circumstance, a minimum 14-day running average flow of 4,000 cfs is required in May and June. Additional Delta outflow objectives are contained in Table A on page 26.

[15] The 7-day running average shall not be less than 1,000 cfs below the monthly objective.

[16] Partial months are averaged for that period. For example, the flow rate for April 1-14 would be averaged over 14 days. The 7-day running average shall not be less than 20% below the flow rate objective, with the exception of the April 15-May 15 pulse flow period when this restriction does not apply.

[17] The water year classification will be established using the best available estimate of the 60-20-20 San Joaquin Valley Water Year Hydrologic Classification (see page 24) at the 75% exceedence level. The higher flow objective applies when the 2 ppt isohaline (measured as 2.64 mmhos/cm surface salinity) is required to be at or west of Chipps Island.

[18] This time period may be varied based on real-time monitoring. One pulse, or two separate pulses of combined duration equal to the single pulse, should be scheduled to coincide with fish migration in San Joaquin River tributaries and the Delta. The time period for this 31-day flow requirement will be determined by the operations group established under the Framework Agreement.

[19] Plus up to an additional 28 TAF pulse/attraction flow during all water year types. The amount of additional water will be limited to that amount necessary to provide a monthly average flow of 2,000 cfs. The additional 28 TAF is not required in a critical year following a critical year. The pulse flow will be scheduled by the operations group established under the Framework Agreement.

[20] Combined export rate for this objective is defined as the Clifton Court Forebay inflow rate (minus actual Byron-Bethany Irrigation District diversions from Clifton Court Forebay) and the export rate of the Tracy pumping plant.

[21] This time period may be varied based on real-time monitoring and will coincide with the San Joaquin River pulse flow described in footnote 18. The time period for this 31-day export limit will be determined by the operations group established under the Framework Agreement.

[22] Maximum export rate is 1,500 cfs or 100% of 3-day running average of San Joaquin River flow at Vernalis, whichever is greater. Variations to this maximum export rate are authorized if agreed to by the operations group established under the Framework Agreement. This flexibility is intended to result in no net water supply cost annually within the limits of the water quality and operational requirements of this plan. Variations may result from recommendations of agencies for protection of fish resources, including actions taken pursuant to the State and federal Endangered Species Act. Disputes within the operations group will be resolved by the CALFED policy group. Any agreement on variations will be effective immediately and will be presented to the Executive Director of the SWRCB. If the Executive Director does not object to the variations within 10 days, the variations will remain in effect.

[23] Percent of Delta inflow diverted is defined on page 25. For the calculation of maximum percent Delta inflow diverted, the export rate is a 3-day running average and the Delta inflow is a 14-day running average, except when the CVP or the SWP is making storage withdrawals for export, in which case both the export rate and the Delta inflow are 3-day running averages.

[24] The percent Delta inflow diverted values can be varied either up or down. Variations are authorized subject to the process described in footnote 22.

[25] If the best available estimate of the Eight River Index (described in footnote 13) for January is less than or equal to 1.0 MAF, the export limit for February is 45% of Delta inflow. If the best available estimate of the Eight River Index for January is greater than 1.5 MAF, the February export limit is 35% of Delta inflow. If the best available estimate of the Eight River Index for January is between 1.0 MAF and 1.5 MAF, the export limit for February will be set by the operations group established under the Framework Agreement within the range of 35% to 45%. Disputes within the operations group will be resolved by the CALFED policy group.

[26] For the November-January period, close Delta Cross Channel gates for up to a total of 45 days, as needed for the protection of fish. The timing of the gate closure will be determined by the operations group established under the Framework Agreement.

[27] For the May 21-June 15 period, close Delta Cross Channel gates for a total of 14 days. The timing of the gate closure shall be based on the need for the protection of fish and will be determined by the operations group established under the Framework Agreement. Variations in the number of days of gate closure are authorized if agreed to by the operations group established under the Framework Agreement. Variations shall result from recommendations from agencies for the protection of fish resources, including actions taken pursuant to the State and federal Endangered Species Acts. The process for the approval of variations shall be similar to that described in footnote 22.

FOOTNOTE 2 FOR TABLE 1 AND FOOTNOTE 3 FOR TABLES 2 AND 3

Sacramento Valley
Water Year Hydrologic Classification

Year classification shall be determined by computation of the following equation:

$$\text{INDEX} = 0.4 * X + 0.3 * Y + 0.3 * Z$$

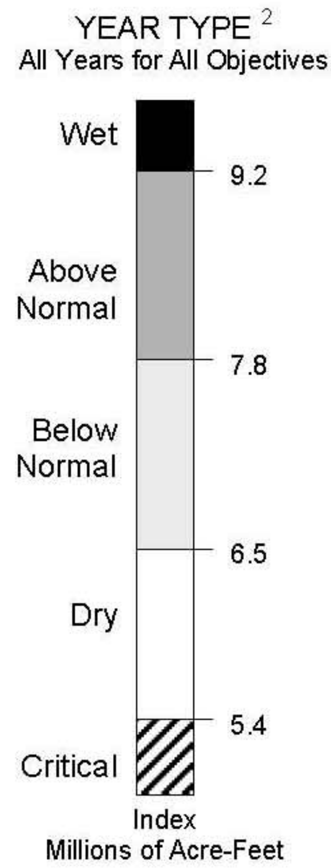
Where: X = Current year's April – July Sacramento Valley unimpaired runoff

Y = Current October – March Sacramento Valley unimpaired runoff

Z = Previous year's index[1]

The Sacramento Valley unimpaired runoff for the current water year (October 1 of the preceding calendar year through September 30 of the current calendar year), as published in California Department of Water Resources Bulletin 120, is a forecast of the sum of the following locations: Sacramento River above Bend Bridge, near Red Bluff; Feather River, total inflow to Oroville Reservoir; Yuba River at Smartville; American River, total inflow to Folsom Reservoir. Preliminary determinations of year classification shall be made in February, March, and April with final determination in May. These preliminary determinations shall be based on hydrologic conditions to date plus forecasts of future runoff assuming normal precipitation for the remainder of the water year.

Classification	Index Millions of Acre-Feet (MAF)
Wet……………………	Equal to or greater than 9.2
Above Normal………	Greater than 7.8 and less than 9.2
Below Normal………..	Equal to or less than 7.8 and greater than 6.5
Dry……………………	Equal to or less than 6.5 and greater than 5.4
Critical………………	Equal to or less than 5.4



[1] A cap of 10.0 MAF is put on the previous year's index (Z) to account for required flood control reservoir releases during wet years.

[2] The year type for the preceding water year will remain in effect until the initial forecast of unimpaired runoff for the current water year is available.

FOOTNOTE 17 FOR TABLE 3

San Joaquin Valley
Water Year Hydrologic Classification

Year classification shall be determined by computation of the following equation:

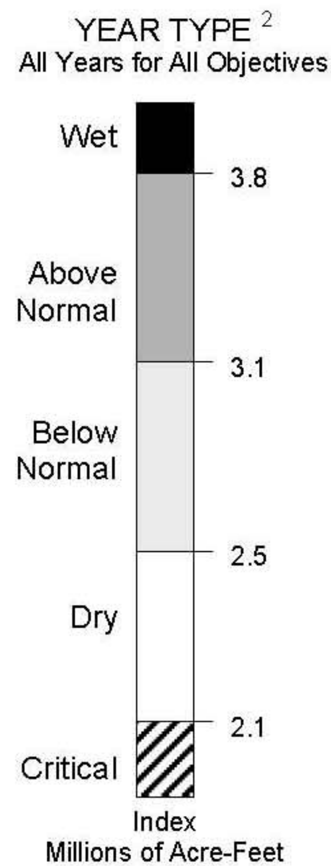
INDEX = 0.6 * X + 0.2 * Y + 0.2 * Z

Where: X = Current year's April – July San Joaquin Valley unimpaired runoff

Y = Current October – March San Joaquin Valley unimpaired runoff

Z = Previous year's index[1]

The San Joaquin Valley unimpaired runoff for the current water year (October 1 of the preceding calendar year through September 30 of the current calendar year), as published in California Department of Water Resources Bulletin 120, is a forecast of the sum of the following locations: Stanislaus River, total flow to New Melones Reservoir; Tuolumne River, total inflow to Don Pedro Reservoir; Merced River, total flow to Exchequer Reservoir; San Joaquin River, total inflow to Millerton Lake. Preliminary determinations of year classification shall be made in February, March, and April with final determination in May. These preliminary determinations shall be based on hydrologic conditions to date plus forecasts of future runoff assuming normal precipitation for the remainder of the water year.



Classification	Index Millions of Acre-Feet (MAF)
Wet………………………	Equal to or greater than 3.8
Above Normal………	Greater than 3.1 and less than 3.8
Below Normal………..	Equal to or less than 3.1 and greater than 2.5
Dry…………………….	Equal to or less than 2.5 and greater than 2.1
Critical………………	Equal to or less than 2.1

1 A cap of 4.5 MAF is put on the previous year's index (Z) to account for required flood control reservoir releases during wet years.

2 The year type for the preceding water year will remain in effect until the initial forecast of unimpaired runoff for the current water year is available.

FOOTNOTES 11 AND 23 FOR TABLE 3

NDOI and PERCENT INFLOW DIVERTED [1]

The NDOI and the percent inflow diverted, as described in this footnote, shall be computed daily by the DWR and the USBR using the following formulas (all flows are in cfs):

NDOI = DELTA INFLOW - NET DELTA CONSUMPTIVE USE - DELTA EXPORTS
PERCENT INFLOW DIVERTED = (CCF + TPP) ÷ DELTA INFLOW

where *DELTA INFLOW = SAC + SRTP + YOLO + EAST + MISC + SJR*

SAC	=	Sacramento River at Freeport mean daily flow for the previous day; the 25-hour tidal cycle measurements from 12:00 midnight to 1:00 a.m. may be used instead.
SRTP	=	Sacramento Regional Treatment Plant average daily discharge for the previous week.
YOLO	=	Yolo Bypass mean daily flow for the previous day, which is equal to the flows from the Sacramento Weir, Fremont Weir, Cache Creek at Rumsey, and the South Fork of Putah Creek.
EAST	=	Eastside Streams mean daily flow for the previous day from the Mokelumne River at Woodbridge, Cosumnes River at Michigan Bar, and Calaveras River at Bellota.
MISC	=	Combined mean daily flow for the previous day of Bear Creek, Dry Creek, Stockton Diverting Canal, French Camp Slough, Marsh Creek, and Morrison Creek.
SJR	=	San Joaquin River flow at Vernalis, mean daily flow for the previous day.

where *NET DELTA CONSUMPTIVE USE = GDEPL - PREC*

GDEPL	=	Delta gross channel depletion for the previous day based on water year type using the DWR's latest Delta land use study.[2]
PREC	=	Real-time Delta precipitation runoff for the previous day estimated from stations within the Delta.

and where *DELTA EXPORTS*[3] *= CCF + TPP + CCC + NBA*

CCF	=	Clifton Court Forebay inflow for the current day.[4]
TPP	=	Tracy Pumping Plant pumping for the current day.
CCC	=	Contra Costa Canal pumping for the current day.
NBA	=	North Bay Aqueduct pumping for the current day.

1 Not all of the Delta tributary streams are gaged and telemetered. When appropriate, other methods of estimating stream flows, such as correlations with precipitation or runoff from nearby streams, may be used instead.

2 The DWR is currently developing new channel depletion estimates. If these new estimates are not available, DAYFLOW channel depletion estimates shall be used.

3 The term "Delta Exports" is used only to calculate the NDOI. It is not intended to distinguish among the listed diversions with respect to eligibility for protection under the area of origin provisions of the California Water Code.

4 Actual Byron-Bethany Irrigation District withdrawals from Clifton Court Forebay shall be subtracted from Clifton Court Forebay inflow. (Byron-Bethany Irrigation District water use is incorporated into the GDEPL term.)

FOOTNOTE 14 FOR TABLE 3

TABLE A

Number of Days When Maximum Daily Average Electrical Conductivity of 2.64 mmhos/cm Must Be Maintained at Specified Location [a]

PMI [b] (TAF)	Chipps Island (Chipps Island Station D10) FEB	MAR	APR	MAY	JUN	PMI [b] (TAF)	Port Chicago (Port Chicago Station C14) [d] FEB	MAR	APR	MAY	JUN	PMI [b] (TAF)	Port Chicago (Port Chicago Station C14) [d] FEB	MAR	APR	MAY	JUN
≤ 500	0	0	0	0	0	0	0	0	0	0	0	5250	27	29	25	26	6
750	0	0	0	0	0	250	1	0	0	0	0	5500	27	29	26	28	9
1000	28 [c]	12	2	0	0	500	4	1	0	0	0	5750	27	29	27	28	13
1250	28	31	6	0	0	750	8	2	0	0	0	6000	27	29	27	29	16
1500	28	31	13	0	0	1000	12	4	0	0	0	6250	27	30	27	29	19
1750	28	31	20	0	0	1250	15	6	1	0	0	6500	27	30	28	30	22
2000	28	31	25	1	0	1500	18	9	1	0	0	6750	27	30	28	30	24
2250	28	31	27	3	0	1750	20	12	2	0	0	7000	27	30	28	30	26
2500	28	31	29	11	1	2000	21	15	4	0	0	7250	27	30	28	30	27
2750	28	31	29	20	2	2250	22	17	5	1	0	7500	27	30	29	30	28
3000	28	31	30	27	4	2500	23	19	8	1	0	7750	27	30	29	31	28
3250	28	31	30	29	8	2750	24	21	10	2	0	8000	27	30	29	31	29
3500	28	31	30	30	13	3000	25	23	12	4	0	8250	28	30	29	31	29
3750	28	31	30	31	18	3250	25	24	14	6	0	8500	28	30	29	31	29
4000	28	31	30	31	23	3500	25	25	16	9	0	8750	28	30	29	31	30
4250	28	31	30	31	25	3750	26	26	18	12	0	9000	28	30	29	31	30
4500	28	31	30	31	27	4000	26	27	20	15	0	9250	28	30	29	31	30
4750	28	31	30	31	28	4250	26	27	21	18	1	9500	28	31	29	31	30
5000	28	31	30	31	29	4500	26	28	23	21	2	9750	28	31	29	31	30
5250	28	31	30	31	29	4750	27	28	24	23	3	10000	28	31	30	31	30
≥ 5500	28	31	30	31	30	5000	27	28	25	25	4	>10000	28	31	30	31	30

[a] The requirement for number of days the maximum daily average electrical conductivity (EC) of 2.64 mmhos per centimeter (mmhos/cm) must be maintained at Chipps Island and Port Chicago can also be met with maximum 14-day running average EC of 2.64 mmhos/cm, or 3-day running average NDOIs of 11,400 cfs and 29,200 cfs, respectively. If salinity/flow objectives are met for a greater number of days than the requirements for any month, the excess days shall be applied to meeting the requirements for the following month. The number of days for values of the PMI between those specified in this table shall be determined by linear interpolation.

[b] PMI is the best available estimate of the previous month's Eight River Index. (Refer to Footnote 13 for Table 3 for a description of the Eight River Index.)

[c] When the PMI is between 800 TAF and 1000 TAF, the number of days the maximum daily average EC of 2.64 mmhos/cm (or maximum 14-day running average EC of 2.64 mmhos/cm, or 3-day running average NDOI of 11,400 cfs) must be maintained at Chipps Island in February is determined by linear interpolation between 0 and 28 days.

[d] This standard applies only in months when the average EC at Port Chicago during the 14 days immediately prior to the first day of the month is less than or equal to 2.64 mmhos/cm.

Salinity Standards from the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins

Table III-3

ELECTRICAL CONDUCTIVITY AND TOTAL DISSOLVED SOLIDS

PARAMETER	WATER QUALITY OBJECTIVES	APPLICABLE WATER BODIES
Electrical Conductivity (at 25°C)	Shall not exceed 230 micromhos/cm (50 percentile) or 235 micromhos/cm (90 percentile) at Knights Landing above Colusa Basin Drain; or 240 micromhos/cm (50 percentile) or 340 micromhos/cm (90 percentile) at I Street Bridge, based upon previous 10 years of record.	Sacramento River (13, 30)
	Shall not exceed 150 micromhos/cm (90 percentile) in well-mixed waters of the Feather River.	North Fork of the Feather River (33); Middle Fork of the Feather River from Little Last Chance Creek to Lake Oroville (36); Feather River from the Fish Barrier Dam at Oroville to Sacramento River (40)
	Shall not exceed 150 micromhos/cm from Friant Dam to Gravelly Ford (90 percentile).	San Joaquin River, Friant Dam to Mendota Pool (69)
Total Dissolved Solids	Shall not exceed 125 mg/l (90 percentile)	North Fork of the American River from the source to Folsom Lake (44); Middle Fork of the American River from the source to Folsom Lake (45); South Fork of the American River from the source to Folsom Lake (48, 49); American River from Folsom Dam to Sacramento River (51)
	Shall not exceed 100 mg/l (90 percentile)	Folsom Lake (50)
	Shall not exceed 1,300,000 tons	Goose Lake (2)